Testing Macroprudential Stress Tests: The Risk of Regulatory Risk Weights[☆]

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Abstract

Macroprudential stress tests have been employed by regulators in the United States and Europe to assess and address the solvency condition of financial firms in adverse macroeconomic scenarios. Financial institutions are required to maintain a capital cushion against such events and stress tests are designed to assess if it is adequate. If it is not, then the capital shortfall is the additional capital needed. We compare the capital shortfall measured by regulatory stress tests, to that of a benchmark methodology — the "V-Lab stress test" — that employs only publicly available market data. We find that when capital shortfalls are measured relative to *risk-weighted assets*, the ranking of financial institutions is very different from the V-Lab stress test, whereas when measured relative to *total assets*, the results are quite similar. We show that the risk measures used in risk-weighted assets are cross-sectionally uncorrelated with market measures of risk as they do not account for the "risk that risk will change." Furthermore, the firms that appeared to be best capitalized relative to risk-weighted assets were no better than the rest when the European economy deteriorated into the sovereign debt crisis in 2011.

Key words: macroprudential regulation, stress test, systemic risk, risk-weighted assets.
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1. Introduction

Since the financial crisis of 2007-2009, macroprudential stress tests have become a standard tool that regulators use to assess the resilience of financial systems. Macro stress tests have been designed to assist and facilitate macroprudential regulation, which essentially aims at preventing the costs of the financial sector's distress spreading to the real economy (Borio and Drehmann, 2009; Hirtle et al., 2009; Acharya et al., 2010; Hanson et al., 2011). Acharya et al. (2010) argue that such spillovers from the financial sector to the real economy arise when the financial sector as a whole is undercapitalized, limiting its capacity to intermediate industrial firms' functions. As part of the regulatory toolkit, macro stress tests should contain such (systemic risk) externalities by ensuring that the financial sector is sufficiently capitalized to continue financial intermediation in a severe economic downturn.

To simulate a severe economic downturn, regulators define a hypothetical stress scenario by specifying shocks to different macroeconomic and financial variables. The adverse scenario is translated into losses to assets on the balance sheet of banks using models that capture the sensitivity of banks' exposures to the stress scenario. These losses are assumed to be first borne by equity capital. The required capitalization of a bank is assessed using measures (the capital ratios) of the financial performance of the bank after application of the stress test model.

The current approach to assessing capital requirements is strongly dependent on the regulatory capital ratios defined under Basel Accords. The capital ratio of a bank is usually defined as the ratio of a measure of its equity to a measure of its assets. A regulatory capital ratio usually employs book value of equity and *risk-weighted assets*, where individual asset holdings are multiplied by corresponding regulatory "risk weights." The regulatory capital ratios in stress tests help regulators determine which banks fail the test under the stress scenario and what supervisory or recapitalization actions should be undertaken to address this failure.

An annual supervisory stress test of the financial sector in the United States has become a requirement with the implementation of Dodd-Frank Wall Street Reform and Consumer Protection Act (Pub.L. 111–203, H.R. 4173) of 2010. Macroprudential stress tests have also been used by U.S. and European regulators to restore market confidence in financial sectors during an economic crisis. As a response to the recent financial crisis, the 2009 U.S. stress test led to a substantial recapitalization of the financial sector in the U.S. In Europe, the 2011 stress test also served as a crisis management tool during the European sovereign debt crisis. The European exercise lacked credibility in this role, however, due largely to the absence of a clear recapitalization plan for firms failing the stress test.

An alternative approach for measuring the financial performance of a firm under stress is presented in Acharya et al. (2010, 2012) and Brownlees and Engle (2011). The proposed measure ($SRISK$) represents the expected amount of capital an institution would need to raise during an economic crisis to restore a target capital ratio. The crisis or stress scenario is defined by a 40% drop in the market equity index over six months. In these market conditions, $SRISK$ is based on the assumption that the book value of the debt of the bank will remain constant, while its market capitalization will decrease by its expected six-month return conditional on a crisis, estimated from a bivariate model of the bank and the market returns. As the stress is on the market value of equity, this methodology — called "V-Lab stress test" — can be viewed as a mark-to-market stress test. The results of this benchmark for macroprudential stress tests are updated weekly on the Volatility Laboratory (V-Lab) website.[1]

The V-Lab stress tests have the advantage that they are inexpensive and non-invasive, as they require only publicly available data. They can show time series variations in financial sector capitalization. However, they do not show anything on financial institutions that are

[1] http://vlab.stern.nyu.edu/.

not traded and they do not reveal information on the weaknesses of financial institutions. The regulatory stress tests have large supervisory data requirements that provide sensitive information and are expensive to collect, analyze and maintain. The creation of scenarios for the tests is essentially a surprise to the sector as otherwise it will distort investment decisions. Thus the time series of regulatory stress tests is unlikely to reveal changes in bank capitalization. Fortunately, regulators can use more than one measure of financial health and it is our goal in this research to show the relationships between the outcomes and the benefits of combining these approaches.

In this paper, we compare the outcomes of stress tests performed by U.S. and European regulators to this benchmark methodology. Stress tests usually disclose two types of performance measures: the projected losses of a bank under the stress scenario and its required capitalization (measured by a capital ratio or a capital shortfall estimate) once these losses are taken into account. In addition, the average risk weight of a bank (the ratio of its risk-weighted assets to total assets) in the supervisory stress test is considered as a measure of the bank's asset risk under the stress scenario. We compare this risk measure with a market measure of asset risk implied by the V-Lab methodology, in particular to the "V-Lab risk weight," which assumes that banks whose market capitalization is predicted to shrink the most in a crisis are the riskiest. The V-Lab risk weight is calculated in a top-down manner at the level of the entire firm, rather than bottom-up (i.e., asset by asset), as in the Basel risk-weighted approach.

Our comparisons reveal the following interesting results. First, the required capitalization in the V-Lab stress test appears always to be larger than in regulatory stress tests, but this contrast appears to be extreme in Europe, reflecting the low number of firms failing the supervisory stress test. As regulatory stress tests and the V-Lab stress tests identify vulnerable banks in a period of economic stress, the ranking of bank vulnerability in the scenarios should, however, be closely related even if the magnitude of the vulnerability is greater in the V-Lab stress test. Similarly, regulatory stress tests and V-Lab stress tests should identify vulnerable banks when there is a realized period of stress. We illustrate this using the 2011 European stress test, which was followed by a global downturn. For this stress test, we compare the outcomes of the regulatory stress test and the V-Lab stress test to realized outcomes of banks during the six months following the stress test disclosure.

We find that the average regulatory risk weight of stress tests is uncorrelated with the V-Lab risk weight. In the 2011 European stress test, the average risk weight of European banks appears completely unconnected with their actual risk (measured by their realized volatility) during the six months following the disclosure of the results of the stress test. Furthermore, we show that Basel risk standards provide no incentives for banks to diversify as regulatory risk weights (derived in a bottom-up manner) ignore the subadditivity feature of portfolio risk. As a result, firms are encouraged to concentrate their entire portfolio on one asset category or exposure,[2] and the underestimation of risk weights automatically leads to excess leverage.

Second, we consider an alternative definition of capital adequacy in stress tests based on the simple leverage ratio, defined as the ratio of book equity to total (un-weighted) assets. When capital adequacy is a function of *risk-weighted assets* in regulatory stress tests, the ranking of financial institutions by capital shortfalls deviates considerably from rankings using the V-Lab market price-based approach. However, when stress tests rely on *total assets* to indicate capital requirements, the bank rankings are similar to the V-Lab rankings.

Overall, the findings indicate that stress tests would be more effective if capital requirements based on risk-weighted assets were supplemented by requirements based on total assets and market risks. A risk-based capital requirement is not sufficient as there is "risk that risk

[2]Empirical evidence that European banks took advantage of regulatory risk weights by concentrating on zero-risk weight sovereign debt exposures of the southern European periphery can be found in Acharya and Steffen (2013).

will change" (Engle, 2009), for example, the risk of an increase in risk over time of some currently safe asset class such as mortgages or sovereign bonds. In addition, risk weights are flawed measures of bank risks cross-sectionally as banks game their risk-weighted assets (cherry-pick on risky but low risk-weight assets) to meet regulatory capital requirements, which does not necessarily reduce economic leverage.

The rest of the paper is structured as follows. In Section 2, we introduce macroprudential stress tests. We also present the alternative V-Lab methodology and discuss important differences with regulatory stress tests in Section 3. We compare the outcomes of regulatory stress tests and V-Lab in Section 4. We conclude in Section 5.

2. Macroprudential stress tests

We describe the general purpose of stress tests, the definition of regulatory capital requirements and the way stress tests are implemented in Europe and in the U.S.

2.1. Why do we need macroprudential stress tests?

Crises occur when financial firms' balance sheets are hit by a common asset shock. The depreciation of the banks' asset values and credit risk concerns may lead creditors to refuse to continue to provide funding, forcing banks to sell assets to cover redemptions. When the only potential buyers of these assets are other financial firms also experiencing funding problems, assets will be sold at a fire sale that will further depress prices in the market. In the presence of fire sales, firms will need to sell even more of their assets to raise cash, thereby limiting the supply of credit available to the real economy.

Firms cannot achieve efficient outcomes privately because they do not bear the cost of (i) ex post bailouts of their insured deposit base, and (ii) externalities they impose on the rest of the economy (through fire sales and credit crunch) when the financial sector is undercapitalized (Acharya et al., 2010). Because of risk-shifting (firms shifting the downside risk of their investments to the lender) and the debt overhang problem (shareholders knowing that their money will go to the senior creditors in the event of default), firms will not build up the ex ante adequate capital buffers on their own.

Microprudential (bank level) and macroprudential (system level) regulations are needed to respectively address the costs financial firms impose on the system via channels (i) and (ii) above. As part of the regulatory toolkit, stress testing should ensure that the financial sector is adequately capitalized to protect taxpayers against (i) and limit the likelihood and the cost of (ii) under a wide range of possible scenarios. Macroprudential stress tests can help address this market failure by bringing the capitalization of the financial sector in line with market perceptions of risk. This should ensure the financial sector's access to short-term funding.

In this paper, we consider stress tests conducted on a U.S. and EU-wide level. These stress tests can be qualified as macroprudential stress tests as opposed to microprudential stress tests conducted on a bank-level as a requirement under Pillar 2 of Basel II (Internal Capital Adequacy Assessment Process (ICAAP)).[3] More importantly, they can be qualified as macroprudential stress tests because of their common goals of restoring market confidence in the financial sector and improving market discipline through more rigorous and transparent assessments of banks' risks.

2.2. How capital requirements are measured in a stress test?

The capital ratio of a bank is typically defined as the ratio of a measure of its capital to a measure of its assets. The measures of capital employed in regulatory ratios correspond to different qualities of capital based on their capacity to absorb asset losses in different states of the world; the Tier 1 Common capital (U.S.) and the Core Tier 1 capital (EU) correspond to

[3]Other macroprudential stress tests, not discussed here, were undertaken by national authorities (e.g., Ireland, UK, Spain) and by the International Monetary Fund.

the highest-quality category and are the closest to common shareholders equity.[4] Measures of a bank's assets are usually its total assets (Tier 1 leverage ratio) or its risk-weighted assets, where different individual asset holdings or asset classes are multiplied by corresponding regulatory "risk weights."

The required capitalization of a bank in "normal times" is defined by the required fraction of (risk-weighted) assets that has to be funded with high-quality capital. To measure the required capitalization "under stress," stress tests rely on models that translate an adverse macroeconomic scenario into losses to assets on the balance sheet of banks. These losses are assumed to be first borne by equity. The resulting capital ratios help regulators determine which banks fail the test under the stress scenario and what supervisory or recapitalization actions are undertaken to address this failure.

