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Whence and Whither?**

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Stress Testing Banks: Whence and Whither?

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Abstract: This paper provides a brief overview of the recent practice of stress testing banking institutions, focusing on capital adequacy. We argue that stress testing has been successfully used to mitigate bank opacity; quantify systemic risk under extreme but plausible stress; keep the participants mindful of severely adverse shocks, thereby mitigating “disaster myopia” and concomitant financial instability; and improve the data collection and analytical capabilities of financial institutions. Our paper then reviews several critiques of stress testing made by policymakers and academics. We also propose several modifications of the current stress-testing practice, such as the fusion of liquidity and capital adequacy stress testing, expansion of granular data availability, and explicit modeling of sectors inextricably connected to banking as well as the feedback mechanisms from these sectors. Addressing these issues is likely to keep stress testing highly relevant for promoting financial stability in the future.

Keywords: Stress testing, banks, Dodd-Frank Act, systemic risk, liquidity, disaster myopia, financial instability

JEL Categories: G21, G28

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1 Introduction

The 2008–2009 global financial crisis and the ensuing Great Recession brought about arguably the largest financial reforms since the Great Depression of the 1930s. In the United States, much of this new regulation was implemented following passage of the Dodd-Frank Wall Street Reform and Consumer Protection Act (Dodd-Frank Act or the DFA) in 2010. One of the DFA’s numerous provisions aimed at improving the stability of the U.S. financial system calls for larger banks and bank holding companies to undergo so-called “stress tests” that require both bank managers and regulators to understand what would happen to banking institutions if they were subjected to “exceptional but plausible macroeconomic shocks.”¹ Similar reforms have been undertaken in other countries as well, with stress testing emerging as a commonly used instrument in the toolkit of financial supervision and regulation. The purpose of this paper is to survey current stress-testing practices, discuss their relative advantages and disadvantages, address some of the criticism leveled against stress-testing exercises, and propose improvements to future stress tests. We restrict our analysis to the banking sector and to stress testing mandated by regulatory rules, as opposed to purely internal stress tests conducted by financial institutions.²

We argue that regulatory stress testing is a useful tool for addressing classical concerns with the robustness of financial architecture for the following reasons: First, it could complement Basel capital regulation in capturing systemic risk. Second, it may reduce the opacity of the banking industry and reduce asymmetric information among market participants. Third, it forces both regulators and financial institutions to periodically assess the possible effects of highly adverse scenarios, which tend to be ignored in good times. Fourth, it is useful as a regulatory tool to incentivize banks to collect better data, expand their quantitative analytical capabilities, and engage in more robust and holistic risk management practices.

The first benefit of stress testing is its potential to complement Basel capital regulation in capturing systemic risk. The Group of Ten (2001) defines systemic risk as “the risk that an event will trigger a loss of economic value or confidence in, and attendant increases in uncertainty about, a substantial portion of the financial system that is serious enough to quite probably have significant adverse effects on the real economy.”³ Early efforts at stress testing, as well as Basel capital

¹ Sorge (2004) provides useful definitions and an overview of the early stress-testing practices that preceded the Great Recession. Drehmann (2009) and Kapinos and Mitnik (2015) describe methodological updates to his early contribution. Not all stress testing in the United States is mandated by the DFA; for example, the National Credit Union Administration (NCUA) requires credit unions with more than \$10 billion in assets to undergo stress testing, even though the DFA does not mention credit unions in its stress-testing provisions. See *NCUA Rules and Regulations §702—Capital Planning and Stress Testing* for details.

² The DFA also mandates stress testing of nonbank “systemically important financial institutions” (SIFIs), as determined by the Financial Stability Oversight Council (FSOC). In this paper we do not address stress testing of these institutions.

³ The Group of Ten (2001) then highlights the role of negative externalities in propagating the shocks from the financial system to the broad macroeconomy through payment system, credit, and asset price channels. More recently, De Nicolo, Favara, and Ratnovski (2014) discuss the use of macroprudential tools other than stress testing to mitigate negative financial externalities that may arise in crisis conditions. Acharya, Engle, and Richardson (2012) build on Tarullo (2009) by offering a threefold definition of systemic risk: (a) It materializes when a firm

requirements, have not been fully effective in addressing spillovers across financial institutions or feedbacks to the macroeconomy. In this sense, both programs have remained largely microprudential, though recent work has moved best practice in the direction of these systemic or macroprudential ideas. One of the main arguments of this paper is that more work is needed in this area for stress testing to realize its potential to serve as both a forward-looking and macroprudential complement to Basel capital regulations.⁴

