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Estimating systemic risk for non-listed euro-area banks

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Abstract

The systemic risk measure (SRISK) by V-Lab provides a market view of the vulnerability of financial institutions to a sudden downturn in the economy. To overcome the shortcoming that it cannot be applied to non-listed banks, SRISK characteristics of listed banks are mapped on balance sheet information. Systemic risk tends to be higher for banks that are larger, less profitable and have lower equity funding. Balance sheet information provides a surprisingly good approximation of SRISK for non-listed banks, when compared with banks' capital depletion from the EU-wide stress testing exercises in 2018 and 2021. The proposed methodology can usefully complement the more thorough overview provided by traditional stress tests, providing supervisors the option to evaluate the systemic risks of the banking system at a higher frequency and at a fraction of the costs.

Keywords: Systemic risk; stress testing; banks' balance sheet information content.

JEL: G21; G28; G1

Non-technical summary

Stress testing has become a standard tool to assess the financial resilience of the banking system. Traditionally, regulatory stress tests start from macro-financial scenarios and the specification of hypothetical macroeconomic shocks, which are then linked to the credit and market risks inherent in banks' balance sheets. Alternatively, stress scenarios can be designed in terms of a shock to financial markets, which propagates to the banking sector via the shock materialization on the capitalization and volatility of banks' market value.

A serious shortcoming of the market-based approach is that it relies on the availability of stock market data. This is a particularly relevant limitation for the euro area, where most of the systemically important institutions under the supervision of European and national authorities are not listed.

In this paper we leverage on the SRISK metric, a well-established market-based indicator of systemic risk developed by Engle et al. (2017) and develop a methodology to estimate SRISK for non-listed banks in the euro area. SRISK is an indicator of banks' capital shortfall due to systemic risk and is freely available on a high frequency basis. We map the SRISK metric to balance sheet information of listed euro-area banks to estimate the relationship between banks' balance sheet indicators and their SRISK. Subsequently, we use the estimated coefficients to compute SRISK for non-listed banks. We show that the estimations of SRISK with our methodology closely follows the original SRISK of euro area listed banks and therefore provide a reasonable approximation of the systemic risk of euro area banks.

To further validate our methodology, we compare the ranking correlation of our SRISK estimations for listed and non-listed banks with banks' capital shortfall estimated via EU-wide stress tests of 2018 and 2021. The ranking in terms of capital shortfall emerging from our exercise is remarkably consistent with that of the EU-wide stress test results, particularly for non-listed banks. This suggests that the proposed methodology can usefully complement the traditional regulatory stress test exercises to give an insight into the health of the financial system, as it can be run at much higher frequency and at a fraction of the implementation costs.

1. Introduction

Stress testing has become a standard tool to assess the resilience of the banking system. Traditionally, regulatory stress tests start from a macro scenario and the specification of a hypothetical macroeconomic shock, which are then mapped through probabilities of default and losses given default into the balance sheets of the banks. Alternatively, the stress scenario can be designed in terms of a shock to the equity market, with different individual bank stock exposures determining how the shock propagates to the banking sector.

While there are advantages and disadvantages in both methodologies, a serious shortcoming of the market-based approach is that it relies on the availability of stock market data. In the case of the euro area, for instance, many supervised banks are not listed and, therefore, the market-based approach cannot be directly applied. At the same time, a stress test based on balance-sheet information can be performed only at low frequencies (either quarterly, or even annually) and only when such information becomes available, which is typically a few months later than the reference period. More generally, accounting information may differ from market-based signals, either because the latter are more timely, or because they capture different market perceptions about risk creation in the system.

This paper analyses these differences and proposes an analytical solution to apply a market-based stress test to non-listed banks in Europe. It first maps market-based systemic risk (SRISK) measures available for listed banks to their balance-sheet information, and next applies such mappings to balance sheet information of non-listed banks to produce an indirect estimate of their exposure to market systemic shocks. The paper finally compares the different methodologies, based on the findings of recently performed regulatory stress tests in Europe.

We find that balance sheet information effectively approximates market-based measures of SRISK. We use the estimated coefficients to extend SRISK to the entire universe of euro area systemically important banks (SI banks), for which market-based information is missing but balance sheet information is available. The results from our SRISK estimates are aligned with those of the EU-wide stress tests of 2018 and 2021: the correlation between banks' capital shortfall according to the two methodologies is remarkably high, particularly for non-listed banks. This suggests that the two approaches, although very different in terms of underlying data and methodology, are consistent and can be reconciled. Balance-sheet and market-based stress-tests can well complement each other: on the one hand, the balance-sheet approach allows for a more granular and detailed assessment, and thus provides a more comprehensive picture; on the other hand, market-based measures can be applied to monitor systemic risk at a high frequency (almost real time) and are much less resource intensive, while at the same time providing consistent results.

One important caveat of the analysis of this paper is that it supposes that the business strategies of the unlisted banks are the same as those of the listed ones. In practice, they may have loan portfolios that are different in some specific ways, for instance, they may be more local or higher yielding and therefore riskier. We control for such potential differences, by constructing business model dummies in one of our robustness exercises and find that the results are qualitatively not changing.

Since the publication of the first Comprehensive Capital Analysis Review (CCAR) in the US in 2011 and the ECB comprehensive assessment in the euro area (ECB, 2014), there has been an active debate on the reliability of regulatory stress tests. One stream of the literature favors the use of market-based approaches for conducting financial stress tests, while other researchers support exercises based on banks' balance-sheet information. Acharya, Engle, and Pierret (2014) used the SRISK – originally introduced by Brownlees and Engle (2011) – as a market-based measure of systemic risk. The authors

used SRISK as a benchmark for assessing the quality of supervisory stress tests conducted both in the US under the Supervisory Capital Assessment Program of 2009 and in the EU under the remit of the European Banking Authority (EBA) since 2011. They found that banks' required capitalization for buffering against financial market shocks predicted by SRISK was substantially larger compared to regulatory stress tests. Furthermore, even when disregarding the discrepancy between capital shortfalls in absolute terms, the rank of vulnerable banks appears to be highly uncorrelated between market-based and regulatory stress test approaches. The debate continued in a series of policy papers where the low correlation between market and regulatory stress tests in Europe has been attributed to the lack of robustness of the EBA/ECB stress test (Acharya and Steffen, 2014a, b, c). Steffen (2014) argued that the Comprehensive Assessment lacks a proper integration of systemic risk factors. Acharya and Steffen (2014b) suggested that the use of risk weighted assets, which is defined at the discretion of national regulators, is a significant determinant of the ECB/EBA stress test results.

On the other hand, some authors question the comparability of market-based stress measures, such as SRISK, and regulatory stress tests. Borio, Drehmann, and Tsatsaronis (2014) underlined that the success of a macro-prudential stress test depends on the objective it was designed for, while Alfaro and Drehmann (2009) concluded that its quality is mainly driven by the plausibility and severity of the scenario and its translation into a stress test shock. Following these considerations, Homar, Kick and Salleo (2016) argued that the designed shocks on bank capital differ greatly between the stress tests conducted by ECB/EBA and SRISK. The authors explain that the impact of a stress test should reflect banks' exposure to a number of risks, most importantly credit and market risks due to macro- and micro-economic factors. They evaluated the ECB comprehensive assessment and SRISK with respect to factors that explain bank fragility and concluded that the shocks included in the EBA/ECB stress tests are consistent with the literature on credit losses, while SRISK is mainly driven by shocks on market leverage ratio and are much less related to other traditional drivers of financial stability.

Engle and Jung (2023) follow a similar approach to ours to estimate SRISK for unlisted Latin American and Chinese financial institutions, by examining the relation between accounting data and market data for listed banks and then applying the same relation to unlisted firms. However, they do not validate their estimation against actual stress testing run by supervisory authorities. Other papers that link banks' cost of equity to their fundamentals include Altavilla et al. (2021), who find that unlisted banks have lower equity costs, and Dimitrov and van Wijnbergen (2023), who follow a credit portfolio approach to assess systemic risk in bank portfolios.

The paper is structured as follows. The next section describes the statistical methodology used by V-Lab to compute SRISK, introducing the standard formula of SRISK by Brownlees and Engle (2017) and the methodological approach of the paper. Section 4 presents the dataset. Section 5 contains the main results, with the various estimates of SRISK using balance sheet information and the comparison with the EU-wide regulatory stress tests. Section 6 reports the results of a few robustness checks. Section 7 concludes.

2. SRISK methodology

The systemic risk measure SRISK introduced by Brownlees and Engle (2017) is defined as the expected capital shortfall of a financial entity conditional on a prolonged market decline. SRISK is a function of balance sheet information (the size of the bank and its leverage) and its expected equity loss conditional on market decline, called Long Run Marginal Expected Shortfall (LRMES). The computation of LRMES requires the market value of banks equity: however, many Euro area banks supervised by the Single Supervisory Mechanism (SSM) are not listed, thus SRISK cannot be computed. This paper suggests computing SRISK for non-listed banks by exploiting the relationship between market value of equity and accounting data for listed banks and applying the estimated coefficients to the accounting data of non-listed banks.

SRISK builds on the notion of capital shortfall (CS). The capital shortfall of bank *i* at time *t* is defined as:

$$CS_{it} = kA_{it} - W_{it} = k(D_{it} + W_{it}) - W_{it}$$

where W_{it} is the market value of equity, D_{it} is the book value of debt, A_{it} is the value of quasi assets, and *k* is the prudential capital fraction, which is set at 8%. SRISK is the expected capital shortfall, conditional on a systemic event. Denoting with $R_{mt+1:t+h}$ the multiperiod market return between *t+1* and *t+h*, the systemic event is defined as $I(R_{mt+1:t+h} < C)$, where *I(·)* is the standard indicator function and *C* is an arbitrary chosen threshold. SRISK is defined as:

$$\begin{aligned} SRISK_{it} &= E_t(CS_{it+h} | R_{mt+1:t+h} < C) \\ &= kD_{it} - (1-k)W_{it}(1 - LMRES_{it}) \end{aligned} \quad (1)$$

where $LMRES_{it} = -E_t(R_{it+1:t+h} | R_{mt+1:t+h} < C)$ is the Long Run Marginal Expected Shortfall, which measures the expected return of bank *i* conditional on the systemic event.

$LMRES_{it}$ is estimated using the Dynamic Conditional Beta model of Engle (2016). Assuming zero expected returns, the return on bank *i* can be expressed in terms of its exposure to the market return:

$$R_{it} = \beta_{it} R_{mt} + u_{it}$$

Assume that individual banks and market returns are normally distributed:

$$\begin{pmatrix} R_{it} \\ R_{mt} \end{pmatrix} | \Omega_t \sim N(0, \mathrm{H}_t(\theta))$$

where Ω_t denotes the information set available at time *t* and θ is a vector of unknown parameters that can be estimated using a Dynamic Conditional Correlation model, as in Engle (2002). An estimate of the dynamic conditional beta is given by:

$$\hat{\beta}_{it} = H_{mmt}^{-1}(\hat{\theta}) \mathrm{H}_{iit}(\hat{\theta})$$

where the subscripts represent natural partitions (see Engle (2016) for details). V-Lab approximates the computation of LRMES with the following formula:

$$LRMES_{it} = 1 - \exp\left(\log(1-C)\,\hat{\beta}_{it}\right)$$

and implements it by setting the threshold *C* at -40% for a time horizon *h* of six months.

One limitation of this approach is that it relies on availability of market prices. Many of the financial institutions supervised by the SSM, however, are not publicly traded. To overcome this problem, this

paper proposes a two-step approach, which relies on the wide availability of banks' balance sheet items. The first step establishes a functional relationship between the SRISK measures available for a set of supervised Euro area banks and their balance sheet characteristics. The second step uses the coefficients estimated in the first step and applies them to the balance sheet characteristics of the remaining universe of non-listed European banks.