2.3. US stress tests

The Board of Governors of the Federal Reserve is responsible for conducting macroprudential stress tests in the U.S. A first stress test exercise called the Supervisory Capital Assessment Program (SCAP) was launched in 2009 as a response to the recent financial crisis. This program led to a substantial recapitalization of the U.S. financial system by forcing 10 bank holding companies to raise a $75 billion capital buffer. Its objective of recapitalizing the U.S. financial sector, as well as that the government would make available an additional capital buffer was clear from its announcement in February 2009.[5]

With the Dodd-Frank Act of 2010, an annual supervisory stress test of the U.S. financial system became a requirement, and the Fed's capital plans rule of 2011 required all U.S. bank holding companies (BHCs) with consolidated assets of $50 billion or more to develop and

[4]See section 225.8(e)(1)(i) of the capital plan rule for a definition of Tier 1 Common capital (U.S.). Definition of Core Tier 1 capital used in the EBA 2011 stress test can be found at http://www.eba.europa.eu/documents/10180/15932/Capital-definition-criteria_1.pdf.

[5]See joint statement by the Treasury, FDIC, OCC, OTS, and the Federal Reserve, February 23, 2009 (available at http://www.federalreserve.gov/newsevents/press/bcreg/20090223a.htm).

submit capital plans to the Federal Reserve on an annual basis. As a result, the Federal Reserve has conducted stress tests as part of the annual Comprehensive Capital Analysis and Review (CCAR) since 2011.

In the Dodd-Frank Act stress tests, banks have to pass regulatory thresholds on four ratios each quarter of the stress scenario: a 4% Tier 1 Capital Ratio, a 8% Total Risk-based Capital Ratio, a 5% Tier 1 Common Capital Ratio, and a bank-specific[6] 3% or 4% Tier 1 Leverage Ratio.[7] When a bank fails the test (obtains a capital ratio below the required threshold), the Federal Reserve can object to the bank's capital distribution plans. The Federal Reserve uses this authority to force banks to improve on some detected deficiencies due to the stress test.

2.4. EU stress tests

EU-wide stress tests were initiated by the Committee of European Banking Supervisors (CEBS) in 2009 and 2010. The CEBS became the European Banking Authority (EBA) on January 1, 2011, which coordinated a new stress test the same year. As opposed to U.S. stress tests by the Federal Reserve, European stress tests are conducted in a bottom-up fashion: banks submit their stress test results to national supervisory authorities (NSAs) for review before NSAs submit to the EBA. For this reason, the EBA qualifies the EU-wide stress test exercise as a microprudential stress test. These stress tests are, however, the outcome of a global macroeconomic scenario defined by the European Central Bank (ECB)

[6]"(...) 3 percent only for a BHC with a composite supervisory rating of "1" or that is subject to the Federal Reserve Board's market-risk rule." (Board of Governors of the Federal Reserve (2013a))

[7]"The Tier 1 ratio is Tier 1 capital divided by risk-weighted assets; the total capital ratio is total regulatory capital (Tier 1 plus Tier 2 plus Tier 3) divided by risk-weighted assets; the leverage ratio is Tier 1 capital divided by average assets; and the Tier 1 common ratio is Tier 1 common capital (common equity minus Tier 1 deductions) divided by risk-weighted assets. All ratios are calculated using existing definitions of capital and risk-weighted assets. See 12 CFR part 225, Appendix A." (Board of Governors of the Federal Reserve, 2011). The disclosed ratios are actual ratios before the stress scenario (actual), stressed ratios at the end of the stress scenario (projected) assuming all capital actions, and minimum ratios over the nine quarters of the stress scenario (min) assuming all capital actions or assuming no capital actions.

and share the objective of an overall assessment of systemic risk in the EU financial system.

The European stress test disclosed in July 2011 was intended to serve as a confidence-building tool during the European sovereign debt crisis. However, the plans for firms failing the 5% Core Tier 1 capital ratio under the stress scenario were less clear compared to the announcement of the U.S. stress test in 2009. In March 2011, the EBA announced that it would be working with national authorities on remedial backstop measures for firms failing the stress scenario but never mentioned capital injections. Without appropriate recapitalization plans for the failing banks, the stress test could not afford to make firms fail the test fearing an adverse reaction by markets on disclosure of the results. This lack of severity considerably undermined the credibility of the stress test and made it miss its goal of restoring confidence in the soundness of banks' balance sheets.

Evidence that the recapitalization needs of the European financial sector were not addressed with the stress test is EBA's launch in December 2011 of a separate recapitalization plan of the European financial sector called the "Capital exercise." The Capital exercise is not a stress test but has been an additional tool to restore market confidence; it recommended creating an "exceptional and temporary capital buffer to address current market concerns over sovereign risk and other residual credit risk related to the current difficult market environment." The estimated capital buffer of €115 billion (including €30 EUR billion for Greek banks)[8] was well above the €2.5 EUR billion estimate of the stress test disclosed five months earlier.

[8]Greek banks are treated separately in the EBA Capital exercise where their capital buffers are defined in order not to conflict with pre-agreed arrangements under the EU/IMF program (European Banking Authority, 2011b).

3. V-Lab stress test

We present the alternative V-Lab stress test, explain its main differences with regulatory stress tests and establish V-Lab as a valuable benchmark that regulators may be interested in using in the assessment of their own stress tests results.

3.1. An alternative to stress tests: V-Lab

In parallel to stress tests conducted by U.S. and European regulators, a team of researchers at New York University Stern School of Business developed an alternative methodology to measure the systemic risk of financial institutions purely based on publicly available information (Acharya et al., 2010, 2012 and Brownlees and Engle, 2011). An important breakthrough of this methodology is that systemic risk does not come from the unconditional failure of a firm, but more specifically from a firm's failure when the whole financial system is undercapitalized. If a firm fails in isolation, other financial firms will step in and take over its activities. However, in a period of aggregate stress where the whole financial sector is undercapitalized, financial firms cannot find the resources to take over other firms' activities; thus, failing firms impose negative externalities to the real economy.

In Acharya et al. (2012), the real systemic risk of a firm is defined as "the real social costs of a crisis per dollar of capital shortage× Probability of a crisis× Expected capital shortfall of the firm in a crisis," where the last term is presented as a useful tool or a substitute for stress tests. Brownlees and Engle (2011) describe a method to derive the expected capital shortfall of a firm in a crisis (called $SRISK$) based on its size, its market leverage, and its stock return under aggregate stress (called Long-Run Marginal Expected Shortfall or $LRMES$). The return of the firm in a crisis is estimated from a bivariate daily time series model, where volatilities are asymmetric GARCH processes and correlations follow a Dynamic Conditional Correlation (DCC) model. The six-month returns of the firm and the market index are simulated many times based on the estimated dynamic volatilities and correlations, along with sampling from a joint distribution that allows for further dependence in the tails. $LRMES$ is the average of the firm's returns across the simulation paths where the market return falls by 40% over a six-month time window.[9]

Defining MV as today's market capitalization of a firm, $LRMES * MV$ is the expected market cap loss that equity holders would face during the six-month crisis scenario described above. The capital shortfall of a firm i at time t ($SRISK_{it}$) is then derived assuming that the book value of its debt (D_{it}) stays unchanged over the six-month scenario while its market cap falls by $LRMES_{it} * MV_{it}$:

$$\begin{aligned} SRISK_{it} &= \mathrm{E}_t\left[k(Debt_{it+h} + MV_{it+h}) - MV_{it+h} | R_{mt+h} \leq -40\%\right] \\ &= kDebt_{it} – (1-k)(1 - LRMES_{it}) * MV_{it}, \end{aligned} \tag{1}$$

where k is the prudential capital ratio, and h is the crisis scenario horizon (six months). The results of this methodology are available on the V-Lab website, where systemic risk rankings are updated weekly both globally and in the U.S.

V-Lab uses a prudential capital ratio k of 8% for U.S. banks and a milder k of 5.5% for European banks to account for the difference in market leverage due to different accounting standards in the two regions: EU banks report under the International Financial Reporting Standards (IFRS) whereas U.S. banks report under the Generally Accepted Accounting Principles (U.S. GAAPs). Under U.S. GAAPs, banks are allowed to report their derivatives on a net basis. The netting of derivatives is most of the time not allowed under IFRS norms, leading to a substantial increase in the size of the balance sheet. Engle et al. (2014) indicate that the total assets of large U.S. banks would be between 40% and 60% larger under IFRS

[9] The equity market return is the S&P 500 for U.S. banks, and the MSCI ACWI World ETF index for European banks. Note that for European banks, the long run simulation is not yet implemented and $LRMES$ is approximated by 1-exp(-18*MES), where MES is the expected daily return of the bank if the daily market return is less than -2%.

norms.

3.2. V-Lab vs. regulatory stress tests design

According to Borio et al. (2012), any stress test has four elements: the scenario, the risk exposures, the model, and the outcome. The scenario specifies the shocks that will be applied to bank data (risk exposures) using a specific model, and the resulting measures are the final outcome of the stress test.

3.2.1. Scenarios

Stress test results are all conditional on the scenario definition. The scenarios of the Federal Reserve, the EBA and V-Lab are different on several dimensions: they consider different variables, horizons, stress levels, and trajectories. The V-Lab scenario is the simplest one; it is a one-factor scenario featuring a 40% drop in equity prices over a six-month period. Other variables are considered endogenous to the market factor.

Stress tests scenarios are multi-factor scenarios and the principal challenge of the scenario design is coherence. Stresses have to be consistent across the multiple variables so that the joint outcome of the scenario is economically realistic. The challenge of coherence also grows as the number of variables increases. The 2009 U.S. stress test considered only three factors: real GDP growth, the unemployment rate, and house prices. The 2012 U.S. stress scenario defined trajectories for 25 macroeconomic and financial variables, and additionally accounted for a global market shock on the six banks with the largest trading activities. The number of factors in the European stress scenario developed by the ECB exceeds 70 variables. In addition, the ECB also considers a market stress scenario conditional on the macroeconomic scenario.

The V-Lab scenario horizon of six months is shorter than stress tests scenarios that typically last two years. The stress scenario of stress tests usually focuses on an adverse macroeconomic scenario defined as a deviation from a baseline scenario. U.S. stress scenarios tend to revert to a "normal" state of the world at the end of each scenario, unlike European stress scenarios that assume further deterioration of the economic situation the second year of the scenario. This is the reason why the Federal Reserve considers minimum ratios over the scenario horizon to determine which banks failed the stress test, while European stress tests consider ratios at the end of the stress scenario.

Relating to V-Lab's 40% equity market index decline over six months, the EBA stress scenario considers a fall of 10% to 20% in equity prices over two years. The 2012 U.S. stress scenario assumes a 50% drop in the Dow Jones total stock market index in the middle of the scenario (late 2012) but reverts to a higher level at the end of the scenario.

A potential unintended consequence of applying a similar specific scenario and methodology repeatedly on banks (as in the CCAR) is the risk of banks specializing on a particular stress scenario. Banks adjust their portfolios to appear less risky to one specific stress scenario, but this does not necessarily make them more robust to the next crisis (which could be very different from the stress test scenario). Comparing the stress test risk assessments to the V-Lab outcomes adds an additional discipline to stress testing as the V-Lab scenario (a 40% drop in a broad market index) encompasses a wider range of scenarios.

3.2.2. Data

Stress tests conducted by U.S. and EU regulators use extended bank supervisory data. Bank holding companies in the U.S. submit their data confidentially to the Federal Reserve using FR Y-14A forms. These forms contain detailed information on capital composition, loan and security portfolios, trading and counterparty exposures, and historical profit and loss (P&L) data. The reports additionally collect banks' own projections of losses and revenues, as well as their estimates of exposure sensitivities to a set of risk factors specified by the Federal Reserve. In Europe, banks implement stress tests themselves and use their own data. The EBA encourage banks to use all the time series available on credit risk parameters and P&L figures for the application of the macro scenario.

Relating to EU and U.S. stress tests, V-Lab could be qualified as a non-invasive stress test. V-Lab results are obtained from a reduced dataset of publicly available data including historical market prices, market capitalization, and leverage.

Stress scenarios are generally applied to accounting data in supervisory stress tests, whereas V-Lab stress applies to the market value of equity. In that respect, V-Lab may be considered a mark-to-market stress test. There are four key advantages and limitations in using market data in a stress test. First, market prices are believed to reflect market participants' expectations on bank performance and are available in real time. Accounting data can only reflect past performance at reporting dates.