Second, stress testing may reduce the opacity of the banking industry and reduce asymmetric information among market participants. To the extent that the results are made public, stress tests can make financial institutions more transparent, effectively acting as another form of financial disclosure. This reduction of asymmetric information can be particularly valuable during crises. In addition, Bookstaber, Cetina, Feldberg, Flood, and Glasserman (2014) argue that disclosure “enhances market discipline as a tool for financial stability, strengthens the incentives for financial institutions to meet supervisory standards, and reinforces confidence in the functioning of the financial system.” Two strands of the literature are rapidly emerging to address this issue. Theoretical papers evaluate the desirability of disclosing stress-testing results. Goldstein and Sapra (2012) argue that disclosing such results improves financial stability by imposing market discipline, which leads to improvements in resource allocation. They caution, however, that bank-specific effects may impose costs, such as inducing excessively volatile reactions to results releases, thereby reducing the incentive for analysts to monitor banks. Goldstein and Leitner (2015) study a tradeoff between disclosure that reduces market breakdowns but that also possibly reduces banks’ risk-sharing incentives. They argue in favor of partial disclosure in stressful conditions and no disclosure in normal times. On the empirical front, the cumulative abnormal return methodology has been used to evaluate the stock market reaction to the release of stress-test results. Morgan, Peristian, and Savino (2014) find that the market largely knew which banks would pass or fail the Federal Reserve’s 2009 Supervisory Capital Assessment Program (SCAP), but the release of the size of capital shortfalls provided useful information.⁵ Candelon and Sy (2015) review the evidence for subsequent stress tests and argue that while the market reaction to their releases has decreased from the SCAP levels, it continues to be significant.⁶ Petrella and Resti (2013) discuss evidence that the 2011 European stress-testing exercise provided useful information for market participants. Therefore, stress tests do appear to reduce the opacity of the banking industry.

Third, stress testing can keep the participants mindful of severely adverse shocks. As Minsky (1975, 1986, 1992) and Guttentag and Herring (1986) argue, financial systems exhibit fundamentally destabilizing behavior. Minsky refers to the idea as the “financial instability hypothesis” and Guttentag

experiences a capital shortfall and has difficulty continuing to provide financial services; (b) it becomes a policy concern when such shortfalls affect the broader economy; and (c) its quantification critically depends on a failing firm’s contribution to system-wide failure.

⁴ Wall (2014) also argues that the forward-looking nature of stress testing makes it a useful complement to the more backward-looking Basel regulations. Van Lelyveld (2009) explains how stress testing may address Pillars 1 and 2 of Basel II regulations.

⁵ Morgan et al. (2014) also provide a brief review of the literature on bank opacity whose balance, with caveats, appears to support the notion that the banking industry is more opaque than other sectors of the U.S. economy.

⁶ Similarly, Glasserman and Tangirala (2015) find that the CCAR results are becoming increasingly predictable.

and Herring call it “disaster myopia,” but the intuition is similar: periods of economic and financial calm cause the financial system to become less resilient to extreme shocks because market participants perceive a reduced probability of their realization and engage in accordingly riskier behavior. By subjecting individual banks and the financial system to severely adverse hypothetical scenarios in times of stability, stress testing may uncover emerging fragility in bank portfolios. Hence, stress testing can serve as a formal structure to remind market participants that such hypothetical adversity may yet happen in practice, deterring destabilizing behaviors.

Fourth, stress testing is useful as a regulatory tool to incentivize banks to collect better data, expand their quantitative analytical capabilities, and engage in more robust and holistic risk management practices. Schuermann (2015) argues that financial institutions have had to evaluate more holistically their approach to risk management, which, in most cases, has driven improved data collection, model development, and validation capabilities. As we discuss below, this aspect of regulatory stress testing has been especially challenging for smaller financial institutions.

Notwithstanding its usefulness, stress testing faces a number of important technical challenges and conceptual critiques. One such challenge relates to the modeling of systemic impacts and spillovers of financial stress and bank failures. Addressing this challenge will involve the inclusion of liquidity risk and firms’ interaction in regulatory stress tests, an area of ongoing but incomplete progress (see Bookstaber et al., 2014). Adequately stressing liquidity risk in turn may require the incorporation of market, as opposed to book, equity into stress-testing models, given the empirical relationship between market equity and liquidity (IMF, 2012a, and Annaert, De Ceuster, Van Roy, and Vespro, 2013).⁷ Another technical challenge facing stress testing is that reasonable assumptions regarding difficult-to-model elements of bank balance sheets can lead to meaningfully different results. Finally, we address several critiques of stress testing, including that it may implicitly commit regulators to bail out banks that perform unexpectedly poorly; that it represents an undue burden on banks, particularly smaller institutions; and that, as currently conducted, it represents an unduly opaque regulatory process.

Our view is that there is considerable room for improvement to the current practices of regulatory stress testing. Addressing the technical challenges above will likely make the process more useful for regulators and banks alike. Our discussion of the critiques of the fundamental appropriateness of stress testing, however, suggests that most of the criticism is misplaced and that stress testing is a fundamentally useful regulatory tool, albeit one that can, and should be, streamlined and improved.