We propose two approaches to perform the first step described above: a direct and an indirect estimation, that differ in terms of sub-steps needed to estimate SRISK.

The *direct* methodology to estimate SRISK is based on the following panel regression:

$$\widehat{SRISK}_{it}^{d} = \hat{\delta} X_{it} + \hat{\alpha}_t + \hat{\gamma}_c \quad (2)$$

where X_{it} is a vector of banks' balance sheet characteristics, while γ_c and α_t represent the country and time fixed effect, respectively.

The *indirect* methodology is instead based on two intermediate steps to first estimate the market value of equity $\widehat{W}_{it}$ and the dynamic conditional beta $\hat{\beta}_{it}$, and, based on them, the Long Run Marginal Expected Shortfall (LRMES) and finally SRISK, as follows:

$$\widehat{W}_{it} = \hat{\delta}^{W} X_{it} + \hat{\alpha}_t^{W} + \hat{\gamma}_c^{W} \quad (3)$$

$$\hat{\beta}_{it} = \hat{\delta}^{\beta} Z_{it} + \hat{\alpha}_t^{\beta} + \hat{\gamma}_c^{\beta} \quad (4)$$

$$\widehat{SRISK}_{it}^{ind} = kD_{it} - (1-k)\widehat{W}_{it}(1 - \widehat{LRMES}_{it}) \quad (5)$$

In this second case, the coefficients estimated via (3) and (4) for listed banks are used to derive the market value of equity, the beta and the LRMES of non-listed banks, to finally obtain an estimate of SRISK via equation (5).

3. Dataset

Our main analysis draws on two key datasets. The first dataset is the Volatility Laboratory (V-Lab) at New York University, which provides information on the SRISK and beta of listed financial institutions worldwide. The second dataset comprises information on Euro area banks' balance sheet and accounting data and is retrieved from the supervisory reporting framework of the European Banking Authority (also mentioned as SUBA). For the regression analyses described in equations (2)-(5) and the relative robustness checks, we complement these two datasets with information on banks' market capitalization from Bloomberg and banks' business models following the classification provided by the supervisory authority of the ECB (SSM). Finally, we use data from the EBA Stress Tests of 2018 and 2021 on the expected capital shortfall under the adverse scenario, as a benchmark to compare and interpret the SRISK estimated using accounting data.

For the euro area, V-Lab reports SRISK and betas for a set of 236 listed financial firms (including banks, insurance firms and investment companies) on a daily basis and starting from the year 2000. SRISK estimates are based on the Global Dynamic MES model (GMES)[1] which has been calibrated using the following standard inputs:

- Crisis threshold of 40% which reflects the approximate market decline observed during the 2007-2009 crisis. A systemic crisis is defined and is triggered when the broad market index falls by more than the threshold over a six-month period.
- Prudential capital requirement of 8%, defined as the amount of capital over total assets that a firm would need to overcome a financial crisis.

These parameters become extremely relevant when comparing the SRISK measures estimated for non-listed banks with the EU-wide stress test results, as they are direct determinants of SRISK (see Section 5.3).

Supervisory data is reported for a set of 2415[2] unconsolidated banks in the euro area, on a quarterly basis and spanning from 2014-Q4 to 2023-Q1. For the scope of this exercise, we focus on significant institutions (SIs) only, which are the banks under direct supervision by the SSM. The dataset includes a total of 181 SIs (see Appendix B for the complete list) over the whole period covered by SUBA.[3] Figure 4.1 (a) provides an overview of the changes in the number of SIs over time, also distinguishing between listed and non-listed SIs.[4] Non-listed banks represent about two thirds of the euro area banks in number and slightly less than a half as a fraction of total assets (Chart 4.1 (b)). This confirms the

[1] This is a model used to calculate a variety of risk measures for global financial firms, whose main feature is that it allows to account for discrepancies in market information that are generated by different market closing times worldwide. See https://vlab.stern.nyu.edu/docs/srisk/GMES for further details.

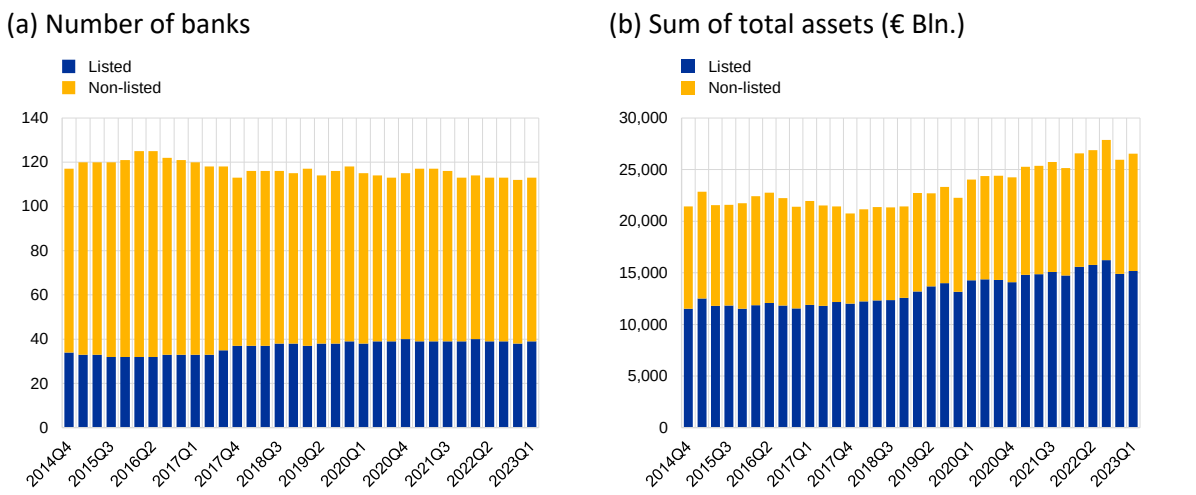
[2] This number refers to the banks available in the dataset for the first quarter of 2023.

[3] The significance status of all banks authorised within the participating countries is checked regularly by the ECB, and can change over time, either through normal business activity or due to one-off events such as mergers or acquisitions. The criteria for determining whether banks are considered significant - and therefore under the ECB's direct supervision - are set out in the SSM Regulation and the SSM Framework Regulation. To qualify as significant, banks must fulfil at least one of these four criteria: (a) the total value of its assets exceeds €30 billion; (b) it is considered of economic importance for the specific country or the EU economy as a whole; (c) the total value of its assets exceeds €5 billion and the ratio of its cross-border assets/liabilities in more than one other participating Member State to its total assets/liabilities is above 20%; (d) it has requested or received funding from the European Stability Mechanism or the European Financial Stability Facility. A supervised bank can also be considered significant if it is one of the three most significant banks established in a particular country.

[4] Listed banks are defined as all the SIs for which data are available in V-Lab.

need to rely also on accounting rather than just market-based information to comprehensively understand the resilience of the euro area banking system in a possible distress situation. The total number of entities directly supervised by the SSM remains relatively stable over time, with small fluctuations that can be attributed mainly to mergers and acquisitions.[5]

Figure 4.1: Euro area SIs over time



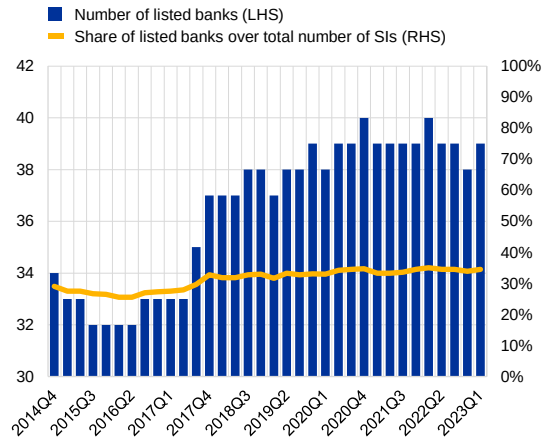
Sources: Authors' calculations based on V-Lab and Supervisory dataset (SUBA).
Notes: Panel (a) reports the number of listed and non-listed banks. Panel (b) reports the share of listed and non-listed banks in terms of total assets. The fluctuations visible in the charts are mainly due to mergers and acquisitions which have occurred during the period of study.

The regression sample of banks used for the estimation is obtained by taking the intersection between banks covered by V-Lab and SUBA. Figure 4.2 (a) plots the number of euro area SIs included in the regression sample, which ranges from a minimum of 32 in 2016-Q2 to a peak of 40 in 2022-Q1. The regression sample represents around 30% of all supervised entities for which accounting data is available in SUBA. Figure 4.2 (b) represents the number of euro area SIs in the regression sample by country in 2023-Q1. The sample is heterogenous across the euro area with more than 50% of listed supervised banks concentrated in Italy, Spain, Germany, and Greece. Note that all the entities in Greece are listed banks, while in other countries only non-listed banks are present (Bulgaria, Luxembourg, Latvia, and Slovakia).

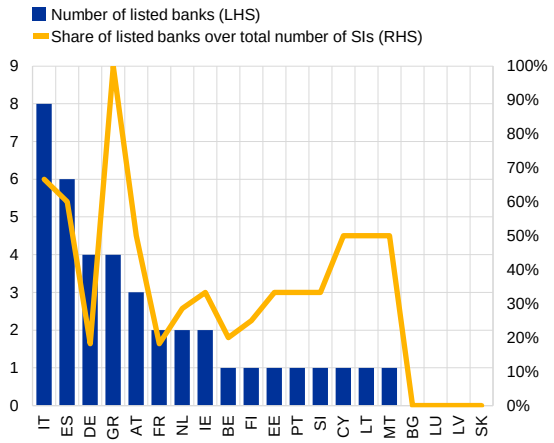
[5] This is for example the case of Credito Valtellinese S.p.A. that on 24th April 2022 merged into Crédit Agricole Italia S.p.A. with the result of its name being deleted from the list of significant supervised entities. Changes to the list of supervised entities are regularly published in the SSM website and are available at: https://www.bankingsupervision.europa.eu/banking/list/html/index.en.html

Figure 4.2: Coverage of the regression sample compared to the SIs

(a) Over time



(b) By country, as of 2023-Q1



Sources: Authors' calculations based on V-Lab and Supervisory dataset (SUBA).

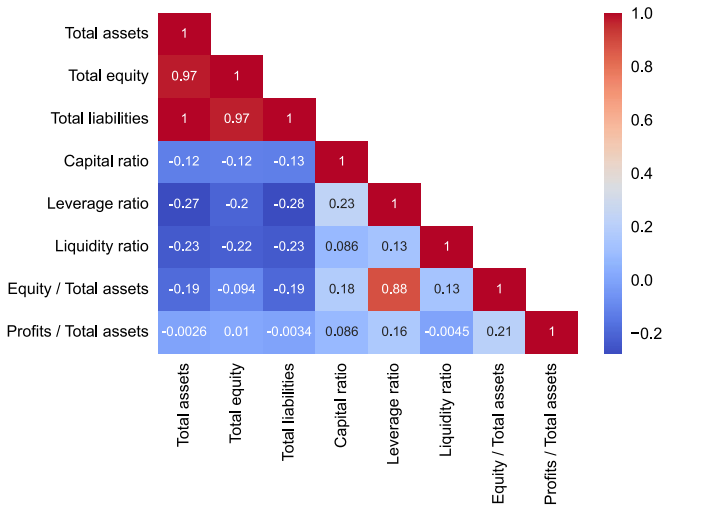
Table 4.1 summarizes some key balance-sheet and market-based indicators for the entire number of SIs over the period 2014-Q4 to 2023-Q1, distinguishing between non-listed and listed banks (the regression sample). For leverage ratio and liquidity ratio, the number of observations is lower than for other variables due to different reporting obligations in force until 2016-Q3. Observations associated to reporting mistakes (such as negative values for the regulatory ratios, or extreme outliers), have been dropped. Observations associated with a beta higher than 4 have been removed from the regression sample to avoid an unreasonable skew in the distribution. The listed banks are on average almost 3 times larger in terms of total assets (364 Bln vs. 127 Bln) and in terms of total equity (22 Bln vs. 8 Bln) when compared to unlisted banks, while profits over total assets and equity over total assets are relatively similar for the two groups of banks. Non-listed banks are on average characterized by better regulatory ratios, although with a wider dispersion. Figure 4.3 depicts the cross-correlation of banks' key balance-sheet variables. Banks' total assets, book equity and liabilities highly correlated with each other, which suggests not to combine these variables into a regression model to prevent collinearity issues. Furthermore, banks' leverage-ratio highly correlates with their equity-over-total assets.