Second, a stress test based on market prices does not show anything on financial institutions that are not traded and they do not reveal information on the weaknesses of financial institutions. Conversely, accounting data are available for a larger sample of banks and give important complementary information on the assets and liabilities composition of the bank.

Third, the consistency of stress test assessments across banks is challenged by the lack of uniformity of accounting data. Accounting rules are subject to different interpretations at the country and bank level. This is particularly challenging in the case of European stress tests, where large cross-border differences are observed by the EBA.

Fourth, a capital requirement based on market data would be difficult to implement in a regulatory context given the high volatility of market prices and its procyclicality, implying higher capital requirements in a downturn. The higher capital requirements in a credit crisis have the potential to worsen the crisis when banks cannot raise equity and have to sell more assets to restore their capital ratios. This observation makes $SRISK$ only an adequate ex ante measure of the capital shortfall of a firm.

3.2.3. *V-Lab as a macroprudential benchmark*

The V-Lab stress test can be viewed as a non-invasive mark-to-market stress test. V-Lab stress test does not have the information granularity of the supervisory data of regulatory stress tests; thus, it does not reveal information on the weaknesses of financial institutions. However, its use of publicly available market data allows for real-time forward-looking measures. The simple V-Lab scenario (a 40% drop in a broad market index) encompasses a wider range of scenarios, making V-Lab outcomes robust to various economic environments. By applying a constant scenario and a constant requirement rule in different states of the world, V-Lab is less subject to regulatory discretion. Its comparison with stress test outcomes highlights the role of discretionary rules in regulatory stress tests. It is therefore viewed as a macroprudential benchmark that regulators may be interested in using in the assessment of their own stress tests outcomes.

4. Assessing the outcomes of macroprudential stress tests

Only three U.S. and two EU-wide macroprudential stress tests publicly disclosed a bank-level outcome of the stress test exercise: the SCAP 2009, the CCAR 2012, and the CCAR 2013 in the US; the CEBS 2010 and the EBA 2011 in the EU. These five macroprudential stress tests with bank level disclosure are the sample of stress tests we employ in this study.[10]

Stress tests usually disclose two types of performance measures: the projected losses of the bank under the stress scenario and its required capitalization (measured by a capital ratio or a capital shortfall estimate) once these losses are taken into account. These outcomes are summarized in Appendix A.[11]

In the assessment of stress tests results, we consider a smaller sample of participating

[10] See Board of Governors of the Federal Reserve (2009, 2012, 2013b); European Banking Authority (2010, 2011a).

[11] See the online supplementary materials at Elsevier's website: http://www.journals.elsevier.com/journal-of-monetary-economics/.

banks in stress tests that are also publicly traded and available in V-Lab. V-Lab reports the results of 18 of the 19 U.S. banks (all except Ally Financial Inc.) and close to 60% of the banks in European stress tests. We show the results of stress tests and V-Lab in Table 1.

Table 1 reveals the striking contrast in severity between stress tests and V-Lab results. V-Lab is more severe than stress test outcomes, but this contrast appears extreme in Europe where the sum of projected net losses is more than 10 times larger under the V-Lab scenario than the regulatory stress test in 2010 and almost 6 times larger in 2011. There is an important gap between the "Loss" and the "Net Loss" of European stress tests (difference between projected losses and projected revenues) due to the effect of projected revenues under the stress scenario. V-Lab losses appear closer to the amplitude of the "pure" losses of stress tests that do not include the stressed revenues. As a result, the capital shortfall estimates of European stress tests (resp. €0.2 billion in 2010 and €1.2 billion in 2011) appear extremely low compared to the corresponding $SRISK$ (€796 billion and €886 billion, respectively), and reflect our discussion above concerning the different goals of European stress tests.

Without discussing the optimal level of capitalization of the financial system, this paper rather focuses on rankings. As stress tests and V-Lab share the goal of identifying vulnerable banks in a period of stress, we try to understand how and why the rankings of banks' performances diverge between these two exercises. The next sections consider the rankings of banks by their risk measures (Section 4.1) and required capitalization (Section 4.2). An analysis of the rank correlations of the projected losses of stress tests and the V-Lab losses is relegated to Appendix B.

4.1. Evaluating regulatory risk weights in stress tests

In this section, we assess the efficacy of regulatory risk weights as a measure of the overall bank risk in a stress test.

4.1.1. Concerns about Basel I and Basel II risk-weighted assets

Risk-weighted assets (RWA) fall by 6.1% at the end of the U.S. stress scenario of 2012, while they increase by 14% under the European stress scenario of 2011. Definitions of RWA are however not the same in U.S. and European stress tests; RWA are derived under Basel I in the U.S. (before 2013) and under Basel II in the EU. This leads to important differences in risk measures and stress test models. Risk weights are fixed for different asset categories under Basel I, whereas banks can use their own models to derive RWA under Basel II.

Under Basel I, RWA are defined such that assets are assigned to four different asset categories with different static risk weights (0%, 20%, 50%, 100%). These four categories could be roughly described as exposures to sovereigns (0%), banks (20%), mortgages (50%), and corporates (100%). By definition, Basel I risk weights cannot reflect the risk evolution of different asset categories; they cannot reflect "the risk that risk will change" ((Engle, 2009)).

The problem of static risk weights is addressed in Basel II, where the risk weights of asset exposures can change over time according to banks' internal risk models. The capital requirement for credit risk in Basel II — the most important component of RWA — is defined in terms of exposures at default (EAD) and risk parameters. Risk parameters (probability of default and loss given default) are used to assign weights to each exposure. In the EBA 2011 stress test, the increase of RWA under the stress scenario comes from the credit risk component (around 80% of RWA); the changes are located in risk weights (stressed LGDs and PDs) since exposures are considered invariant under a static balance sheet assumption (the size of the balance sheet remains constant over the stress scenario). This is a major difference with the U.S. methodology, which assumes a dynamic evolution of the size of the balance sheet and fixed risk weights, even if credit rating migrations are allowed (assets can migrate to a higher risk-weight category under stress).[12]

[12] The RWA methodology was however updated in the CCAR 2013 where the stressed RWA also included BHC's projections of a market risk component defined under the stricter Basel 2.5 market risk rule.

Concerns on the robustness of Basel II risk weights were raised in Haldane (2012), given their degree of over-parametrization and the risk parameter estimates purely based on in-sample statistical fit over short historical samples. The use of banks' internal models to derive their risk parameters under the internal rating-based (IRB) approach of Basel II has also been criticized. First, Basel II was designed so that the use of banks' internal models would allow them to derive lower RWA in order to incentivize banks to update their risk management practices. Le Lesle and Avramova (2012) indicate that this resulted in lower RWA under Basel II, and therefore lower capital charges than under Basel I, whereas the internal models did not necessarily imply lower risks. Second, concerns about the consistency of risk weights across firms are raised in Haldane (2012); Le Lesle and Avramova (2012); Basel Committee on Banking Supervision (2013a,b); European Banking Authority (2013); Mariathasan and Merrouche (2013). The Basel Committee confirmed these concerns, indicating in their "Regulatory Consistency Assessment Programme" (RCAP) that differences in risk weights (in the trading book) across firms reflect modeling choices and supervisory decisions rather than actual risk taking.[13] Furthermore, Mariathasan and Merrouche (2013) attribute the decline in risk weights when banks switch to the IRB approach to strategic risk modeling, and that effect to be particularly important for weakly capitalized banks. Third, the internal models used to derive risk weights are completely opaque. Haldane (2012) indicates that risk weights are black boxes that investors do not understand or trust. These concerns have important implications for the European stress tests outcomes knowing that 59 of the 90 participating banks in the 2011 stress test are IRB banks (i.e., they use their own models to derive risk weights under the stress scenario).

We raise a further concern on Basel risk-weighted assets (both Basel I and Basel II

[13]The RCAP of the banking book disclosed in July 2013 however indicates that three quarters of differences in banking book risk weights across banks are explained by differences in banks' exposures (Basel Committee on Banking Supervision, 2013a).

definitions) as a measure of the overall bank risk. This concern comes from the observation that risk is not an additive concept. We show in Appendix C the weakness of Basel regulatory risk weights as an aggregate measure of bank risk where the bank is viewed as a portfolio of assets. The main observation is that the risk of a portfolio is always less than or equal to the sum of the risks of its components. The use of risk-weighted assets (derived in a bottom-up manner) ignores this portfolio feature of risk, thus there is no incentive from a regulatory perspective to diversify. The only case where this measure is appropriate is when all assets are perfectly correlated. Furthermore, we show that the bank's leverage is an inverse function of the risk weight of the optimal asset. If risk weights are not consistently estimated across asset classes, a bank will choose the optimal asset with the most underestimated risk weight, which will automatically lead to excessive leverage. Consequently, banks will take excessive leverage if their risk weights are not adequately adjusted (i.e., remain static) to more severe economic conditions.

4.1.2. Stress tests vs. V-Lab risk weight

Acharya et al. (2012) define the effective market risk weight to quasi-market assets corresponding to a $SRISK$ of zero. In this case, a firm is expected to be adequately capitalized in a crisis. This constraint implies that its current market capitalization is above a fraction k of some "market risk-weighted" assets:

$$MV \geq \frac{k}{1-(1-k)LRMES}(MV + Debt), \tag{2}$$

Therefore, the V-Lab risk weight of the firm is:

$$\text{V-lab risk weight} = (1-(1-k) * LRMES)^{-1}, \tag{3}$$

and is comparable to the average regulatory risk weight of a bank defined by the ratio of its RWA to total assets. Firms whose market capitalization is predicted to shrink the most in a crisis are the riskiest according to the V-Lab risk weight. This market-implied risk weight is calculated in a top-down manner at the level of the entire firm rather than bottom-up (i.e., asset by asset), as in the Basel risk-weighted approach.

As the V-Lab risk weight is conditional on a crisis, we compare it to the *stressed* average risk weights of stress tests. In Figure 1a, we compare the projected Basel risk weight at the end of the 2011 EBA stress scenario with the V-Lab risk weight. These measures of risk have nothing in common; the rank correlation is negative (-0.238) and not significant at the 5% level. In the US, the V-Lab risk weight also appears uncorrelated with some approximation of the stressed risk weight of the 2009 stress test; the rank correlation is slightly negative (-0.011) and not significant at the 5% level.

Dexia and Crédit Agricole are among the riskiest banks according to the V-Lab risk weight and among the safest with the EBA risk weight; both banks have values above the 75% quantile of the V-Lab risk weight distribution and both appear below the 25% quantile of the EBA risk weight distribution. The EBA risk ranking is hard to rationalize given that three months after disclosure of the stress test, Dexia was the first bank to be bailed out in the context of the European sovereign crisis in October 2011. The bank was bailed out a second time in November 2012 and reported a net loss of €2.9 billion for 2012.[14] Crédit Agricole also announced a net loss of €6.5 billion for 2012.[15]

Furthermore, we show in Figure 1b that the rank correlation between stressed risk weights and stressed Tier 1 leverage ratios (the ratio of Tier 1 capital to total assets) in the 2011 European stress test is 0.62 and increases to 0.89 for the 15 largest banks. As a result, banks with low risk weights have the highest leverage. This illustrates well the perverse incentives created by risk weights and helps explain the portfolio decisions of many eurozone banks during the European sovereign debt crisis. Acharya and Steffen (2013) document that the

[14]Fresh Franco-Belgian bailout for Dexia, Financial Times, November 8, 2012. "Dexia at 'turning point' amid more losses," Financial Times, February 21, 2013.

[15]"Second year in red for Crédit Agricole," Financial Times, February 20, 2013.

increase of exposures to risky sovereign debt is partly explained by regulatory arbitrage; banks with higher risk weights increased their exposures to risky sovereign debt to reduce the cost of raising fresh capital, as these exposures have a zero capital requirement (zero-risk weight). To a large extent, it also helps explain the misguidance of stress tests about European banks risks. For example, Dexia was holding a portfolio of risky sovereign bonds of almost a third of its balance sheet, which were largely financed with short-term debt. Acharya and Steffen (2013) further show that this type of behavior was pervasive among eurozone banks. Therefore, the reliance on Basel static risk weights appears to have both misguided the recapitalization of the financial sector and incentivized the build up of risky sovereign debt exposures.