Table 4.1: Descriptive statistics

		N	Mean	Std.	Min	25% p.	50% p.	75% p.	Max
Non-listed banks	Capital ratio	2667	0.217	0.092	0.028	0.164	0.192	0.233	0.716
	Leverage ratio	2057	0.070	0.031	0.014	0.048	0.064	0.086	0.208
	Liquidity ratio	2054	2.237	1.271	0.078	1.481	1.819	2.477	10.707
	Total assets (Bln)	2677	127.312	253.442	0.156	22.400	48.772	108.409	2113.440
	Total equity (Bln)	2677	8.404	16.712	-0.198	1.498	3.432	7.766	136.561
	Profits (Bln)	2677	0.270	0.800	-5.518	0.025	0.081	0.228	9.963
	Equity / Total assets	2677	0.083	0.057	-0.528	0.053	0.074	0.098	0.919
	Profits / Total assets	2677	0.002	0.016	-0.496	0.001	0.002	0.004	0.200
Listed banks	Capital ratio	1241	0.175	0.034	0.095	0.154	0.171	0.190	0.326
	Leverage ratio	1010	0.060	0.017	0.023	0.049	0.058	0.067	0.149
	Liquidity ratio	979	1.936	0.946	0.263	1.394	1.618	2.138	8.129
	Total assets (Bln)	1241	364.328	513.091	2.478	57.839	113.832	517.890	2766.386
	Total equity (Bln)	1241	22.400	28.308	0.312	3.737	9.318	29.909	131.872
	Profits (Bln)	1241	0.812	1.871	-11.330	0.040	0.241	1.040	10.764
	Equity / Total assets	1241	0.074	0.023	0.013	0.059	0.071	0.083	0.158
	Profits / Total assets	1241	0.002	0.006	-0.041	0.001	0.002	0.004	0.021
	Beta	1238	1.216	0.531	-0.041	0.966	1.230	1.500	3.738
	SRISK (Bln)	1241	22.541	35.084	-3.549	2.540	6.179	28.597	204.352
	Market value (Bln)	1241	12.856	17.845	0.001	1.538	4.082	18.319	98.663

Sources: Authors' calculations based on V-Lab, Supervisory dataset (SUBA), and Bloomberg.
Notes: Capital ratio, leverage ratio and liquidity ratio follow the regulatory definitions based on EBA reporting standards.

Figure 4.3: Cross-correlation of banks' book values



Sources: Authors' calculations based on V-Lab and Supervisory dataset (SUBA).

4. SRISK estimation

This section presents the main results of the analysis. It first discusses the direct and indirect estimation of SRISK for listed banks, then it derives SRISK for the sample of non-listed banks according to the two methodologies and finally it compares such estimated SRISK with the results of the EU-wide stress test.

5.1. Direct estimation

The direct estimation approach regresses the SRISK values obtained by V-Lab relative to total assets directly on banks' balance sheet characteristics. The results are presented in Table 5.1, where four model specifications are reported. We use as potentially explanatory variables total assets, equities, profits- and equities-over-total assets, various regulatory ratios and a dummy for peripheral countries. In addition, we add a squared term for either log-total assets or equity-over-assets to test for potential non-linearities. Among the book balance sheet variables, profits-over-total assets has a negative and strongly statistically significant coefficient. Profits are computed as a rolling average over three quarters and, since they signal the profitability of the bank, they tend to significantly reduce SRISK. The size of a bank, measured with log-total assets, is a key driver of SRISK and has a positive and statistically significant coefficient. Among the financial ratios, only the liquidity-ratio has a statistically significant and robust impact on SRISK, as expected. Model (iii) suggests a possible non-linear relationship between SRISK and the squared term of log-total assets; however, under these specifications the impacts of the periphery dummy and of CET1-ratio become non-significant. The model fit ranges from 47% to 53%. Overall, specification (i) is chosen which removes non-significant and non-robust variables and is based on a larger sample.

Table 5.1: Direct SRISK estimation – Regression results for SRISK over total assets

	SRISK over TA (i)	SRISK over TA (ii)	SRISK over TA (iii)	SRISK over TA (iv)
Log-total assets	0.006***	0.006***	0.023***	0.023***
	(0.000)	(0.000)	(0.002)	(0.002)
Profits-over-total assets	-1.561***	-1.480***	-1.472***	-1.472***
	(0.112)	(0.132)	(0.128)	(0.128)
Equity-over-total assets	-0.300***	-0.378***	-0.348***	-0.348***
	(0.028)	(0.033)	(0.033)	(0.032)
Periphery dummy	0.007***	0.009***	0.003**	0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
CET1-ratio		0.052**	0.001	
		(0.020)	(0.021)	
Liquidity-ratio		0.001	0.003***	0.003***
		(0.001)	(0.001)	(0.001)
Log-total assets squared			-0.002***	-0.002***
			(0.000)	(0.000)
Intercept	0.025***	0.032***	0.007	0.007
	(0.005)	(0.007)	(0.007)	(0.007)
Observations	1113	951	951	951
R-squared	0.462	0.502	0.529	0.529
Time fixed effects	Yes	Yes	Yes	Yes

Notes: Standard errors in parentheses. * p<.1, ** p<.05, ***p<.01. The periphery dummy equals to one if a bank resides in either Spain, Greece, Ireland, Italy, or Portugal.

5.2. Indirect estimation

The indirect estimation of SRISK as described in section 2 is based on three steps:

I. A relationship between the market value of banks and their balance-sheet variables, as described in equation (3).
II. A relationship between banks' betas and their balance sheet variables, as described in equation (4).
III. The calculation of SRISK according to equation (5), based on the first two steps.

The panel regression results for step I described are reported in Table 5.2. It shows that banks' balance sheet information significantly correlates with their market value and explains a substantial amount of its variation (R-squared ranging between 73% and almost 79%). The large and positive role of profits-over-total assets (which are averaged over the past three quarters) is consistent with standard asset pricing models, for which the value of a firm is given by the stream of profits. The positive and significant relationship between (log) total book assets and banks' market value indicates that markets put a premium on large banks. On the other hand, the negative signs of the CET1-ratio suggest that markets price in the costs of higher capital. On the other hand, the positive and significant sign of the liquidity-ratio indicates that markets reward banks with higher liquidity. The positive sign of equity-over-total assets shows that banks with large equity financing benefit from higher market capitalization. Column (v) indicates that relative book equity (over total assets) is non-linearly correlated with market value: it increases banks' market value up to a certain level, after which its marginal benefit is lost. On the other hand, when controlling for the squared term of log-total assets, as reported in Column (iv), the impact and significance of the periphery dummy is removed.

The sign and significance level of the predictors remain mostly robust across the specifications in Table 5.2. Time fixed effects are always included however stay mostly insignificant. Banks located in peripheral countries display a lower market value compared to their competitors in other jurisdictions, all the rest being equal. For SRISK estimation, we use the model specification in column (v) given its better fit in terms of adjusted -R-squared. We furthermore run the same regressions but replace total assets with total equity and find that the coefficients remain robust in terms of size, sign and significance. The results of this robustness check can be found in section 6.

Table 5.2: Indirect SRISK estimation - Regression results for log of market capitalization

	Log market cap (i)	Log market cap (ii)	Log market cap (iii)	Log market cap (iv)	Log market cap (v)
Log-total assets	1.004***	1.052***	1.052***	0.530***	1.088***
	(0.019)	(0.025)	(0.025)	(0.122)	(0.023)
Equity-over-total assets	18.452***	21.874***	21.874***	20.946***	104.673***
	(1.379)	(1.706)	(1.706)	(1.703)	(7.120)
Profits-over-total assets	68.430***	69.208***	69.208***	68.932***	69.343***
	(5.525)	(6.719)	(6.719)	(6.655)	(6.255)
Periphery dummy	-0.089	-0.190***	-0.190***	-0.020	-0.214***
	(0.058)	(0.067)	(0.067)	(0.077)	(0.063)
CET1-ratio		-4.040***	-4.040***	-2.437**	-2.794***
		(1.038)	(1.038)	(1.092)	(0.972)
Liquidity-ratio		0.127***	0.127***	0.076*	0.092**
		(0.041)	(0.041)	(0.042)	(0.038)
Log-total assets squared				0.052***	
				(0.012)	
Equity-over-total assets squared					-484.889***
					(40.643)
Intercept	-4.605***	-4.865***	-4.865***	-4.081***	-8.356***
	(0.222)	(0.343)	(0.343)	(0.384)	(0.433)

Observations	1113	951	951	951	951
R-squared	0.733	0.748	0.748	0.753	0.782
Time fixed effects	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors in parentheses. * p<.1, ** p<.05, ***p<.01. The periphery dummy equals to one if a bank resides in either Spain, Greece, Ireland, Italy, or Portugal.

Table 5.3 refers to step II above and reports the regression results for banks' betas, i.e. their exposure to market risk. Compared to the results in Table 5.2, the fit and significance of banks' balance sheet information is lower. Log-total assets, a proxy for the size of banks, has a positive and significant relationship with beta, indicating that large banks are riskier. Specifications (iii) and (iv) suggest the presence of non-linear effects. Equity-over-total assets is positively correlated with beta as well. Additionally, banks' profitability negatively correlates with beta, suggesting that more profitable banks are less exposed to market risks. Once we add the squared term for log-total assets, the significance of the impact of the CET1- and liquidity-ratios are removed. Different to banks' market value, the squared-term for equity-over-total assets is insignificant for beta. Similar to the results for banks' market value, banks located in peripheral economies seem be more exposed to market risk compared to banks in other jurisdictions. The sign and significance of the coefficients are robust across all specifications. Specification (iv) will be used to derive LRMES according to equation (5) and as specified in step III above, as it has the best performance in terms of R-squared.

Table 5.3: Indirect SRISK estimation - Regression results for beta

	Beta (i)	Beta (ii)	Beta (ii)	Beta (iv)	Beta (v)
Log-total assets	0.206***	0.184***	0.528***	0.581***	0.208***
	(0.008)	(0.009)	(0.044)	(0.041)	(0.008)
Profits-over-total assets	-24.650***	-14.433***	-14.352***	-23.235***	-24.787***
	(2.239)	(2.503)	(2.421)	(2.159)	(2.243)
Equity-over-total assets	3.234***	1.504**	2.128***	3.177***	5.971**
	(0.551)	(0.624)	(0.608)	(0.530)	(2.587)
Periphery dummy	0.145***	0.145***	0.033	0.051**	0.142***
	(0.023)	(0.025)	(0.028)	(0.024)	(0.023)
CET1-ratio		0.897**	-0.156		
		(0.379)	(0.389)		
Liquidity-ratio		-0.053***	-0.020		
		(0.015)	(0.015)		
Log-total assets squared			-0.034***	-0.039***	
			(0.004)	(0.004)	
Equity-over-total assets squared					-15.489
					(14.310)
Intercept	-0.196**	0.533***	0.015	-0.855***	-0.310**
	(0.088)	(0.125)	(0.137)	(0.110)	(0.138)
Observations	1110	949	949	1110	1110
R-squared	0.543	0.565	0.594	0.577	0.543
Time fixed effects	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors in parentheses. * p<.1, ** p<.05, ***p<.01. The periphery dummy equals to one if a bank resides in either Spain, Greece, Ireland, Italy, or Portugal.