4.1.3. Forecasting risk during the European sovereign debt crisis

Stress tests outcomes are estimates of bank performance conditional on a specific adverse macroeconomic scenario. As such, stress test outcomes cannot be considered as forecasts. However, if the goal of a macro stress test is to make banks more robust to aggregate stress conditions, we would expect that stress test outcomes would identify the vulnerabilities of banks when there is aggregate stress. In other words, comparing stress test outcomes to realized outcomes in a crisis can help determine whether the stress test scenario was credible, as well as identify other deficiencies of the stress test that would prevent it from detecting the most obvious vulnerabilities of banks.

We compare the performance of the stress test risk weight and V-Lab risk weight to predict a realized measure of risk. The six-month realized volatility defined by:

$$RV_{i,t,W} = \sqrt{\frac{1}{W}\sum_{t+1}^{t+1+W}(r_{it} - \bar{r}_{it,W})^2}, \tag{4}$$

where $W = 130$ days (six months) and $\bar{r}_{it,W}$ is the six-month forward average stock return of bank i at date t (the stress test's disclosure date). We focus on the EBA stress test disclosed on July 15, 2011 as it is the only stress test with bank-level disclosure followed by a global economic downturn. The realized returns in the last six months of 2011 of U.S. (S&P 500), European (EURO STOXX 50), and global (MSCI ACWI World) indices were -4.89%, -20.67%, and -13.47%, respectively. This outcome was less severe than the V-Lab scenario (40% decline in the World equity index) and is closer to the ECB scenario (15% decline in stock prices in the euro area).

High-risk banks would be expected to have highly volatile stock market returns in a realized crisis. Comparing the ranking of the six-month realized volatility of European banks' stock returns during this period to the ranking of EBA risk weights and V-Lab risk weights, we find a negative correlation (-0.140) with the EBA risk weight, whereas the correlation with the V-Lab risk weight (0.535) is positive and significant at the 1% level (in Table 2, Panel A). Similarly, Das and Sy (2012) find that risk-weighted assets cannot, in general, be used to predict market measures of risk. The absence of correlation between the *stressed* regulatory risk weights and the realized risk of banks during the European downturn shows furthermore that Basel risk weights were also misleading in the 2011 EBA stress test.

When comparing the risk measures against realized *book* measures we find that both the V-Lab risk weight and the EBA risk weights are negatively correlated to the future book performance of banks (measured by the net income divided by total assets, and the book equity return). The V-Lab risk weight does not seem to indicate the ranking of realized book performance in the wrong direction, in contrast to the regulatory risk weights when predicting realized market risk.

In Table 3, we show the estimates of different risk factors regressed on the realized volatility measure defined in (4). The effect of individual risk factors is reported in columns 2 to 4, where the impact of accounting-based versus market-based risk measurement is accounted for by including the book-to-market ratio in each regression. In column 4, the EBA risk weight parameter is negative and not significant but becomes positive and significant at the 10% level when we control for the other risk factors in column 6. This result suggests that regulatory risk weights add information on risk once we account for other more important risk factors like the V-Lab risk weight, and the Tier 1 leverage ratio. The improvement in terms of adjusted R^2 is small (3.76%, columns 5 to 6), however, when the EBA risk weight is added to the regression.

4.2. Risk weights-based vs. leverage-based capital requirements

Regulatory ratios and shortfalls are expressed as a function of risk-weighted assets whereas V-Lab uses quasi-market assets. We consider in this section an alternative measure of the capital shortfall based on total assets.

4.2.1. Risk-based ratio, leverage ratio, and V-Lab ratio

To facilitate the comparison with stress test ratios, we define the V-Lab market leverage ratio under stress ($M\text{-}LVGR_s$) as the ratio of market cap to quasi-market assets under the V-Lab stress scenario:

$$\text{V-lab } M\text{-}LVGR_s = \frac{MV(1-LRMES)}{MV(1-LRMES)+D}. \tag{5}$$

The rank correlations between this V-Lab ratio and the stress tests ratios are reported in Panel A of Table 4. For all stress tests, the correlations increase substantially when risk-weighted assets in stress tests ratios are replaced by total assets (defining a Tier 1 leverage ratio). The assessment of bank leverage using a Tier 1 leverage ratio ($T1LVGR$) defined as the ratio of Tier 1 capital to total (un-weighted) assets is a recommendation of Basel III to supplement the risk-based regime (Basel Committee on Banking Supervision, 2011). Haldane (2012) shows that this ratio significantly predicts the failure of financial firms whereas the risk-based Core Tier 1 capital ratio ($T1CR$) does not. Our results show that this is also true in the context of macroprudential stress tests (i.e., that the *stressed* Tier 1 leverage ratio is more informative about banks' risks than its risk-based counterpart).

The Tier 1 leverage ratio is one of the four ratios examined in Dodd-Frank Act stress tests. In 2012, two banks (Citigroup and MetLife) failed the leverage ratio under the stress scenario. In 2013, Goldman Sachs had the lowest stressed leverage ratio, followed by Morgan Stanley and J.P.Morgan; two firms (Ally Financial Inc. and American Express) failed to meet the recommended leverage ratio under stress when the effect of their original submissions of planned capital actions was considered. We build a Tier 1 leverage ratio for the European banks of the 2011 stress test and find that Deutsche Bank would have failed the stress test if the Basel III 3% leverage requirement had existed.

In Figure 2, the correlation between the market leverage ratio under the V-Lab stress ($M\text{-}LVGR_s$) and the stressed Tier 1 leverage ratios appears to be strong in the last U.S. and European stress tests (CCAR 2013 and EBA 2011). The rank correlation with the V-Lab ratio in Table 4 (Panel A) increases from 0.581 to 0.877 when risk-weighted assets, the denominator of capital ratios, are replaced by total assets in the CCAR 2013. We obtain similar results one year earlier (CCAR 2012), and in the European stress test of 2011.

Based on the assumption that the stress test outcomes should indicate the ranking of banks' financial performance during a period of stress, we compare different capital ratios in predicting the ranking of European banks by their realized stock returns during the six months following the disclosure of the 2011 EBA stress test (Table 2, Panel B). The correlations are not high as these are contingent predictions of stock market returns. If the market correctly anticipated the downturn, it should be nearly impossible to predict relative performance. The cross-sectional rank correlation for the V-Lab ratio is 0.354, for the Tier 1 leverage ratio, it is 0.208 and for the Core Tier 1 capital ratio it is 0.046. For this stress test, the weakness of financial institutions is not well predicted when using capital ratios relative to risk-weighted assets but is somewhat better using total assets. The best measure in this case is the stressed leverage ratio from V-Lab.

In Table 4 (Panel A), another source of difference between stress tests and V-Lab ratios comes from the information about capital plans that is included in stress tests outcomes but not in V-Lab. The impact of capital actions on ratios is negative in the CCAR since capital actions are capital distribution plans (submitted as part of the CCAR). Conversely, capital actions are capital raising plans in the SCAP and in European stress tests and have a positive impact on stress tests outcomes.[16] For all stress tests, rank correlations with V-Lab measures increase when capital actions are ignored.

4.2.2. Stress tests capital shortfalls vs. SRISK: the European case

In addition to the capital ratios, European stress tests also disclose capital shortfall estimates, defined by:

$$\text{Disclosed Capital Shortfall} = \max(0, [k' * RWA_S - Capital_S]), \quad (6)$$

where k' is the prudential capital ratio threshold used in the stress test (5% in the 2011 EBA), and RWA_S and $Capital_S$ are the risk-weighted assets and the capital level of a bank at the end of the stress scenario, respectively. This capital shortfall estimate is zero for most banks, reflecting our discussions above on the severity of the stress test (see Figure 3a).

Most European banks actually end up with a capital excess at the end of the stress scenario when we remove the zero bound and derive the "absolute" capital shortfall ($k' * RWA_S - Capital_S$). The rank correlation with $SRISK$ (reported in Table 4, Panel B) is highly negative, significant, and is almost the same in the last two European stress tests

[16] Capital actions in the CCAR 2012 include all proposed future capital distribution plans (issuance of capital instruments, dividends payments, and share repurchases) throughout the stress scenario. In the 2011 EBA, capital actions include issuance of common equity, government injections of capital, and conversion of lower-quality capital instruments into Core Tier 1 capital. The EBA additionally considers the effect of mandatory restructuring plans and the final outcomes only consider mandatory measures announced before disclosure. In the SCAP, the capital actions include the proposed capital actions and the effects of the results of the first quarter of 2009. The correlation between $SRISK$ and the SCAP capital buffer also increases from 0.507 to 0.562 when capital actions are not included.

(-0.791 in 2010 and -0.790 in 2011). Banks with the highest estimated capital shortfall in V-Lab are considered to be the safest and the most well capitalized in European stress tests. We show this result in Figure 4a for the 2011 EBA stress test and obtain a similar pattern for the 2010 stress test.

Alternatively, we consider the capital shortfall estimates the EBA stress test would have produced if capital adequacy was measured by a simple leverage ratio. Figure 4 shows how the rank correlation between $SRISK$ and the capital shortfall of the 2011 EBA stress test rotates from highly negative (-0.790) to highly positive (0.679) when the EBA shortfall is written as a function of total assets (Figure 4b) instead of risk-weighted assets (Figure 4a). The leverage-based capital shortfall is given by:

$$\text{Capital Shortfall (TA)} = k * TA_S - Capital_S, \tag{7}$$

where k is the same prudential ratio used in V-Lab (5.5% for European banks) and TA_S is the total assets of the bank at the end of the stress scenario. With this definition, the required capitalization of 53 EU banks would have increased from €1.2 billion to €390 billion.

The heterogeneity in size in the sample of European banks however plays a major role in this result. We may not want to completely remove the impact of the size[17] from the analysis of capital shortfalls as size is a major factor contributing to the systemic importance of a bank. Size, by amplifying correlations, also shows how important discretionary rules on the final outcomes are. To attenuate the size effect, we also look at correlations on the subsamples of (very) large banks (with Core Tier 1 capital over $19 billion) and small banks. The 15 large banks include HSBC, Barclays, BNP Paribas, Deutsche Bank, etc. and are comparable to the 19 participating bank holding companies in the U.S. The negative correlation of the stress test risk-based capital shortfalls with $SRISK$ is indeed very sensitive to size; the correlation decreases for small banks (-0.53 in the EBA 2011 stress test) and is not significant in the

[17] This is done in the analysis of ratios in Section 4.2.1.

group of large banks. However, the rank correlation between the leverage-based stress test shortfalls (7) and $SRISK$ remains high and significant at 1% in the small (0.634) and large bank (0.743) groups.

Five months after the disclosure of the stress tests results, the EBA disclosed alternative capital shortfall estimates in its Capital exercise in December 2011. The recommended capital buffer (the "overall shortfall") is defined by

$$\text{EBA overall shortfall} = \max(0, [0.09 * RWA - T1C]) + BuffSOV. \tag{8}$$

The overall shortfall is not the outcome of a stress test but is the result of three main drivers: the target 9% Core Tier 1 capital ratio (instead of 5%), the application of Basel 2.5 to derive risk-weighted assets (increasing the capital requirement for market risk), and an additional capital buffer ($BuffSOV \geq 0$) for eurozone sovereign debt exposures (one-third of the buffer).[18] The rank correlation of $SRISK$ with the EBA overall shortfall is positive (0.133) but not significant at 5%. The EBA corrected for the underestimated sovereign risk weights with the additional sovereign buffer but many top $SRISK$ banks still end up with a capital shortfall of zero in the Capital exercise (see Figure 3b).

Increasing the capital requirement rule (k'), as in the Capital exercise, has had a positive effect on rank correlations with V-Lab, although this correlation appears to only reflect the size of banks. If the capital requirement rule of the 2011 stress test (k') in equation (6) had been increased from 5% to 9% of RWA, the correlation with $SRISK$ would have been positive (0.418) and significant at the 1% level, although this result is not robust when controlling for size. More importantly, many banks like Dexia would still end up with an estimated capital excess with this definition, while having a positive capital shortfall with the leverage-based definition in equation (7). The strategy of increasing the capital requirement rule can indeed succeed at recapitalizing the financial sector (the required capitalization of 53

[18]European Banking Authority (2011b).