5.3. Predicting SRISK

We use the direct and indirect models discussed in the previous two sub-sections to predict the SRISK for the sample of euro area SIs available. First, we predict SRISK for listed banks and evaluate the in-sample goodness of fit of the regression approaches. Next, we predict the SRISK for the sample of non-listed banks and assess the quality of our estimates by comparing them with the results of the EU-wide stress test of 2018 and 2021, using the expected capital shortfall under the adverse scenario as a benchmark. For the indirect method, we furthermore report the prediction results of market equity and beta in Annex A.

5.3.1. In-sample estimation for listed banks

The performance of the SRISK predictions for listed SIs are assessed by directly comparing them with the SRISK estimations from V-Lab. We first compare the SRISK estimates at an aggregate level by looking at the total SRISK by country. In the second step, we compare the SRISK at bank-level.

Both approaches of estimating SRISK have reasonable performance, when compared to the SRISK estimates from V-Lab. Table 5.4 shows that the mean squared error (MSE) computed at country level is lower for Cyprus, Germany, Greece, and Spain when considering the indirect method. When looking at the overall MSE, the indirect method performs slightly better with a MSE of 32 compared to 38 for the direct method.

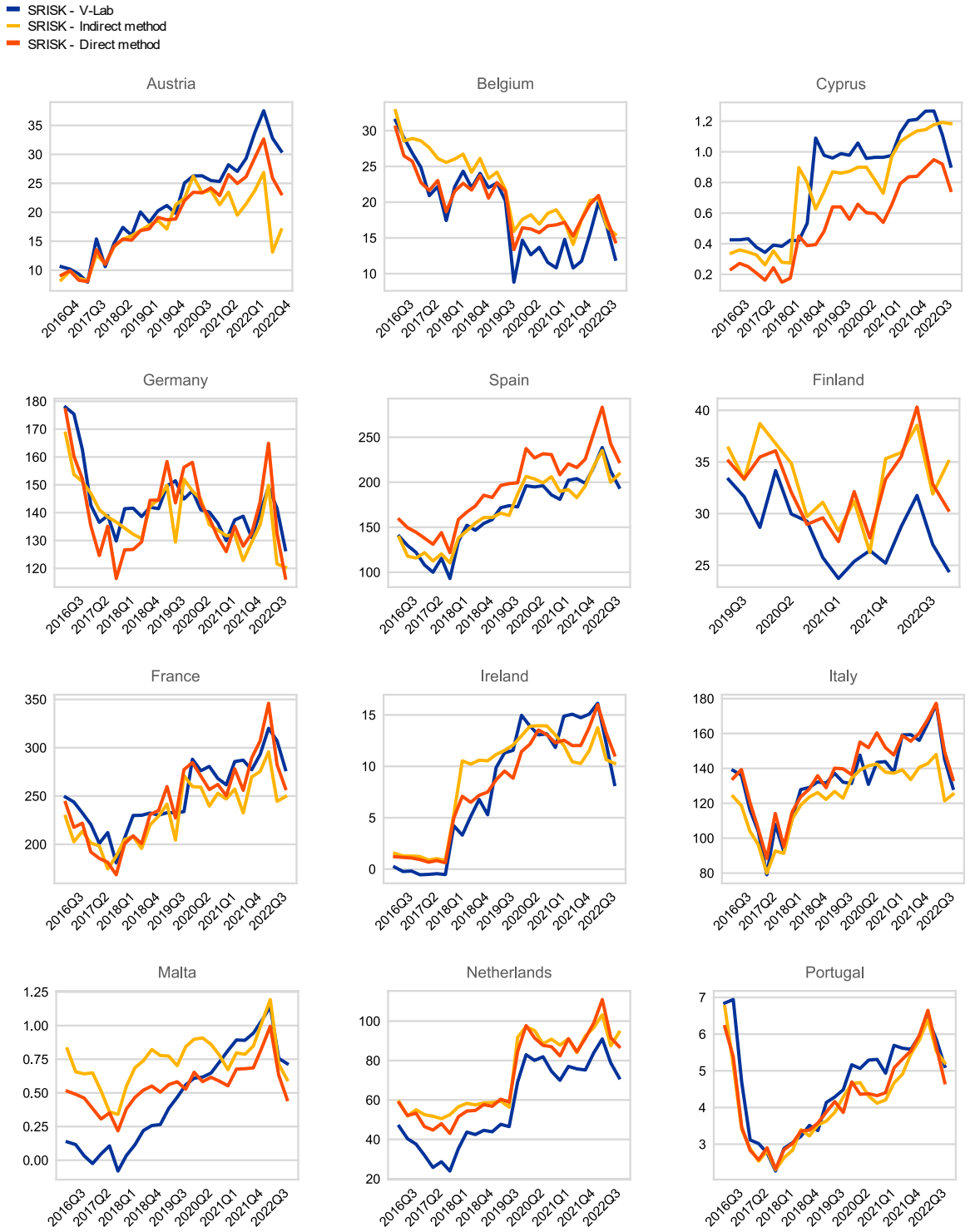
Table 5.4: Mean Squared Error

	Indirect method	Direct method
Austria	13.32	4.15
Belgium	17.13	12.86
Cyprus	0.03	0.10
Finland	37.56	25.93
France	242.94	187.71
Germany	13.55	15.32
Greece	1.10	1.79
Ireland	4.72	1.80
Italy	22.13	12.78
Lithuania	0.02	0.01
Malta	0.04	0.01
Netherlands	180.85	149.39
Portugal	0.32	0.25
Slovakia	1.00	0.87
Slovenia	1.21	0.07
Spain	13.17	99.46
Total	**32.46**	**38.40**

Sources: Authors' calculations based on V-Lab and SUBA.

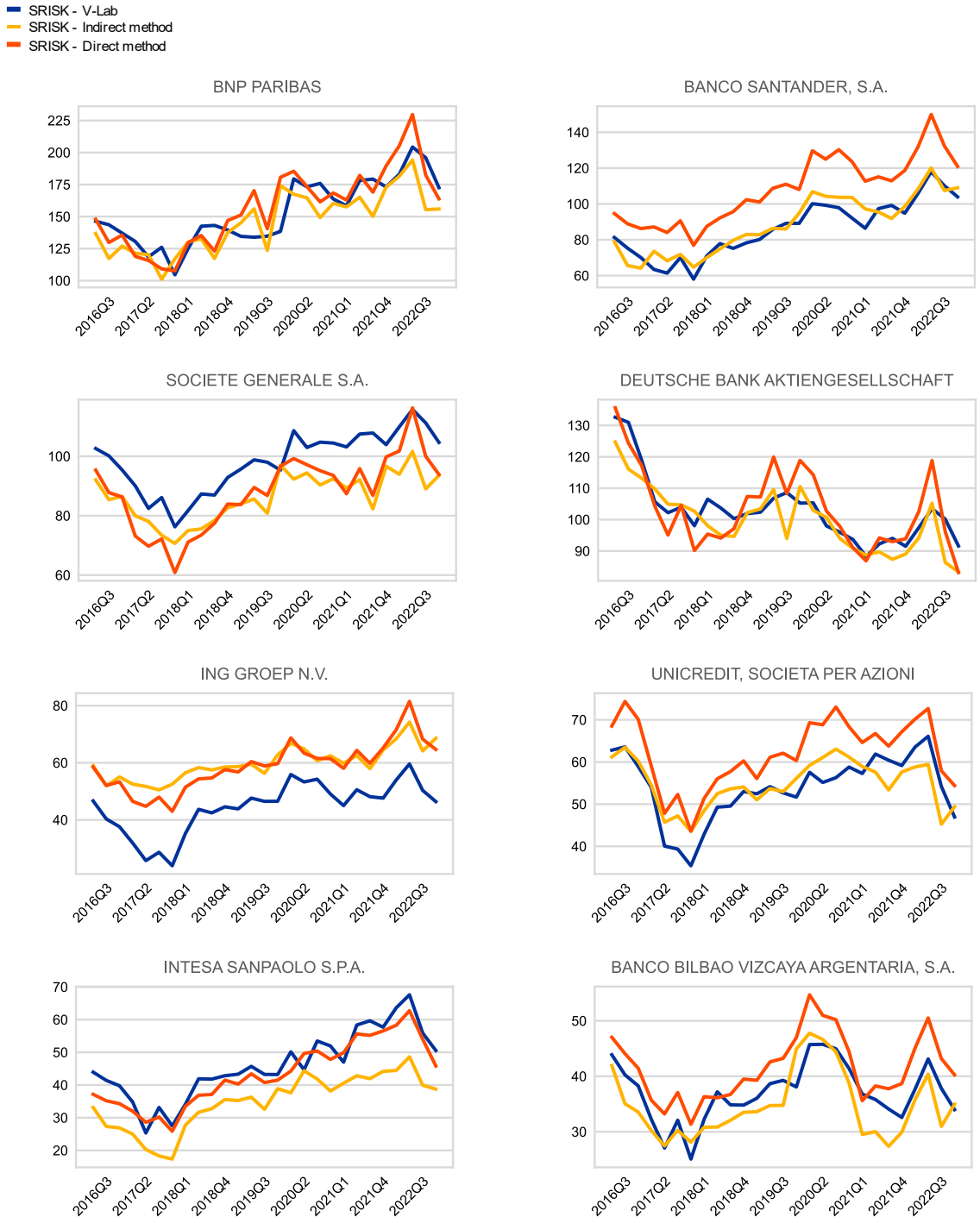
The charts in Figure 5.1 (a) present the sum of SRISK by country. The direct and indirect SRISK estimations are close to each other, and we cannot distinguish visually any major difference, or patterns that suggest heterogeneous behaviors across models. Figure 5.1 (b) plots the SRISK estimations at bank-level for the 8 largest banks, distinguishing between the SRISK as reported in V-Lab and the SRISK estimations using the direct and indirect models. When looking at the results at bank level, considerations are similar to those made for data at country level.

Figure 5.1 (a): Observed and estimated SRISK for listed Euro-area banks, aggregated by country



Sources: Authors' calculations based on V-Lab, Supervisory dataset (SUBA) and Bloomberg.
Notes: Results are not reported for Greece, Lithuania, Slovenia and Slovakia.

Figure 5.1 (b): Observed and estimated SRISK for listed Euro-area banks, 8 largest banks

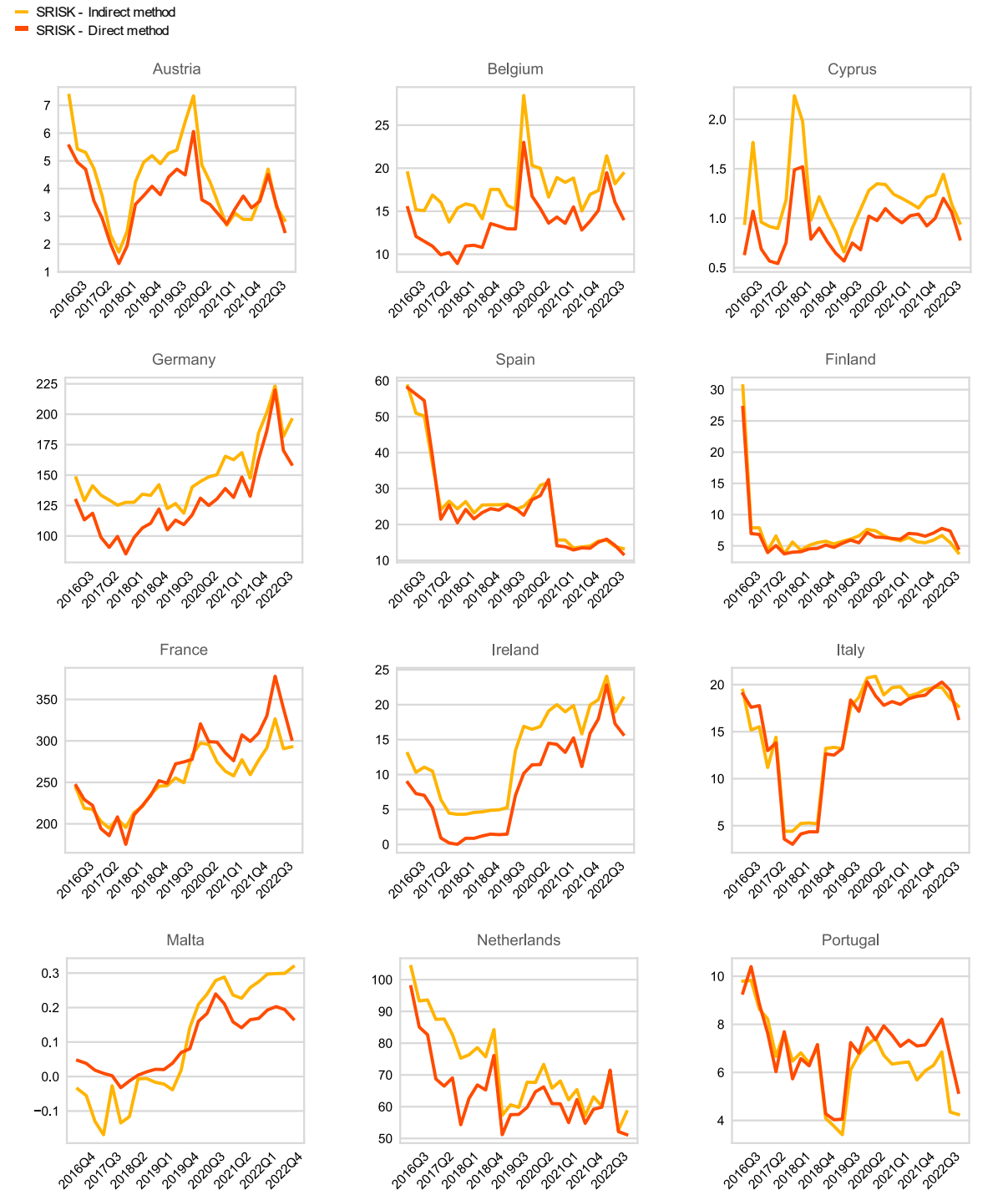


Sources: Authors' calculations based on V-Lab, Supervisory dataset (SUBA) and Bloomberg.
Notes: Results are shown for the 8 largest listed banks in terms of total assets as of 2023-Q1.

5.3.2. Out-of-sample estimation for non-listed banks

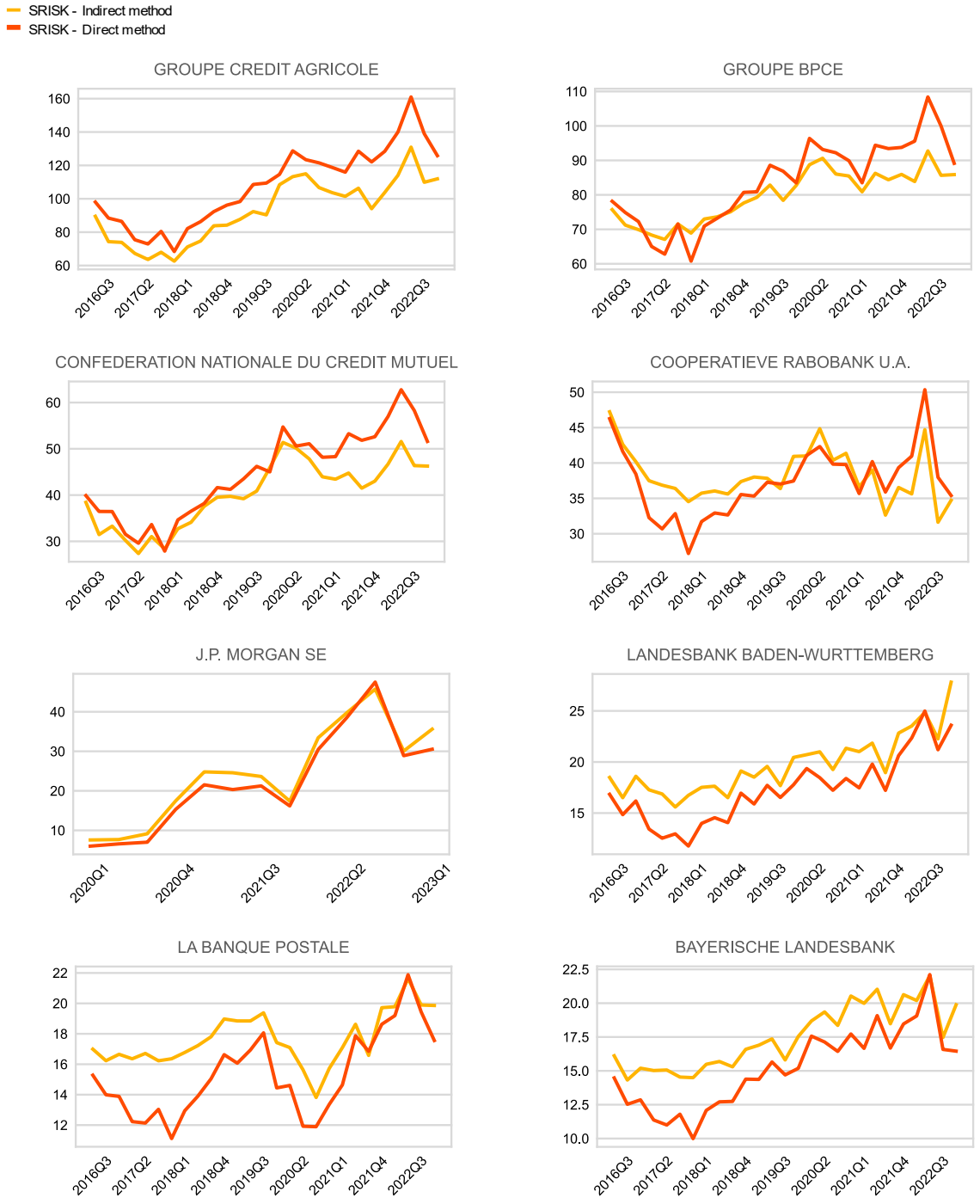
Like the prediction for listed banks, the two approaches yield similar SRISK estimates for non-listed banks over time. The evolution over time of the two different SRISK estimates is presented by country in Figure 5.2 (a) and for the 8 largest non-listed banks in Figure 5.2 (b). Some small differences can be noted for Belgium, Germany, and Ireland, while at bank level, for La Banque Postale and Bayerische Landesbank.

Figure 5.2 (a): Predicted SRISK for non-listed Euro-area banks, aggregated by country



Sources: Authors' calculations based on V-Lab, Supervisory dataset (SUBA) and Bloomberg.
Notes: Results are reported only for those countries that are also included in Figure 5.1 (a).

Figure 5.2 (b): Predicted SRISK for non-listed Euro-area banks, 8 largest banks



Sources: Authors' calculations based on V-Lab, Supervisory dataset (SUBA) and Bloomberg.
Notes: Results are shown for the 8 largest non-listed banks in terms of total assets as of 2023-Q1.

5.4. Comparison with EU-wide regulatory Stress Test results

To further assess the performance of the SRISK estimation models we run a benchmark analysis to compare them with the results of the European Banking Authority (EBA)'s EU-wide stress test conducted in 2018 and 2021 (European Banking Authority, 2018 and 2021). We compare the estimated SRISK for the last quarter of 2017 and 2020 with the projected expected capital shortfall under the adverse scenario for the year 2018 and 2021 respectively, since stress test starting points

are based on accounting data from the end of the previous year. Data on EBA capital depletion is available for 87 (for the stress test of 2018) and 89 (for the stress test of 2021) supervised banks, of which some are mapped to the sample of listed banks, and others are included in the sample of non-listed banks.

The EU wide stress test is a constrained bottom-up stress test exercise which assesses the resilience of euro area banks' balance sheets and capital positions based on a common methodology and against a scenario which assumes adverse market developments over a 1-year period.[6] As an example, the scenario in 2021 comprised a general adverse macroeconomic downturn over a three-year horizon drawing upon a prolonged COVID-19 state in a "lower for longer" interest rate environment. Specifically, the scenario projects annual real GDP growth rates of 1.5%, -1.9% and -0.2% in 2021, 2022 and 2023 respectively, with a cumulative deviation of real GDP growth from its baseline level of -12.9%.

There are substantial differences in the methodology of the SRISK and EU-wide stress test. SRISK captures the potential *capital shortfall* of banks stemming from systemic risk factors using financial market indices, where the capital shortfall is defined as the distance to the minimum capital threshold k (set at a level of 8% for the purpose of this analysis, see Sections 2 and 3 for details) relative to banks' total assets. The EU-wide stress test focuses on measuring banks' capital depletion in terms of their CET1-ratio, using banks' balance sheet information. To make the two measures of stress comparable, we transform them as follows.

For the EBA measure, we first obtain the absolute CET1 depletion by multiplying the $CET1\ Ratio$ by the risk-weighted assets (RWA), next we rescale this number by banks' total assets, and finally the resulting ratio is subtracted from $k = 8\%$, the same threshold used in the calculation of SRISK. For SRISK, we simply rescale it by banks' total assets. Schematically:

$$8\% - \frac{stressed\ CET1\ Ratio \times RWA}{Total\ Assets} \quad \Leftrightarrow \quad \frac{SRISK}{Total\ Assets}$$

The resulting numbers are estimates of the capital shortfall relative to the prudential threshold, in the event of a stress scenario.

Table 5.5: Correlation between estimates of SRISK and EBA capital shortfall

		Pearson's correlation			Spearman's correlation		
		SRISK V-Lab	SRISK Indirect	SRISK Direct	SRISK V-Lab	SRISK Indirect	SRISK Direct
Listed banks	EBA 2018 shortfall	30.08%	34.04%	35.82%	51.46%	45.15%	33.92%
	EBA 2021 shortfall	50.00%	57.19%	47.72%	62.43%	59.66%	44.59%
Non-listed banks	EBA 2018 shortfall	*n.a.*	35.00%	81.13%	*n.a.*	80.45%	74.35%
	EBA 2021 shortfall	*n.a.*	37.53%	62.77%	*n.a.*	71.35%	70.27%

Sources: Authors' calculations based on V-Lab, Supervisory dataset (SUBA) and EBA Stress Tests.
Notes: Pearson's correlation measures the linear correlation between SRISK and EBA capital shortfall (the latter corresponds to the capital at the end of the period under the advserse scenario). The Spearman's correlation (or rank correlation) measures the ordinal association between the two quantities, which is particularly relevant to assess to which extent the same bank ranks with respect to the others with the two approaches.

[6] More information about the methodology and scenario of the EU-wide stress test can be found in European Banking Authority, 2018 and 2021.