EU banks would have increase from €1.2 billion to €139 billion). It does not, however, solve the misallocation problem of capital shortfalls across banks due to the reliance on regulatory risk weights.

5. Conclusion

Macroprudential stress tests conducted by U.S. and European regulators use the regulatory capital ratio — the ratio of equity capital to risk-weighted assets — as a measure of capital adequacy. Stress tests models translate an adverse macroeconomic scenario into asset losses on the balance sheet of banks. The resulting capital ratios are used by the regulator to determine which banks fail the test under the stress scenario and what supervisory or recapitalization actions should be undertaken to address this failure.

We compare the outcomes of these regulatory stress tests to an alternative approach to stress testing — the V-Lab stress test — that relies on publicly available market data. As the stress scenario is projected on the market capitalization of the bank, the V-Lab methodology could be viewed as a mark-to-market stress test.

Our comparisons reveal the following interesting results. First, the required capitalization in V-Lab stress test appears always to be larger than in regulatory stress tests, but this contrast appears to be extreme in Europe, reflecting the low number of firms failing the supervisory stress test (as the stress scenario was politically chosen to be weak). As regulatory stress tests and V-Lab share the goal of identifying vulnerable banks in a period of stress, the ranking of bank vulnerability in the scenarios should, however, be closely related even if the magnitude of the vulnerability is greater in the more severe V-Lab stress test.

We find that the average regulatory risk weight (the ratio of the bank's risk-weighted assets to total assets) of stress tests is uncorrelated with a market measure of asset risk implied by the V-Lab stress test (called V-Lab risk weight). In the 2011 European stress test, we show that the regulatory risk weights have no link with the realized risk of banks during the six months following the stress test disclosure. Risk weights tend to be informative only when we control for the V-Lab risk weight and the Tier 1 leverage ratio (ratio of Tier 1 capital to total assets). Furthermore, Basel risk standards based on risk-weighted assets reduce the incentives for banks to diversify as they ignore the subadditivity feature of portfolio risk. As a result, banks are encouraged to invest their entire portfolio in one asset category, and the underestimation of risk weights automatically leads to excess leverage.

Second, we consider an alternative definition of capital adequacy in stress tests based on the Tier 1 leverage ratio. When capital adequacy is a function of *risk-weighted assets* in regulatory stress tests, the ranking of financial institutions by capital shortfalls deviates considerably from rankings using the V-Lab market price-based approach. However, when stress tests rely on *total assets* to indicate capital requirements, the bank rankings are similar to the V-Lab rankings.

Overall, the results indicate that stress tests would be more effective if capital requirements were measured differently from the current static risk-weighted approach. A capital requirement based on risk-weighted assets is not sufficient as regulatory risk weights do not reflect the "risk that risk will change." To address this failure, we recommend that regulatory stress tests complement their assessment of bank and system risks by using leverage-based and market-based measures of risk. The paper therefore welcomes the new Basel III Tier 1 leverage ratio, but the misguidance of the asset risk-return allocation is likely to be present in future stress tests as long as the reliance on static regulatory risk weights prevails under Basel III.

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Table 1: **V-Lab vs. stress tests: aggregate results.** This table presents the aggregate outcome of the samples of common banks between V-Lab and regulatory stress tests. V-Lab output is available on the website vlab.stern.nyu.edu, under "NYU Stern Systemic Risk Rankings of U.S. Financials with Simulation" for U.S. banks (where $k = 0.08$ in eq. (1)), and "NYU Stern Systemic Risk Rankings of World Financials without Simulation" for European banks (where $k = 0.055$ in eq. (1)). V-Lab output (converted in euros for European banks) is downloaded on the last date before the scenario start date of each stress test exercise. V-Lab download date: 12/31/2008 (SCAP), 09/30/2011 (CCAR 2012), 09/28/2012 (CCAR 2013), 12/31/2009 (CEBS), 12/31/2010 (EBA), 09/30/2011 (EBA Capital exercise). V-Lab MV loss = $MV * LRMES$, $SRISK$ is the V-Lab's capital shortfall estimate defined in eq. (1), V-Lab $M\text{-}LVGR_s$ is the ratio of market cap to quasi-market assets under V-Lab stress scenario (eq. (5)). Stress tests ratios ($T1CR$ for EBA and CCAR, $T1R$ for CEBS) are cross-sectional averages at the end of the stress scenario in EU stress tests, and cross-sectional averages of min ratios over the stress scenario in U.S. stress tests (without the effect of BHCs planned capital actions). Stress tests losses are the sum of projected losses over the stress scenario and across banks. "Loss" (SCAP) = *Total Loss estimates* , "Loss" (CCAR) = *Loan Losses + Trading and Counterparty Losses + Realized Losses on Securities + Other Losses*, "Loss" (CEBS & EBA) = *Impairment losses + Trading losses.* "Net Loss" (SCAP) = max(0, *Total Loss estimates - Resources Other Than Capital to Absorb Losses in the More Adverse Scenario*), "Net Loss" (CCAR) = max(0, - *Projected Net Income before Taxes*), "Net Loss" (CEBS) = max(0, Loss - *pre-impairment income after the adverse scenario*), "Net Loss" (EBA) = max(0, - *Net profit after tax*). In parentheses: number of banks failing the systemic risk criterion. In brackets: cross-sectional average ratio change with the stress scenario.

US		Stress tests estimates				V-Lab estimates		
	Sample	Shortfall	Ratio	Loss	Net loss	*SRISK*	$M\text{-}LVGR_s$	MV loss
SCAP 2009	18 U.S. BHCs	63.1 $ bn (9)		590 $ bn	229 $ bn	674 $ bn (18)	2.39% [-4.82%]	438 $ bn
CCAR 2012	18 U.S. BHCs		7.55% (0) [-3.34%]	529 $ bn	226 $ bn	669 $ bn (17)	3.54% [-4.54%]	447 $ bn
CCAR 2013	17 U.S. BHCs		8.37% (0) [-2.68%]	457 $ bn	197 $ bn	494 $ bn (14)	5.48% [-5.36%]	525 $ bn
EU								
	Sample	Shortfall	Ratio	Loss	Net loss	*SRISK*	$M\text{-}LVGR_s$	MV loss
CEBS 2010	50 EU banks	0.2 EUR bn	8.98% (1) [-1.38%]	425 EUR bn	39 EUR bn	796 EUR bn (48)	2.6% [-2.01%]	399 EUR bn
EBA 2011	53 EU banks	1.2 EUR bn	7.98% (4) [-1.02%]	381 EUR bn	70 EUR bn	886 EUR bn (51)	2.26% [-1.73%]	402 EUR bn
EBA Capital Exercise	44 EU banks (excluding Greek banks)	72 EUR bn (22)				1061 EUR bn (42)	1.56% [-1.66%]	336 EUR bn

Table 2: **Forecasting during the European sovereign debt crisis.** This table presents the rank correlations of the EBA and V-Lab outcomes with the realized outcomes of banks after disclosure of the EBA stress test in July 2011 (p-values in parentheses). Panel A: rank correlations of the EBA stressed risk weight and V-Lab risk weight with the six-month realized volatility $RV_{i,t,130}$ (eq. (4)). Panel B: rank correlations of capital ratios with the 6-month realized return ($\sum_{t+1}^{t+131} \ln(p_{it}/p_{it-1})$). EBA risk weight is the ratio of risk-weighted assets to total assets at the end of the EBA stress scenario. V-Lab $M\text{-}LVGR_s$ is the ratio of market cap to quasi-market assets under V-Lab stress scenario (eq. (5)). EBA $T1CR$ is the ratio of Core Tier 1 capital to risk-weighted assets at the end of the EBA stress scenario. EBA $T1LVGR$ is the ratio of Tier 1 capital to total assets at the end of the EBA stress scenario. V-Lab output was downloaded before the disclosure date of the EBA stress test: 06/30/2011. Sample size: 15 (large), 38 (small), 53 (all).

Panel A: Rank correlations with 6-month realized volatility

	Estimated risk measure	Large	Small	All
V-Lab	risk weight (eq. (3))	0.554	0.561	0.535
		(0.032)	(0.000)	(0.000)
EBA	risk weight, scenario end	-0.111	-0.055	-0.140
		(0.694)	(0.742)	(0.318)

Panel B: Rank correlations with 6-month realized return

	Estimated capital ratio	Large	Small	All
V-Lab	$M\text{-}LVGR_s$ (eq. (5))	0.721	0.293	0.354
		(0.002)	(0.074)	(0.009)
EBA	$T1CR$, scenario end	0.446	-0.031	0.046
		(0.095)	(0.854)	(0.742)
EBA	$T1LVGR$, scenario end	0.275	0.152	0.208
		(0.321)	(0.364)	(0.136)

Table 3: **Realized volatility regressions.** Parameter estimates of cross-sectional regressions. Dependent variable: six-month realized volatility (eq. (4)) after disclosure of the EBA stress test in July 2011. EBA $T1LVGR$ is the ratio of Tier 1 capital to total assets at the end of the EBA stress scenario; EBA risk weight is the ratio of risk-weighted assets to total assets at the end of the EBA stress scenario. V-Lab download date: 06/30/2011. White's heteroskedasticity-consistent standard errors are in parentheses. * indicates statistical significance at the 5% level; ** at the 1% level. Sample size: 53.

		1	2	3	4	5	6
	Constant	4.39**	-0.12	6.34**	5.34**	1.70	0.12
		(0.27)	(1.82)	(0.83)	(0.88)	(1.89)	(1.90)
	Book-to-market	0.03**	0.03**	0.03**	0.03**	0.03**	0.04**
		(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.004)
V-Lab	risk weight (eq. (3))		2.50*			2.62**	2.99**
			(0.96)			(0.79)	(0.78)
EBA	$T1LVGR$, scenario end			-39.99*		-41.39*	-62.44*
				(16.82)		(19.02)	(26.39)
EBA	risk weight, scenario end				-1.75		3.56
					(1.52)		(2.08)
	F-test	11.48**	10.2**	11.88**	6.43**	12.72**	11.25**
	Adj. R^2 (%)	16.78	26.14	29.50	17.28	40.34	44.10

Table 4: **V-Lab vs. stress tests: rank correlations.** This table presents the rank correlations of stress tests and V-Lab results. Panel A: rank correlations with V-Lab $M\text{-}LVGR_s$, i.e., the ratio of market cap to quasi-market assets under the V-Lab stress scenario (eq. (5)). Panel B: rank correlations with V-Lab's capital shortfall $SRISK$ (eq. (1)). $T1CR$ is the Tier Common Capital Ratio ($T1CR = T1C/RWA$); $T1R$ is the Tier 1 capital Ratio ($T1R = T1/RWA$); $T1LVGR$ is the Tier 1 leverage ratio ($T1LVGR = T1/TotalAssets$), where $T1$ is the Tier 1 capital, $T1C$ is the Tier 1 Common (U.S.) or Core (EU) capital, and RWA are the risk-weighted assets. "min" stands for the minimum ratio over the nine quarters of the CCAR scenario or the minimum ratio over the two years of the 2011 EBA stress scenario, other ratios are ratios at the end of the stress scenario. * indicates ratios based on stress tests results without the effect of capital actions and restructuring plans. V-Lab download date: 12/31/2008 (SCAP), 09/30/2011 (CCAR 2012), 09/28/2012 (CCAR 2013), 12/31/2009 (CEBS), 12/31/2010 (EBA), 09/30/2011 (EBA Capital exercise). * indicates statistical significance at the 5% level; ** at the 1% level. Sample size: 18 (SCAP and CCAR 2012), 17 (CCAR 2013), 50 (CEBS), 53 (EBA), 44 (EBA Cap. Ex.).