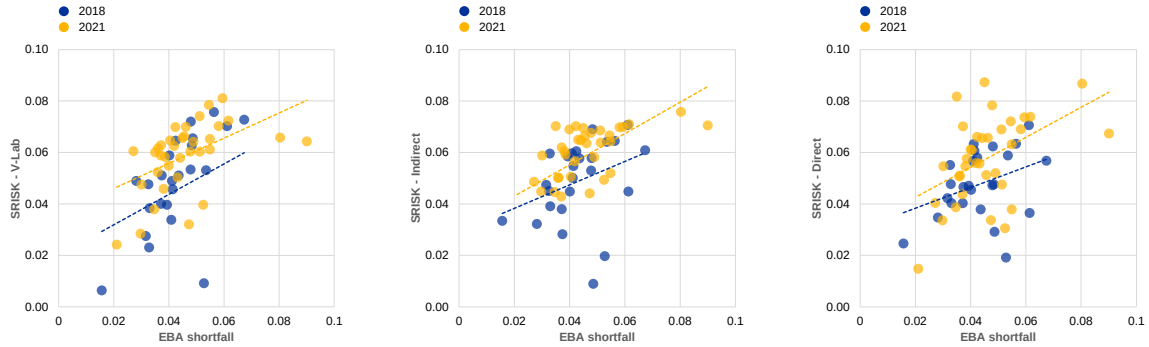
Table 5.5 presents the Pearson's and Spearman's correlation coefficients between EBA and SRISK capital shortfalls for both listed and non-listed banks. Overall, the Spearman's correlation tends to be higher than the Pearson's correlation for the two samples of banks, with a more pronounced difference recorded for non-listed banks. This suggests that vulnerable non-listed banks are positioned similarly in both the regulatory and market-based stress test and that the shocks applied in each method affect them in a similar way. Considering the most recent Stress Test and the sample of listed banks, Pearson's correlation between our estimated SRISK and EBA amounts to 57% and 47% for the indirect and direct models, respectively. The Spearman's correlation is higher when estimating SRISK with the indirect method and amounts to around 60%. For non-listed banks, the ranking correlation stands at 72% for the SRISK computed with the indirect model and performs better than Pearson's correlation by almost 40%. For the direct model, the Pearson's and Spearman's measures are comparable, recording a correlation of 62% and 70% respectively. Results for the year 2018 are in line with those of 2021 for the non-listed banks, but significantly different for the listed banks. This is likely due to the sample of listed banks being somewhat smaller in 2018, because data quality issues in the Supervisory data forced us to drop many observations.

Figure 5.3 plots the EBA capital shortfall estimated against SRISK for listed and non-listed banks. It shows that the SRISK is based on a more severe stress than EBA, since most of the observations lie above the diagonal line. This is simply due to a different definition of stress and is up to the good judgment of the supervisor to decide a realistic stress scenario. In principle, it would be possible to calibrate the stress in the SRISK methodology (the threshold defining the systemic event, as explained in Section 2) in such a way that the average capital shortfall equals that of the EU-wide stress test. This would be an interesting exercise, which would map the stress scenario of the supervisor onto the market decline incorporated in the SRISK methodology.

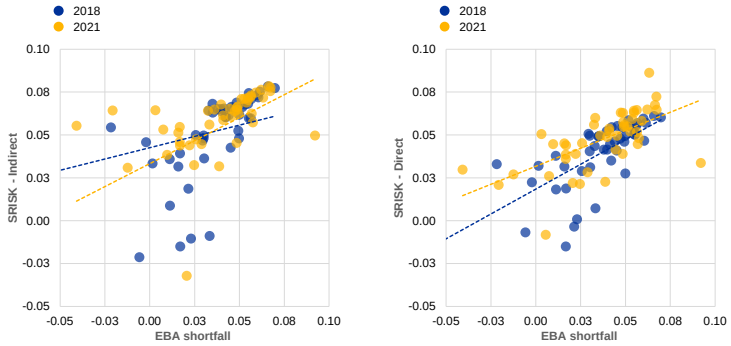
Despite the difference in magnitudes, it is reassuring that there is a substantial positive correlation between the capital shortfalls of the SIs of the two methodologies, not just when comparing them directly with the SRISK estimates provided by V-Lab, but also when comparing them with indirect estimation approach advocated in this paper. This holds true for both the listed and non-listed banks. Overall, the substantial performance correlation between the two stress testing methodologies indicates that estimating SRISK with balance sheet data can be a complementary tool to the regulatory stress tests.

Figure 5.3: Comparing EBA ST shortfalls and SRISK

(a) Listed banks



(b) Non-listed banks



Sources: Authors' calculations based on V-Lab, Supervisory dataset (SUBA) and EBA Stress Tests.
Notes: To ensure comparability with EBA shortfalls, SRISK is divided by Total Assets. Panel (a): SRISK based on V-Lab (left), SRISK based on the indirect (middle) and direct (right) estimation methods. Panel (b): SRISK based on indirect (left) and direct (right) estimation method. Trend lines are reported separately for the two periods.

5. Validation and robustness tests

In this section we conduct several robustness checks on the estimation of SRISK. Focusing on the regression specifications chosen for the final predictions (column 1 in table 5.1, column 5 in table 5.2 and column 4 in table 5.3), we re-run the same model specifications as reported in Tables 5.1 to 5.3 but we i) replace total assets with book total equity and ii) add to our primary specifications beta dummy for banks' business model. Tables 6.1 and 6.2 show that all coefficients largely remain significant and maintain their magnitude and sign. For robustness check i), it can be seen that like log-total assets, the coefficient for log-total equity is positive and statistically significant. We refrain from using both total assets and equity in the models because of collinearity of the two variables.

For robustness check ii), we find that adding business models fixed effects to the models slightly improves their fit in terms of R^2 and AIC (Tables 6.2). Nonetheless, they remove explanatory power from other time-varying variables in the case of banks' market equity and beta (columns 4 and 6). In addition, business model dummies are largely non-significant for the prediction of market equity (column 6). Therefore, we refrain from using it in the final model specifications.

Table 6.1: Replacing total assets with book equity in the regression models

	SRISK over TA (1)	SRISK over TA (2)	Log market cap (3)	Log market cap (4)	Beta (5)	Beta (6)
Log-total assets	0.006***		1.065***		0.581***	
	(0.000)		(0.018)		(0.041)	
Profits-over-total assets	-1.561***	-1.566***	63.719***	63.502***	-23.235***	-23.769***
	(0.112)	(0.113)	(4.958)	(4.890)	(2.159)	(2.150)
Equity-over-total assets	-0.300***	-0.376***	110.428***	80.382***	3.177***	-4.163***
	(0.028)	(0.026)	(5.812)	(5.599)	(0.530)	(0.705)
Periphery dummy	0.007***	0.007***	-0.244***	-0.250***	0.051**	0.039
	(0.001)	(0.001)	(0.058)	(0.058)	(0.024)	(0.024)
Log-total book equity		0.006***		1.065***		0.588***
		(0.000)		(0.017)		(0.040)
Equity-over-total assets squared			-518.944***	-423.117***		
			(32.207)	(31.446)		
CET1-ratio			-1.742**	-1.844**		
			(0.875)	(0.863)		
Log-total assets squared					-0.039***	-0.039***
					(0.004)	(0.004)
Intercept	0.025***	0.046***	-8.093***	-3.589***	-0.855***	1.243***
	(0.005)	(0.004)	(0.361)	(0.327)	(0.110)	(0.104)
Observations	1113	1113	1113	1113	1110	1110
R-squared	0.462	0.459	0.786	0.792	0.577	0.580
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors in parentheses. * p<.1, ** p<.05, ***p<.01. The periphery dummy equals to one if a bank resides in either Spain, Greece, Ireland, Italy, or Portugal.

Table 6.2: Adding banks' business models into the regression model

	SRISK over TA (1)	SRISK over TA (2)	Log market cap (3)	Log market cap (4)	Beta (5)	Beta (6)
Log-total assets	0.006***	0.007***	1.065***	1.000***	0.581***	0.718***
	(0.000)	(0.001)	(0.018)	(0.019)	(0.041)	(0.048)
Profits-over-total assets	-1.561***	-1.492***	63.719***	61.625***	-23.235***	-22.443***
	(0.112)	(0.108)	(4.958)	(3.920)	(2.159)	(2.144)
Equity-over-total assets	-0.300***	-0.281***	110.428***	64.193***	3.177***	2.502***
	(0.028)	(0.027)	(5.812)	(4.936)	(0.530)	(0.531)
Periphery dummy	0.007***	0.005***	-0.244***	-0.182***	0.051**	0.031
	(0.001)	(0.001)	(0.058)	(0.048)	(0.024)	(0.024)
General lender		0.009***		-0.067		-0.183***
		(0.002)		(0.071)		(0.050)
Specialized lender		-0.002		0.037		-0.200***
		(0.003)		(0.101)		(0.064)
Other		0.027***		-3.661***		-0.633***
		(0.004)		(0.149)		(0.086)
Equity-over-total assets squared			-518.944***	-289.405***		
			(32.207)	(26.942)		
CET1-ratio			-1.742**	-1.043		
			(0.875)	(0.734)		
Log-total assets squared					-0.039***	-0.056***
					(0.004)	(0.005)
Intercept	0.025***	0.017***	-8.093***	-5.678***	-0.855***	-0.799***
	(0.005)	(0.005)	(0.361)	(0.301)	(0.110)	(0.110)
Observations	1113	1113	1113	1113	1110	1110
R-squared	0.462	0.510	0.786	0.869	0.577	0.596
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors in parentheses. * p<.1, ** p<.05, ***p<.01. The periphery dummy equals to one if a bank resides in either Spain, Greece, Ireland, Italy, or Portugal.

6. Conclusions

SRISK is a well-established measure of systemic risk and is freely available on a high frequency basis from the V-Lab website maintained by the New York University. One limitation of this indicator is that it relies on market data and therefore cannot be computed for non-listed financial institutions: this limitation is particularly relevant in Europe, where the share of listed banks is relatively small, especially if compared with the same sector in the US. We have mapped the various components of SRISK to available balance sheet information of euro-area banks and used such mappings to compute SRISK also for non-listed banks. We have looked at various measures to validate our approach. We have shown that the fitted values of our estimation explain most of the variation in the SRISK for listed banks, suggesting that our balance sheet model provides a reasonable approximation of the systemic risk of euro area banks calculated with market values. We have further validated our model by comparing the ranking of the estimated SRISK for listed and non-listed banks with that provided by the EU-wide stress tests of the European Banking Authority (EBA) and the ECB, conducted in 2018 and 2021. Even though the EU-wide stress test relies on detailed balance sheet information and an altogether different methodology, the ranking in terms of capital shortfall emerging from our exercise is remarkably consistent with that of the stress test. This suggests that the proposed methodology can usefully complement the traditional regulatory stress testing exercises to give an insight into the health of the financial system, as it can be run at much higher frequency and at a fraction of the implementation costs.

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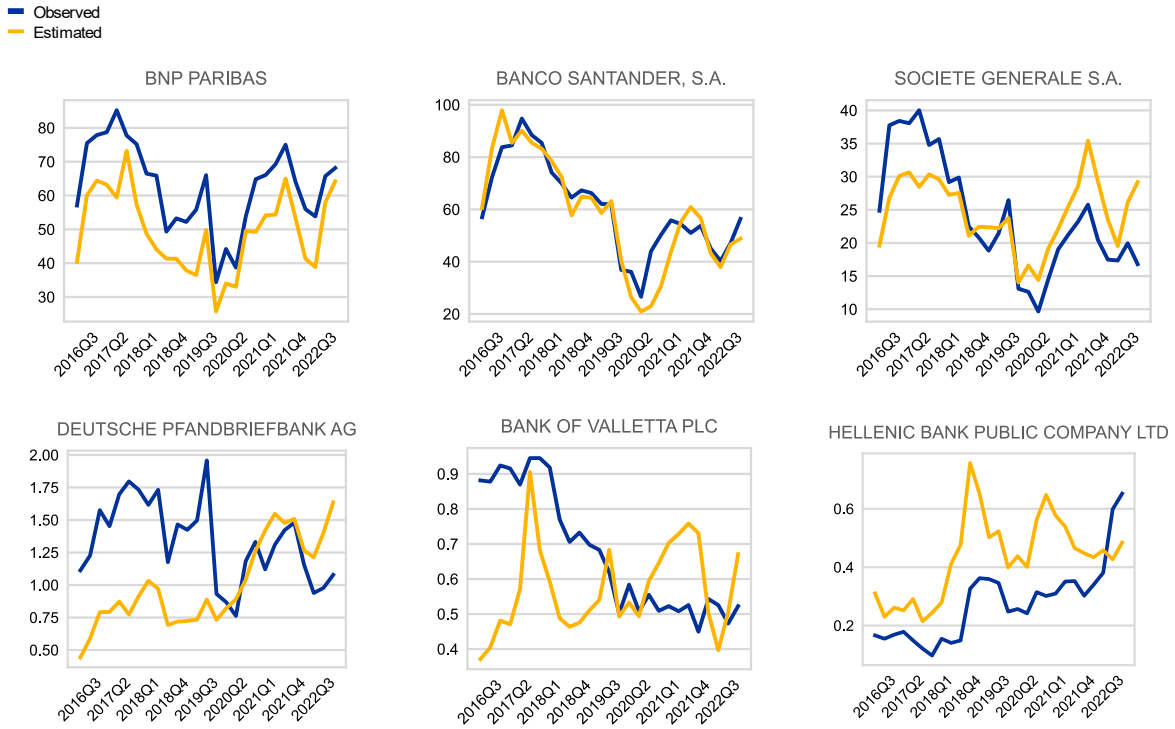
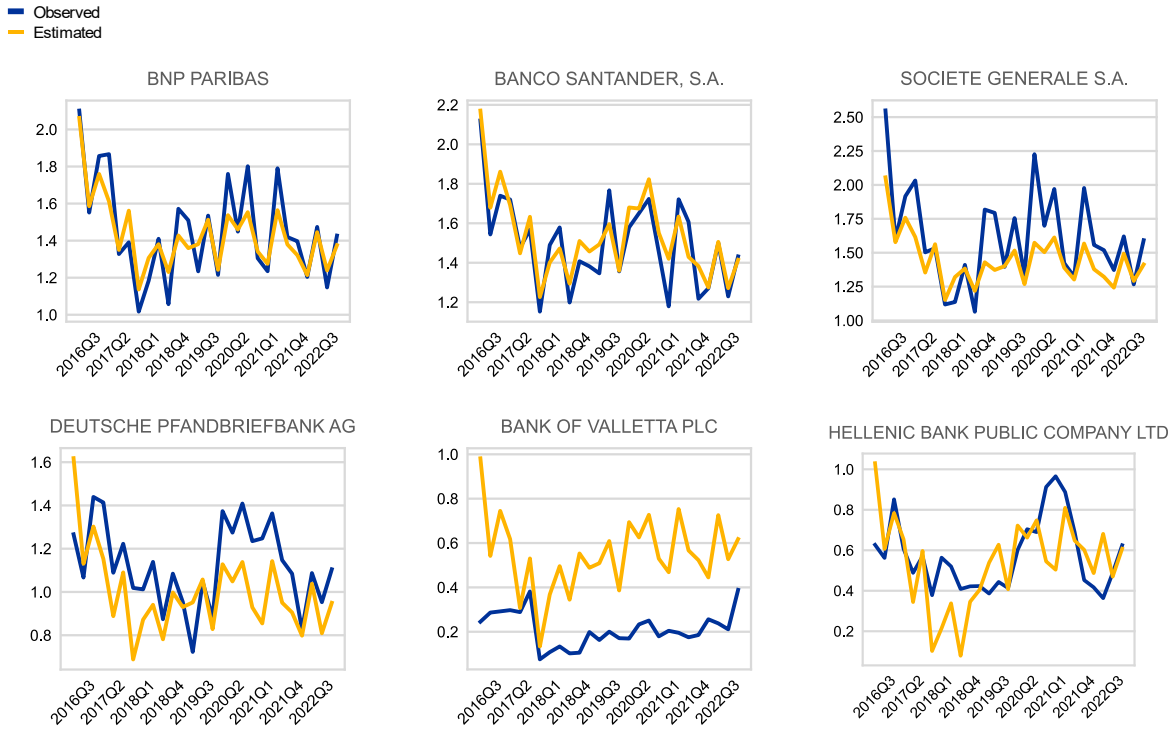
Annex A Market value and beta estimation for Indirect method

Figure A.1: Observed and estimated market value of equity



Sources: Authors' calculations based on V-Lab and Supervisory Dataset (SUBA).
Notes: Data refers to the 3 largest and 3 smallest listed banks in terms of total assets as of 2023-Q1.

Figure A.2: Observed and estimated beta



Sources: Authors' calculations based on V-Lab and Supervisory Dataset (SUBA).
Notes: Data refers to the 3 largest and 3 smallest listed banks in terms of total assets as of 2023-Q1.

Annex B List of Euro-area Significant Institutions in the dataset

Country	Name	LEI code	Regression sample
AT	BAWAG GROUP AG	529900S9YO2JHTIIDG38	YES
AT	ERSTE GROUP BANK AG	PQOH26KWDF7CG10L6792	YES
AT	OSTERREICHISCHE VOLKSBANKEN AG	FJDBAXYL0TCMGLPQ4563	YES
AT	RAIFFEISEN BANK INTERNATIONAL AG	9ZHRYM6F437SQJ6OUG95	YES
BE	DEXIA	D3K6HXMBBB6SK9OXH394	YES
BE	KBC GROEP	213800X3Q9LSAKRUWY91	YES
CY	BANK OF CYPRUS PUBLIC COMPANY LTD	PQ0RAP85KK9Z75ONZW93	YES
CY	HELLENIC BANK PUBLIC COMPANY LTD	CXUHEGU3MADZ2CEV7C11	YES
DE	AAREAL BANK AG	EZKODONU5TYHW4PP1R34	YES
DE	COMMERZBANK AG	851WYGNLUQLFZBSYGB56	YES
DE	DEUTSCHE BANK AG	7LTWFZYICNSX8D621K86	YES
DE	DEUTSCHE PFANDBRIEFBANK AG	DZZ47B9A52ZJ6LT6VV95	YES
EE	AS LHV GROUP	529900JG015JC10LED24	YES
ES	BANCO BILBAO VIZCAYA ARGENTARIA, S.A.	K8MS7FD7N5Z2WQ51AZ71	YES
ES	BANCO DE SABADELL, S.A.	SI5RG2M0WQQLZCXKRM20	YES
ES	BANCO SANTANDER, S.A.	5493006QMFDDMYWIAM13	YES
ES	BANKINTER, S.A.	VWMYAEQSTOPNV0SUGU82	YES
ES	CAIXABANK, S.A.	7CUNS533WID6K7DGFI87	YES
ES	UNICAJA BANCO, S.A.	5493007SJLLCTM6J6M37	YES
FI	NORDEA BANK ABP	529900ODI3047E2LIV03	YES
FR	BNP PARIBAS	R0MUWSFPU8MPRO8K5P83	YES
FR	SOCIETE GENERALE S.A.	O2RNE8IBXP4R0TD8PU41	YES
GR	ALPHA SERVICES AND HOLDINGS S.A.	5299009N55YRQC69CN08	YES
GR	EUROBANK ERGASIAS SERVICES AND HOLDINGS S.A.	JEUVK5RWVJEN8W0C9M24	YES
GR	NATIONAL BANK OF GREECE, S.A.	5UMCZOEYKCVFAW8ZLO05	YES
GR	PIRAEUS FINANCIAL HOLDINGS	M6AD1Y1KW32H8THQ6F76	YES
IE	AIB GROUP PLC	635400AKJBGNS5WNQL34	YES
IE	BANK OF IRELAND GROUP PLC	635400C8EK6DRI12LJ39	YES
IE	PERMANENT TSB GROUP HOLDINGS PLC	635400DTNHVYGZODKQ93	YES
IT	BANCA CARIGE S.P.A.	F1T87K3OQ2OV1UORLH26	YES
IT	BANCA MONTE DEI PASCHI DI SIENA S.P.A.	J4CP7MHCXR8DAQMKIL78	YES
IT	BANCA POPOLARE DI SONDRIO SOCIETA PER AZIONI	J48C8PCSJVUBR8KCW529	YES
IT	BANCO BPM SOCIETA PER AZIONI	815600E4E6DCD2D25E30	YES
IT	BPER BANCA S.P.A.	N747OI7JINV7RUUH6190	YES
IT	FINECOBANK BANCA FINECO S.P.A.	549300L7YCATGO57ZE10	YES
IT	INTESA SANPAOLO S.P.A.	2W8N8UU78PMDQKZENC08	YES
IT	MEDIOBANCA - BANCA DI CREDITO FINANZIARIO S.P.A.	PSNL19R2RXX5U3QWHI44	YES
IT	UNICREDIT, SOCIETA PER AZIONI	549300TRUWO2CD2G5692	YES
IT	UNIONE DI BANCHE ITALIANE SOCIETA PER AZIONI	81560097964CBDAED282	YES
LT	AKCINE BENDROVE SIAULIU BANKAS	549300TK038P6EV4YU51	YES
MT	BANK OF VALLETTA PLC	529900RWC8ZYB066JF16	YES
MT	HSBC BANK MALTA P.L.C.	549300X34UUBDEUL1Z91	YES
NL	ABN AMRO BANK N.V.	BFXS5XCH7N0Y05NIXW11	YES
NL	ING GROEP N.V.	549300NYKK9MWM7GGW15	YES
PT	BANCO BPI, SA	3DM5DPGI3W6OU6GJ4N92	YES
PT	BANCO COMERCIAL PORTUGUES, SA	JU1U6S0DG9YLT7N8ZV32	YES
SI	NOVA LJUBLJANSKA BANKA D.D., LJUBLJANA	5493001BABFV7P27OW30	YES
SK	VSEOBECNA UVEROVA BANKA, A.S.	549300JB1P61FUTPEZ75	YES
AT	ADDIKO BANK AG	529900UKZBMDBDZIXD62	NO
AT	PROMONTORIA SACHER HOLDING N.V.	5299004SNO5GECIBWJ18	NO
AT	RAIFFEISENBANKENGRUPPE OO VERBUND EGEN	529900XSTAE561178282	NO
AT	RAIFFEISEN-HOLDING NIEDEROSTERREICH-WIEN	529900SXEWPJ1MRRX537	NO
AT	RAIFFEISEN-LANDESBANKEN-HOLDING GMBH	529900JP9C734S1LE008	NO
AT	SBERBANK EUROPE AG IN ABWICKLUNG	529900IZ8TASAYR3A694	NO
AT	VOLKSBANKEN VERBUND	AT0000000000043000VB	NO
BE	AXA BANK BELGIUM	LSGM84136ACA92XCN876	NO
BE	BANK DEGROOF PETERCAM	549300NBLHT5Z7ZV1241	NO
BE	BELFIUS BANK	A5GWLFH3KM7YV2SFQL84	NO
BE	CRELAN	549300DYPOFMXOR7XM56	NO
BE	SOCIETE DINVESTISSEMENTS ARGENTA	5493008QOCP58OLEN998	NO
BE	THE BANK OF NEW YORK MELLON	MMYX0N4ZEZ13Z4XCG897	NO
BG	DSK BANK AD	529900GEH0DAUTAXUA94	NO