Panel A: Rank correlations with V-Lab M-LVGR$_s$

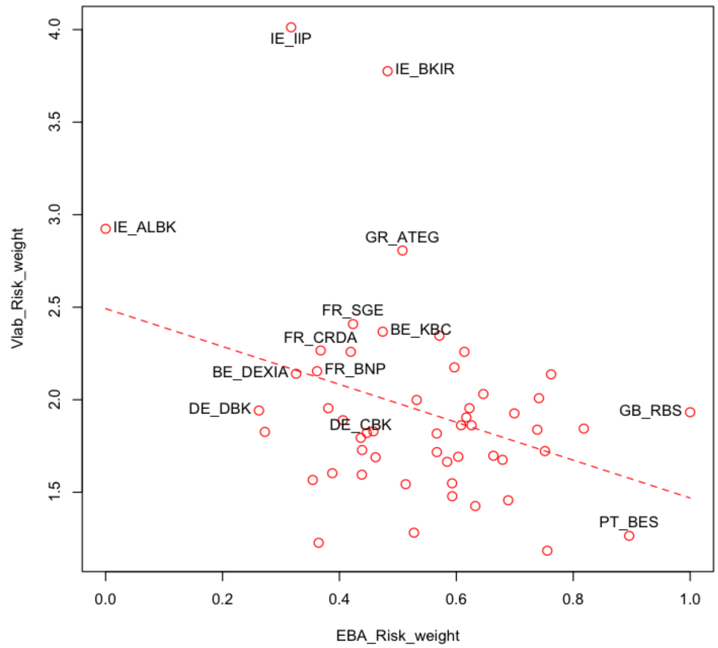
Stress tests projected ratios	SCAP 2009	CCAR 2012	CCAR 2013	CEBS 2010	EBA 2011
$T1R$, scenario end		0.204		0.043	0.280*
$T1CR$, scenario end		0.242			0.282*
$T1CR^\star$, scenario end			0.453		0.546**
$T1LVGR$, scenario end		0.576*			0.570**
min $T1CR$		0.463	0.078		0.274*
min $T1CR^\star$		0.797**	0.581*		0.530**
min $T1LVGR$		0.684**	0.561*		0.550**
min $T1LVGR^\star$		0.846**	0.877**		

Panel B: Rank correlations with V-Lab SRISK

Stress tests capital shortfalls	SCAP 2009	CCAR 2012	CCAR 2013	CEBS 2010	EBA 2011	EBA Cap. Ex.
max(0, Shortfall (RWA))	0.507*			-0.153	-0.273*	0.133
Shortfall (RWA)				-0.791**	-0.790**	
Shortfall (TA)					0.679**	

Figure 1: **Stress test risk weight vs. V-Lab risk weight and T1 leverage ratio.** Projected regulatory risk weight at the end of the EBA 2011 stress scenario (horizontal axis) against V-Lab risk weight (a), and the projected Tier 1 leverage ratio at the end of the EBA 2011 stress scenario (b). V-Lab download date: 12/31/2010.

(a) Projected regulatory risk weight versus V-Lab risk weight.



(b) Projected regulatory risk weight versus projected Tier 1 leverage ratio at the end of the EBA 2011 stress scenario.

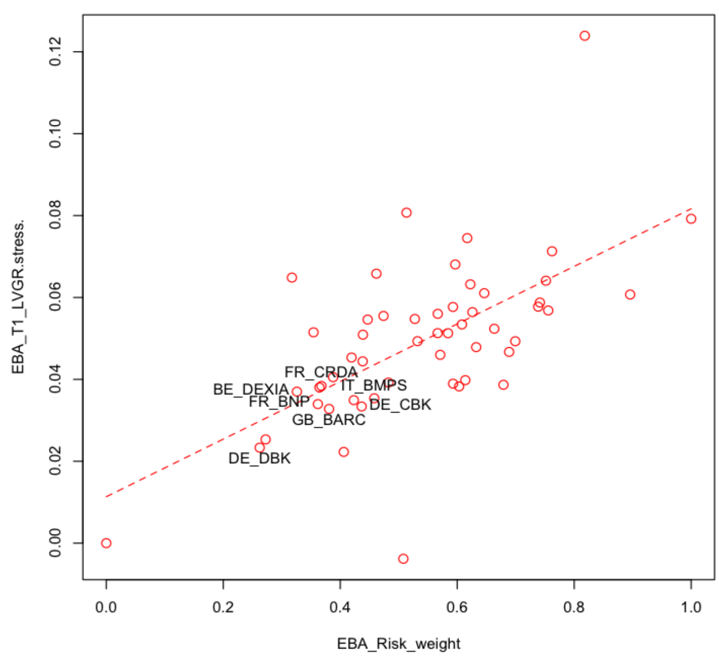
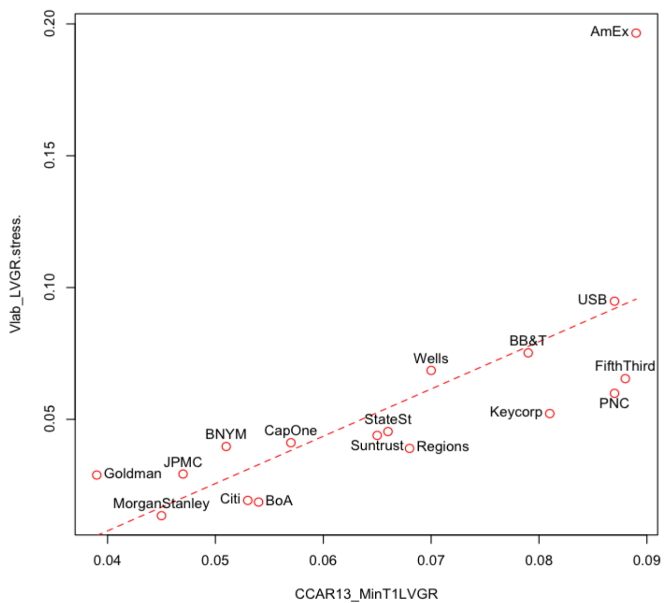


Figure 2: **Stress tests Tier 1 leverage ratios vs. V-Lab market leverage ratio.** The Tier 1 leverage ratio ($T1LVGR$) is the ratio of Tier 1 capital to total assets. The V-Lab market leverage ratio ($M\text{-}LVGR_s$) is the ratio of market cap to quasi-market assets under the V-Lab stress scenario (eq. (5)). "Min" stands for the minimum ratio across the nine quarters of the U.S. stress scenario of 2013 (CCAR 2013). CCAR 2013 ratios do not consider the effect of planned capital actions and are disclosed in the Dodd-Frank Act stress test (DFAST 2013). EBA 2011 ratios are the projected ratios at the end of the stress scenario.

(a) CCAR 2013 min T1 leverage ratio (without the effect of capital actions) versus V-Lab market leverage ratio. V-Lab download date: 09/28/2012.



(b) EBA 2011 stressed T1 leverage ratio versus V-Lab market leverage ratio. V-Lab download date: 12/31/2010.

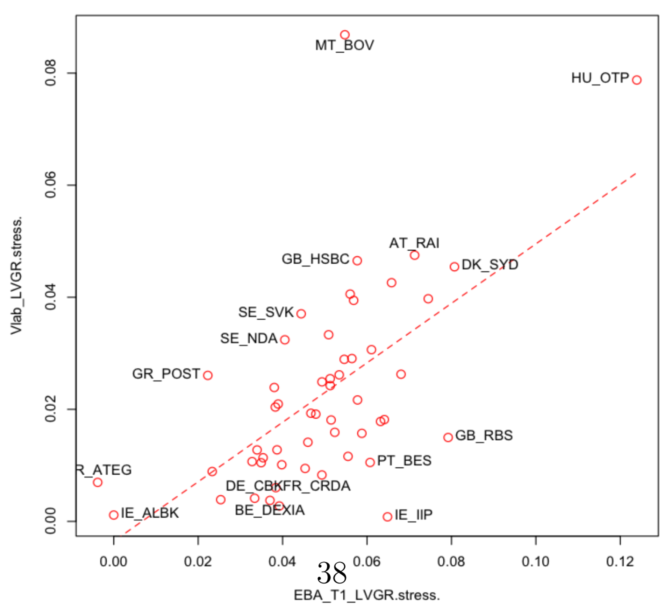
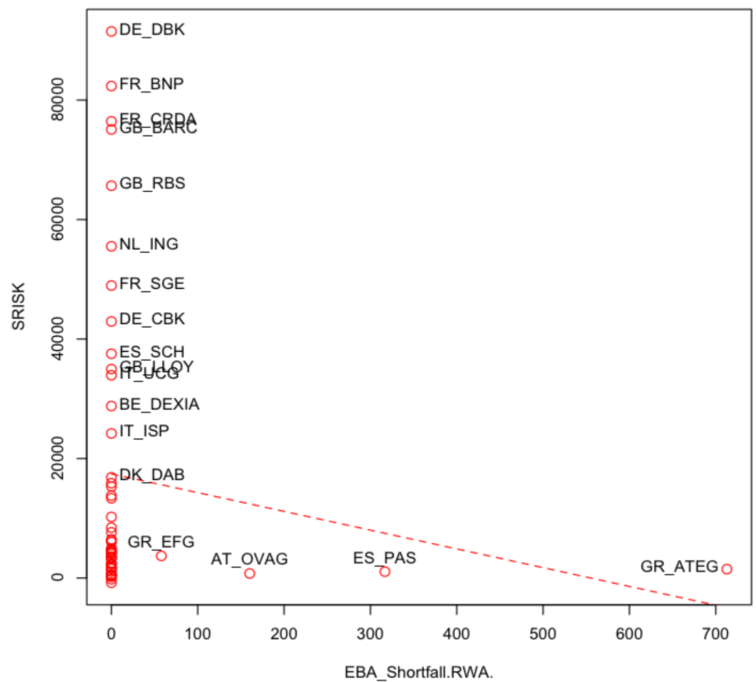


Figure 3: **EBA capital shortfalls vs. SRISK.** The capital shortfall estimates $SRISK$ under V-Lab stress scenario (vertical axis) against the capital shortfall estimates in the EBA stress test disclosed in July 2011 (a), and the "overall shortfall" estimates disclosed in the EBA Capital exercise in December 2011 (b).

(a) Disclosed capital shortfall in the EBA 2011 stress test (eq. (6)) versus $SRISK$ (€ millions). V-Lab download date: 12/31/2010.



(b) EBA Capital exercise "overall shortfall" (eq. (8)) versus $SRISK$ (€ millions). V-Lab download date: 09/30/2011.

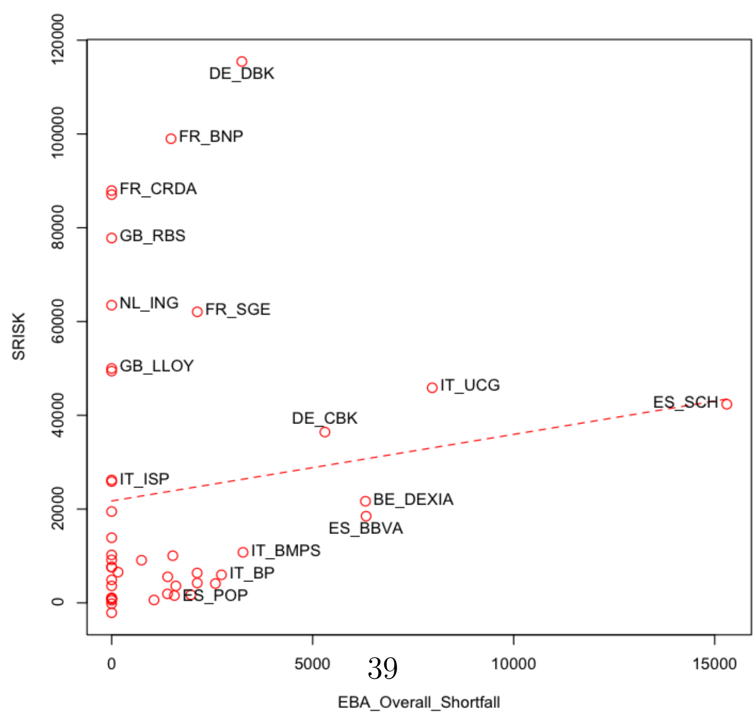
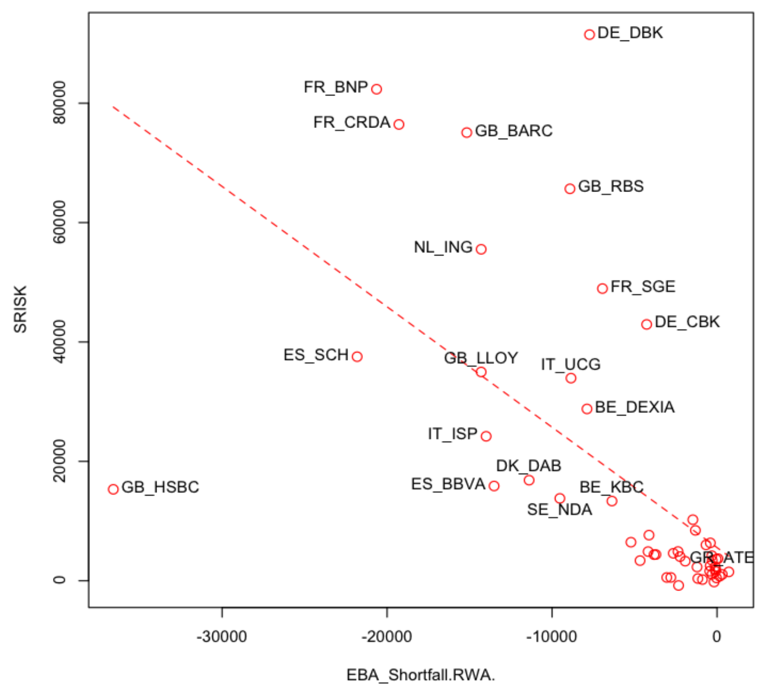
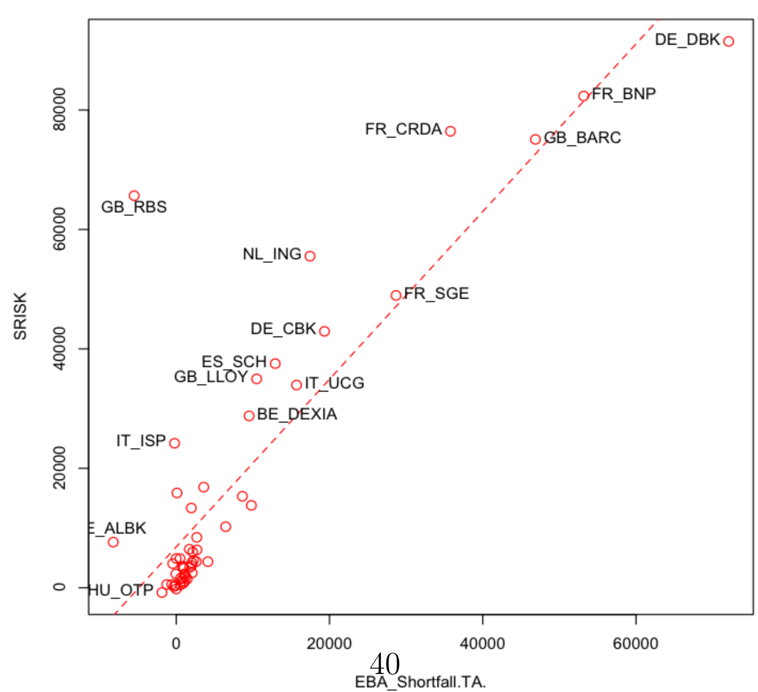


Figure 4: **EBA risk-based and leverage-based capital shortfalls vs. SRISK.** The capital shortfall estimates $SRISK$ under V-Lab stress scenario (vertical axis) against the “absolute” risk-based capital shortfall estimates in the EBA 2011 stress test (a), and the alternative leverage-based capital shortfall estimates for the EBA 2011 stress test (b).

(a) EBA 2011 stress test “absolute” risk-based capital shortfall/excess vs. $SRISK$ (€ millions). V-Lab download date: 12/31/2010.



(b) EBA 2011 stress test leverage-based shortfall (eq. (7)) versus $SRISK$ (€ millions). V-Lab download date: 12/31/2010.



Appendix

Appendix A includes two tables that summarize the results of regulatory stress tests implemented in the U.S. (Table 5) and in the EU (Table 6).

Appendix B covers the comparison of the projected losses in regulatory stress tests with V-Lab market cap losses.

Appendix C presents a resource allocation problem of a bank that invests in a portfolio of assets subject to a risk budget constraint based on risk-weighted assets.

A. US and EU stress tests results

Table 5: **U.S. stress tests results.** This table presents the aggregate outcome of U.S. stress tests for which a bank-level outcome is publicly available. $T1$ is the Tier 1 capital, $T1C$ is the Tier 1 Common capital, and RWA are the risk-weighted assets. $T1CR$ is the Tier Common Capital Ratio ($T1CR = T1C/RWA$); $T1R$ is the Tier 1 Capital Ratio ($T1R = T1/RWA$); $Total\,CR$ is the Total Risk-based Capital Ratio ($Total\,CR = Total\,Capital/RWA$); $T1LVGR$ is the Tier 1 leverage Ratio ($T1LVGR = T1/TotalAssets$). In parentheses: number of banks failing the regulatory criterion. "min" stands for the cross-sectional average (unweighted) of banks minimum ratios over the nine quarters of the CCAR scenario. The different minimum ratios may not happen on the same quarter. The column "After scenario*" presents the aggregate results of stress tests without the effect of BHCs planned capital actions (results disclosed in the Dodd-Frank Act stress test 2013 for the CCAR 2013).

	Disclosure	Sample	Scenario horizon	Measure and threshold	Before scenario	After scenario	After scenario*
SCAP 2009	05/07/2009	19 U.S. banks	2009 - 2010	T1	837 $ bn		
		(19 BHCs)	(2 years)	T1C	413 $ bn		
				RWA	7815 $ bn		
				T1CR $\geq$ 4%	6.7% (2)		
				T1R $\geq$ 6%	11.5%		
				T1C shortfall $\leq$ 0		74.6 $ bn (10)	185 $ bn (10)
CCAR 2012	03/13/2012	19 U.S. banks	Q4 2011 -	T1	907 $ bn	540 $ bn	
		(19 BHCs)	Q4 2013	T1C	741 $ bn	438 $ bn	
			(9 quarters)	RWA	7356 $ bn	6904 $ bn	
				T1CR $\geq$ 5%	10.1%	6.6% min (3)	7.3% min (1)
				T1R $\geq$ 4%	12.3%	8.0% min (0)	8.7% min (0)
				Total CR $\geq$ 8%	15.5%	10.8% min (2)	11.5% min (2)
				T1 LVGR $\geq$ 3-4%	7.4%	5.2% min (2)	5.7% min (1)
CCAR 2013	03/14/2013	18 U.S. banks	Q4 2012 -	T1C	792 $ bn		
		(18 BHCs)	Q4 2014	T1CR $\geq$ 5%	11.3%	6.9% min (1)	8.0% min (1)
			(9 quarters)	T1R $\geq$ 4%	13.1%	8.3% min (0)	9.8% min (0)
				Total CR $\geq$ 8%	15.6%	10.7% min (0)	12.1% min (0)
				T1 LVGR $\geq$ 3-4%	8.8%	5.7% min (2)	6.8% min (0)

Table 6: **EU stress tests results.** This table presents the aggregate outcome of EU-wide stress tests for which a bank-level outcome is publicly available. $T1$ is the Tier 1 capital, $T1C$ is the Tier 1 Core capital, and RWA are the risk-weighted assets. $T1CR$ is the Core Tier 1 Capital Ratio ($T1CR = T1C/RWA$); $T1R$ is the Tier 1 Capital Ratio ($T1R = T1/RWA$). In parentheses: number of banks failing the regulatory criterion. Ratios are cross-sectional average ratios at a specific date (scenario start or scenario end). The column "After scenario*" presents the aggregate results of stress tests without the effect of capital actions and restructuring plans.

	Disclosure	Sample	Scenario horizon	Measure and threshold	Before scenario	After scenario	After scenario*
CEBS 2010	07/23/2010	91 banks,	2010 - 2011	T1	1162 EUR bn	1118 EUR bn	
		65% of	(2 years)	RWA	11.29 EUR tn	12.15 EUR tn	
		EU-27 assets		T1R $\geq$ 6%	10.3%	9.2% (7)	
				T1 shortfall $\leq$ 0		3.5 EUR bn	
EBA 2011	07/15/2011	90 banks,	2011 - 2012	T1	1218 EUR bn	1199 EUR bn	
		65% of	(2 years)	T1C	1006 EUR bn	1001 EUR bn	954 EUR bn
		EU-27 assets		RWA	11.37 EUR tn	13 EUR tn	13.12 EUR tn
				T1CR $\geq$ 5%	8.9% (3)	7.7% (8)	7% (20)
				T1C shortfall $\leq$ 0		2.5 EUR bn	25 EUR bn
EBA Capital	12/08/2011	65 banks		T1	1190 EUR bn		
Exercise		(excluding		T1C	987 EUR bn		
		Greek banks)		RWA	10.55 EUR tn		
				T1CR $\geq$ 9%	10.2% (27)		
				Sovereign buffer	39 EUR bn		
				Overall shortfall $\leq$ 0	85 EUR bn (31)		

B. Evaluating stressed losses

Stress test models can be used to translate the stress scenario into losses to assets on banks' balance sheets. The net loss (difference of projected losses and projected revenues) is the main driver of capital diminution under stress.

The rank correlations of the V-Lab loss with the projected total losses of stress tests are very high and significant in all stress tests (see Table 7).[19] The correlations of the V-Lab loss with the total *net* loss (including stressed revenues) are smaller for all stress tests and negative in Europe; banks with larger profits under European stress scenarios are predicted to have larger losses in V-Lab. Some banks actually report positive profits under the stress scenario of stress tests where stressed revenues cover stressed losses.[20] The profits are then reported in the balance sheet so that the divergence with V-Lab is also visible in capital changes. We show in Figure 5 that the projected profits under the EBA stress scenario lead to increasing capital levels for many banks with the largest V-Lab losses. Controlling for the size effect, the correlation between the V-Lab market cap return ($LRMES$) and the return on Core Tier 1 capital over the EBA stress scenario is less important (-0.133) and not significant at the 5% level.

Second, we compare in Table 8 the performance of V-Lab and the EBA 2011 stress test in predicting the actual ranking of banks' realized six-month losses and six-month returns after disclosure of the EBA stress test (i.e., the last two quarters of 2011). The six-month realized return is $-\sum_{t+1}^{t+131} \ln(p_{it}/p_{it-1})$, where p_{it} is the daily stock price of the bank, and the six-month realized loss is the product of the six-month realized return with the market cap of the bank.

For predicting realized losses (Panel A), the V-Lab market cap loss has the highest rank correlation (0.832) with the six-month realized loss. The correlation of the realized loss with the EBA projected net loss is negative (except for large banks) since many banks with

[19] We also report the correlations of the V-Lab loss with the stress test loan losses and trading losses since they are the most important sources of losses (85%) according to CCAR 2012. The correlations of the V-Lab loss with the loan and trading losses are also very high and significant, making V-Lab's ranking and the ranking of losses under supervisory stress scenarios very consistent.

[20] First, the stress scenario is not an absolute scenario as in V-Lab but is defined as a deviation from a baseline scenario. If some banks are projected to make large profits in the baseline scenario, they will make lower but still positive profits under the adverse scenario. Second, the EBA explains that the stress scenario may lead to a higher net interest income where some banks assume that the impact of higher interest rates will be passed onto customers without a corresponding increase in the cost of funding for the bank. Then, the EBA considers a directional market risk stress test; depending on the direction of their exposures, banks can realize trading gains on certain portfolios.

positive projected profits in the stress test actually endured the highest losses during the sovereign debt crisis.

For predicting realized returns (Panel B), V-Lab long-run marginal expected shortfall ($LRMES$) is a better predictor of the *size* of realized returns according to the root mean square error (RMSE). However, the estimated Core Tier 1 capital return over the EBA stress scenario better predicts the *ranking* of realized six-month returns than V-Lab $LRMES$, suggesting that the ranking of stressed returns in the EBA stress test was correct, only the stress applied to banks was too mild compared to what happened during the following six months.