CY	BANK OF CYPRUS HOLDINGS PUBLIC LIMITED COMPANY	635400L14KNHZXPUZM19	NO
CY	COOPERATIVE ASSET MANAGEMENT COMPANY LTD	5493007F6CE5P22TJ731	NO
CY	RCB BANK LTD	253400EBCBBVB9TUHN50	NO
DE	BARCLAYS BANK PLC FRANKFURT BRANCH	00000000000DE0013045	NO
DE	BAYERISCHE LANDESBANK	VDYMYTQGZZ6DU0912C88	NO
DE	CITIGROUP GLOBAL MARKETS EUROPE AG	6TJCK1B7E7UTXP528Y04	NO
DE	DEKABANK DEUTSCHE GIROZENTRALE	0W2PZJM8XOY22M4GG883	NO
DE	DEUTSCHE APOTHEKER- UND ARZTEBANK EG	5299007S3UH5RKUYDA52	NO
DE	DZ BANK AG DEUTSCHE ZENTRAL-GENOSSENSCHAFTSBANK	529900HNOAA1KXQJUQ27	NO
DE	ERWERBSGESELLSCHAFT DER S-FINANZGRUPPE	391200EEGLNXBBCVKC73	NO
DE	GOLDMAN SACHS BANK EUROPE SE	8IBZUGJ7JPLH368JE346	NO
DE	HAMBURG COMMERCIAL BANK AG	TUKDD90GPC79G1KOE162	NO
DE	HASPA FINANZHOLDING	529900JZTYE3W7WQH904	NO
DE	HSH BETEILIGUNGS MANAGEMENT GMBH	529900OQ416JMY9LQO42	NO
DE	HYPO REAL ESTATE HOLDING AG	52990082YOVOZIC8QX60	NO
DE	J.P. MORGAN SE	549300ZK53CNGEEI6A29	NO
DE	LANDESBANK BADEN-WURTTEMBERG	B81CK4ESI35472RHJ606	NO
DE	LANDESBANK HESSEN-THURINGEN GIROZENTRALE	DIZES5CFO5K3I5R58746	NO
DE	LANDESKREDITBANK BADEN-WURTTEMBERG	0SK1ILSPWNVBNQWU0W18	NO
DE	LANDWIRTSCHAFTLICHE RENTENBANK	529900Z3J0N6S0F7CT25	NO
DE	MORGAN STANLEY EUROPE HOLDING SE	549300C9KPZR0VZ16R05	NO
DE	MUNCHENER HYPOTHEKENBANK EG	529900GM944JT8YIRL63	NO
DE	NORDDEUTSCHE LANDESBANK - GIROZENTRALE	DSNHHQ2B9X5N6OUJ1236	NO
DE	NRW.BANK	52990002O5KK6XOGJ020	NO
DE	SEB AG	P0T131ELWMYGYC1G4O52	NO
DE	STATE STREET EUROPE HOLDINGS GERMANY	529900V3O1M5IHMOSF46	NO
DE	UBS EUROPE SE	5299007QVIQ7IO64NX37	NO
DE	VOLKSWAGEN BANK	529900GJD3OQLRZCKW37	NO
DE	VOLKSWAGEN FINANCIAL SERVICES AG	529900USFSZYPS075O24	NO
DE	WGZ BANK AG	EFHQAFG69S4HKHLIZA14	NO
EE	AS SEB PANK	549300ND1MQ8SNNYMJ22	NO
EE	LUMINOR BANK AS	213800JD2L89GGG7LF07	NO
EE	LUMINOR HOLDING AS	213800RZWHE5EUX9R444	NO
EE	SWEDBANK AS	549300PHQZ4HL15HH975	NO
ES	ABANCA CORPORACION BANCARIA, S.A.	54930056IRBXK0Q1FP96	NO
ES	ABANCA HOLDING FINANCIERO SAU	9598003BP0LHPHDWV834	NO
ES	ABANCA HOLDING HISPANIA SA	95980020140005986047	NO
ES	BANCO DE CREDITO SOCIAL COOPERATIVO	95980020140005881190	NO
ES	BANCO MARE NOSTRUM, S.A.	549300PY124PITBSWN73	NO
ES	BANCO POPULAR ESPANOL, S.A.	80H66LPTVDLM0P28XF25	NO
ES	BFA, TENEDORA DE ACCIONES, S.A.	549300GT0XFTFHGOIS94	NO
ES	CATALUNYA BANC, S.A	549300I84DXMIK4UUL30	NO
ES	CRITERIA CAIXA, SA	959800DQQUAMV0K08004	NO
ES	IBERCAJA BANCO, S.A.	549300OLBL49CW8CT155	NO
ES	KUTXABANK, S.A.	549300U4LIZV0REEQQ46	NO
ES	LIBERBANK, S.A.	635400XT3V7WHLSFYY25	NO
FI	DANSKE BANK A/S, SUOMEN SIVULIIKE	FI10786932	NO
FI	DANSKE BANK OYJ	3BAUHUB4IZR54J3EPO08	NO
FI	KUNTARAHOITUS OYJ	529900HEKOENJHPNN480	NO
FI	NORDEA BANK FINLAND ABP	CXW2O4H2U3MBVXMY1773	NO
FI	OP OSUUSKUNTA	7437003B5WFBOIEFY714	NO
FR	AGENCE FRANCAISE DE DEVELOPPEMENT	9695008K5N8MKIT4XJ91	NO
FR	BOFA SECURITIES EUROPE SA	549300FH0WJAPEHTIQ77	NO
FR	BPIFRANCE	969500FYSB4IT3QWYB65	NO
FR	BPIFRANCE	969500STN7T9MRUMJ267	NO
FR	C.R.H. - CAISSE DE REFINANCEMENT DE LHABITAT	969500TVVZM86W7W5I94	NO
FR	CONFEDERATION NATIONALE DU CREDIT MUTUEL	9695000CG7B84NLR5984	NO
FR	GROUPE BPCE	FR9695005MSX1OYEMGDF	NO
FR	GROUPE CREDIT AGRICOLE	FR969500TJ5KRTCJQWXH	NO
FR	HSBC CONTINENTAL EUROPE	F0HUI1NY1AZMJMD8LP67	NO
FR	LA BANQUE POSTALE	96950066U5XAAIRCPA78	NO
FR	RCI BANQUE	96950001WI712W7PQG45	NO
FR	SFIL S.A.	549300HFEHJOXGE4ZE63	NO
IE	ALLIED IRISH BANKS, PUBLIC LIMITED COMPANY	3U8WV1YX2VMUHH7Z1Q21	NO
IE	BANK OF AMERICA EUROPE DESIGNATED ACTIVITY COMPANY	EQYXK86SF381Q21S3020	NO
IE	BARCLAYS BANK IRELAND PLC	2G5BKIC2CB69PRJH1W31	NO
IE	CITIBANK HOLDINGS IRELAND LIMITED	549300K7L8YW8M215U46	NO

IE	THE GOVERNOR AND COMPANY OF THE BANK OF IRELAND	Q2GQA2KF6XJ24W42G291	NO
IE	ULSTER BANK IRELAND DESIGNATED ACTIVITY COMPANY	635400KQIMALJ4XLAD78	NO
IT	BANCA MEDIOLANUM S.P.A.	7LVZJ6XRIE7VNZ4UBX81	NO
IT	BANCA POPOLARE DI MILANO	8156009BC82130E7FC43	NO
IT	BANCA POPOLARE DI VICENZA - SOCIETA PER AZIONI	V3AFM0G2D3A6E0QWDG59	NO
IT	BANCO POPOLARE - SOCIETA COOPERATIVA	5493006P8PDBI8LC0O96	NO
IT	BARCLAYS BANK PLC	IT0000101247669	NO
IT	CASSA CENTRALE BANCA	LOO0AWXR8GF142JCO404	NO
IT	CREDITO EMILIANO HOLDING SOCIETA PER AZIONI	815600AD83B2B6317788	NO
IT	ICCREA BANCA S.P.A. - ISTITUTO CENTRALE DEL CREDITO COOPERATIVO	NNVPP80YIZGEY2314M97	NO
IT	ICCREA HOLDING SPA	815600D79C96B9661149	NO
IT	VENETO BANCA S.P.A.	549300W9STRUCJ2DLU64	NO
LT	AB SEB BANKAS	549300SBPFE9JX7N8J82	NO
LT	LUMINOR BANK AB	213800ZY8OD37RGI4E67	NO
LT	SWEDBANK, AB	549300GH3DFCXVNBHE59	NO
LU	ABLV BANK LUXEMBOURG, S.A.	549300EPED91EAR66X32	NO
LU	BANQUE ET CAISSE DEPARGNE DE LETAT, LUXEMBOURG	R7CQUF1DQM73HUTV1078	NO
LU	BANQUE INTERNATIONALE A LUXEMBOURG	9CZ7TVMR36CYD5TZBS50	NO
LU	J.P. MORGAN BANK LUXEMBOURG S.A.	7W1GMC6J4KGLBBUSYP52	NO
LU	PRECISION CAPITAL S.A.	549300AUUQG072ATL746	NO
LU	QUINTET PRIVATE BANK (EUROPE) S.A	KHCL65TP05J1HUW2D560	NO
LU	RBC INVESTOR SERVICES BANK S.A.	549300IVXKQHV6O7PY61	NO
LU	STATE STREET BANK LUXEMBOURG S.C.A.	RNVZOEETEJ32KW0QXS82	NO
LU	UBS (LUXEMBOURG) S.A.	5299007CS17YR0FL8U25	NO
LV	ABLV BANK, AS	549300IHIJ7SCANBWN17	NO
LV	AKCIJU SABIEDRIBA CITADELE BANKA	2138009Y59EAR7H1UO97	NO
LV	AS PNB BANKA	549300J6I0BUEY33QO16	NO
LV	AS SEB BANKA	549300YW95G1VBBGGV07	NO
LV	LUMINOR BANK AS	213800JDOTKJMCUB1M79	NO
LV	SWEDBANK AS	549300FXBIWWGK7T0Y98	NO
LV	SWEDBANK BALTICS AS	9845006C7B5CC707X660	NO
MT	DEUTSCHE BANK (MALTA) LTD	529900AXSJX810H93N02	NO
MT	MDB GROUP LIMITED	213800TC9PZRBHMJW403	NO
NL	ABN AMRO GROUP N.V.	724500DWE10NNL1AXZ52	NO
NL	BNG BANK N.V.	529900GGYMNGRQTDOO93	NO
NL	COOPERATIEVE RABOBANK U.A.	DG3RU1DBUFHT4ZF9WN62	NO
NL	DE VOLKSBANK N.V.	724500A1FNICHSDF2I11	NO
NL	DE VOLKSHOLDING B.V.	724500VLXQUMMD5BJB61	NO
NL	LP GROUP B.V.	72450088V7QLGDPY6W41	NO
NL	NEDERLANDSE WATERSCHAPSBANK N.V.	JLP5FSPH9WPSHY3NIM24	NO
NL	SNS REAAL N.V.	72450032NPOX5UJQTI97	NO
PT	CAIXA GERAL DE DEPOSITOS, S.A.	TO822O0VT80V06K0FH57	NO
PT	LSF NANI INVESTMENTS S.A R.L.	222100K6QL2V4MLHWQ08	NO
PT	NOVO BANCO, SA	5493009W2E2YDCXY6S81	NO
SI	ABANKA D.D.	549300271OUEJT4RYD30	NO
SI	AGRI EUROPE CYPRUS LIMITED	213800HDJ876ACJXXD05	NO
SI	BISER TOPCO S.A R.L.	222100ZXZ9BRGDMKXL75	NO
SI	NOVA KREDITNA BANKA MARIBOR D.D.	549300J0GSZ83GTKBZ89	NO
SI	OTP LUXEMBOURG S.A R.L.	22210058UCKT3BJTCN24	NO
SI	UNICREDIT BANKA SLOVENIJA D.D.	549300O2UN9JLME31F08	NO
SK	SLOVENSKA SPORITELNA, A.S.	549300S2T3FWVVXWJI89	NO
SK	TATRA BANKA, A.S.	3157002JBFAI478MD587	NO

Sources: Supervisory dataset (SUBA).
Notes: The analysis is based on an overall sample of 181 Significant Institutions, for which data are available. The table is based on the most updated information available for each bank, and until the end of 2023-Q1.

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