Table 7: **V-Lab vs. stress tests losses: rank correlations.** Rank correlations of stress tests losses with V-Lab's MV loss ($LRMES * MV$). "Loss" (SCAP) = *Total Loss estimates* , "Loss" (CCAR) = *Loan Losses + Trading and Counterparty Losses + Realized Losses on Securities + Other Losses*, "Loss" (CEBS & EBA) = *Impairment losses + Trading losses.* "Net Loss" (SCAP) = *Total Loss estimates - Resources Other Than Capital to Absorb Losses in the More Adverse Scenario*, "Net Loss" (CCAR) = - *Projected Net Income before Taxes*, "Net Loss" (CEBS) = Loss - *pre-impairment income after the adverse scenario*, "Net Loss" (EBA) = - *Net profit after tax*. V-Lab download date: 12/31/2008 (SCAP), 09/30/2011 (CCAR 2012), 09/28/2012 (CCAR 2013), 12/31/2009 (CEBS), 12/31/2010 (EBA), 09/30/2011 (EBA Capital exercise). * indicates statistical significance at the 5% level; ** at the 1% level. Sample size: 18 (SCAP and CCAR 2012), 17 (CCAR 2013), 50 (CEBS), 53 (EBA).

Rank correlations with V-Lab MV loss

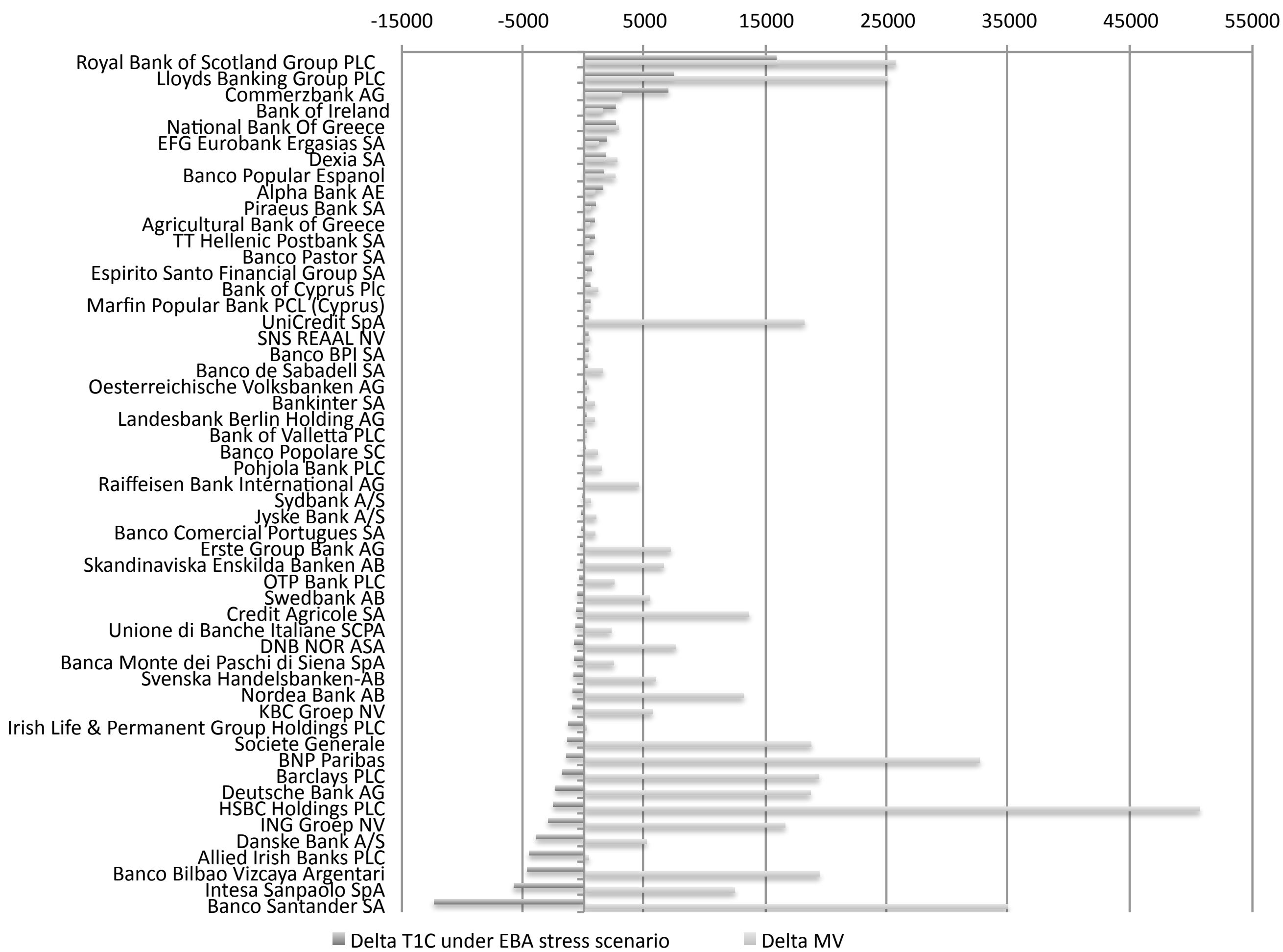
Stress tests projected losses	SCAP 2009	CCAR 2012	CCAR 2013	CEBS 2010	EBA 2011
Total Net Loss	0.280	0.604**	0.507*	-0.296*	-0.476**
Total Loss	0.682**	0.851**	0.842**	0.830**	0.760**
Loan losses	0.580*	0.555*	0.662**	0.837**	0.751**
Trading losses	0.477*	0.660**	0.589*	0.731**	0.694**

Table 8: **Forecasting losses during the European sovereign debt crisis.** This table presents the rank correlations and root mean square errors (RMSE) of the EBA and V-Lab outcomes with the realized outcomes of banks after disclosure of the EBA stress test in July 2011 (p-values in parentheses). Panel A: rank correlations and RMSE with the 6-month realized loss ($-MV_{it} * \sum_{t+1}^{t+131} \ln(p_{it}/p_{it-1})$). Panel B: rank correlations and RMSE with the 6-month realized return ($-\sum_{t+1}^{t+131} \ln(p_{it}/p_{it-1})$). EBA T1C return is the percentage return on Core Tier 1 capital during the EBA 2011 stress scenario. V-Lab output was downloaded before the disclosure date of the EBA stress test: 06/30/2011. Sample size: 15 (large), 38 (small), 53 (all).

Panel A: 6-month realized EUR loss		**Rank correlations**			**RMSE**
	Estimated losses	Large	Small	All	All
V-Lab	MV loss	0.293	0.610	0.832	5086
		(0.289)	(0.000)	(0.000)	
EBA	Total Net Loss	0.329	-0.100	-0.272	11202
		(0.232)	(0.549)	(0.048)	
EBA	Total Loss	0.557	0.527	0.803	4945
		(0.000)	(0.000)	(0.000)	

Panel B: 6-month realized return		**Rank correlations**			**RMSE**
	Estimated returns	Large	Small	All	All
V-Lab	$LRMES$	0.350	0.314	0.299	0.553
		(0.201)	(0.055)	(0.029)	
EBA	T1C return	0.546	0.339	0.354	0.767
		(0.035)	(0.038)	(0.009)	

Figure 5: **EBA stress test change in capital vs. V-Lab market cap loss (EUR millions).** Change in Core Tier 1 capital (Delta T1C) under the EBA 2011 stress scenario (dark grey) against V-Lab's market capitalization loss (Delta MV) (light grey). Negative changes represent a capital increase. Banks are ranked according to their changes in Core Tier 1 capital under the EBA stress scenario. V-Lab download date: 12/31/2010.



C. Portfolio choice under regulatory risk weights

We demonstrate in this section the weakness of Basel regulatory risk weights as an aggregate measure of bank risk where the bank is seen as a portfolio of assets. The bank chooses its resources allocations to maximize its return subject to a tolerable level of risk. Regulators implement several standards of prudent risk but these may sometimes be misguided. Here we consider the allocation of a fixed investment budget to asset categories subject to the regulatory requirement implemented in a stylized version of Basel standards.

Let TA be the total assets to be allocated between cash, C (equivalent to the capital requirement for credit risk in Basel II), and other risky assets. Let there be N risky assets with conditional expected returns given by the $(N \times 1)$ vector m, and conditional covariance matrix given by the $(N \times N)$ matrix H. According to Basel rules, each of these assets has a risk weight w_j between zero and one that we assemble in a $(N \times 1)$ vector w. The solution is a $(N \times 1)$ vector of dollars to be invested in each asset, q. The vector q will also determine the optimal exposures at default under Basel II and the optimal RWA, $w'q$. The risk budget requires that $C \geq kw'q$, where k is the prudential capital ratio and $C = TA - \iota' q$, where ι is a $(N \times 1)$ vector of ones.

To maximize asset returns subject to these constraints, the firm must solve:

$$\begin{aligned} &\max_{q} \; q'm \\ &\text{s.t. } TA - \iota' q \geq kw'q, \;\; q \geq 0. \end{aligned} \tag{9}$$

The Lagrangian of this maximization problem is:

$$L(q, \lambda, \mu) = m'q - \lambda \left(TA - \iota' q - kw'q \right) - \mu' q, \tag{10}$$

where the scalar λ and the $(N \times 1)$ vector μ are Lagrange multipliers. The first order condition of equation (10) with respect to q is given by:

$$m' + \lambda \left(\iota' + kw' \right) - \mu' = 0. \tag{11}$$

Multiplying equation (11) by q and recognizing that either q or μ will be zero for each asset (from the first-order condition of (10) w.r.t. to μ), then:

$$\begin{aligned} m'q + \lambda\left(\iota'q + kw'q\right) &= 0 \\ m'q &= -\lambda TA \\ \lambda &= \frac{-m'q}{TA}. \end{aligned} \tag{12}$$

Replacing λ in (11), we obtain:

$$m' - \left(\frac{m'q}{TA}\right)\left(\iota' + kw'\right) - \mu' = 0. \tag{13}$$

Hence all non-zero allocations, q_j, must satisfy:

$$\begin{aligned} m_j - \left(\frac{m'q}{TA}\right)\left(1 + kw_j\right) &= 0 \\ \frac{m_j}{1 + kw_j} &= \frac{m'q}{TA}. \end{aligned} \tag{14}$$

Supposing that each asset has a different value of $m_j(1 + kw_j)^{-1}$, then the maximum will occur if the entire portfolio of the bank $\iota'q$ is invested in the asset with the greatest value of this ratio. The amount invested in this asset will be:

$$q_j = \frac{TA}{1 + kw_j} \tag{15}$$

If there are multiple assets with the same value of this ratio, the performance will be the same for any feasible allocation to these assets.

The main observation is that the risk of a portfolio is always less than or equal to the sum of the risks of its components. The use of risk-weighted assets ignores this portfolio feature of risk and consequently there is no incentive from the regulatory perspective to diversify. The only case where this measure is appropriate is when all assets are perfectly correlated.

For firms with risk aversion, risk weights act as an additional cost on assets.[21] Glasserman and Kang (2013) show that risk weights that are optimal from both banking and regulatory perspectives have nothing to do with risk but are instead proportional to the asset returns m. These optimal risk weights do not distort the portfolio a bank would choose without the

[21] It can be shown that the additional cost will be greater if the threshold k is large and for a bank with low risk aversion and low capital.

risk-based capital constraint and satisfy the regulator's objective to limit the bank's portfolio riskiness.[22]

Then, if some risk weights are underestimated or are not adjusted to reflect increased risk during a crisis, a bank will choose its optimal asset with the most underestimated risk weight, which will automatically lead to excessive leverage. If w_j is the risk weight of the optimal asset and since $q_j = \iota' q = TA - C$, the leverage ratio C/TA from (15) is $1 - (1 + kw_j)^{-1}$. Consequently, banks will take excessive leverage if their risk weights are not adequately adjusted to more severe economic conditions.

[22] Also note that the portfolio distortion problem does not exist for banks that are only leverage-constrained since the additional charges are the same for all assets.