The rest of this paper is organized as follows. Section 2 provides a broad survey of the current practice of stress testing, as conducted in the United States, the European Union, and the United Kingdom, and discusses both differences in methodological approaches and outcomes from the practical

⁷ Indeed, Kuritzkes and Scott (2009) and Flannery (2013) argue that stress testing should focus on something closer to market equity. Particularly during times of stress, both fundamental solvency and market equity tend to diverge from book equity valuation. Flannery (2005) shows that managers have incentives to inflate book value in these cases. This concern is emphasized by the stylized fact from the above references and Kapinos and Mitnik (2015) that most banks that failed during and after the 2008–2009 crisis had book equity well above regulatory thresholds just before their failure.

implementation of stress tests. Section 3 discusses some of the known challenges to the current practices and offers ways of addressing them. Building on this technical assessment, Section 4 reviews critiques that have been recently advanced against stress testing. Finally, Section 5 summarizes issues that, if addressed, would change existing stress-testing practices; suggests ways for implementing them; and offers conclusions and recommendations on the future of stress testing.

2 The Practice of Stress Testing: History and Implementation

This section discusses current stress-testing practices and provides a brief history of supervisory regimes. Section 2a briefly reviews the history of stress testing, while Section 2b describes the current landscape in capital adequacy stress-test modeling, focusing on the technical details.

2a A Brief History of Stress-Testing Programs

Pre-Crisis Evolution: 1980s–2007

Stress testing began in the 1980s as a relatively minor risk management tool applied largely to individual risks in isolation. Many private institutions and regulators began stressing interest rate risk in the 1980s; see Houpt and Embersit (1991), Sierra and Yeager (2004), OTS (2005, 2006), and Carhill (2009) for several examples. Later, the Market Risk Amendment of 1995 to the Basel Capital Accords required many larger financial institutions to stress market and liquidity risks in their trading books (BCBS, 1996). Based on discussions with market participants and a formal survey of stress-testing practices, the Committee on the Global Financial System (2000, 2001) documented that stress testing was, by the late 1990s, commonly used to assess market, liquidity, and even occasionally credit risk in the trading book.⁸ In addition to stress testing their trading portfolios, a report issued by the Counterparty Risk Management Policy Group (1999) indicated that some firms were developing techniques to stress investment and credit portfolios as well.

With the advent of stress testing by the International Monetary Fund (IMF) under the aegis of the Financial Sector Assessment Program (FSAP), stress testing began to address broader stability concerns. Introduced in 1999, the FSAP includes stress tests conducted by IMF staff or by a combination of IMF and in-country supervisory staff on a periodic, country-by-country basis. Unlike earlier stress tests, FSAP tests focus on aggregate financial stability and jointly stress a wider array of risks, notably including credit, interest, and exchange rate risks (Blaschke, Jones, Majnoni, and Martinez Peria, 2001). While the early FSAP stress tests tended to use models and scenarios which, by current standards, were simplistic, more recent tests are comparable in sophistication to current supervisory stress tests. In addition to any direct financial stability benefits, the FSAP tests served to generate research interest and led some regulators to begin conducting routine stress testing of their financial systems, even before the financial crisis.⁹

⁸ See also Fender, Gibson, and Mosser (2001) for a consolidated summary of the findings of the survey.

⁹ Regulatory authorities in Mexico and Luxembourg routinely conducted stress tests before the advent of FSAP tests. Several others began after their participation in the FSAP, including Finland, Hungary, and Poland. See IMF (2003).

The last element of pre-crisis stress testing worth mentioning serves as something of a cautionary tale, from which we draw several conclusions in Sections 3 and 4. Beginning in 2002, the Office of Federal Housing Enterprise Oversight (OFHEO) stress tested the interest rate and credit risk exposures of Fannie Mae and Freddie Mac, the two U.S. government-sponsored enterprises (GSEs) central to financing the U.S. housing market. Much like recent stress tests, the results were used to determine capital adequacy and effective capital requirements. However, Frame et al. (2015) describe the stress-test exercise as “a spectacular failure,” owing to the fact that the tests suggested the GSEs’ capital was adequate until just a few months before they became insolvent and were placed into conservatorship by the U.S. government. Frame et al.’s analysis suggests that three major lessons should be drawn from the OFHEO experience. First, models should be conceptually evaluated and updated, as well as re-estimated, regularly in order to maintain accuracy and rigor. Perhaps because of cumbersome and detailed publication requirements for the model, OFHEO’s stress-test model and its coefficients were static from their implementation in 2002 onward. Frame et al. find that this failure to update the model resulted in a substantial understatement of stressed losses. Second, regulators must take care to select appropriately stressful scenarios. Stress only set in after an extended period of time in the OFHEO scenarios, at which point existing loans would have acquired considerable seasoning, reducing the probability of their default. Finally, assumptions on balance sheet behavior, especially asset growth, over the stress scenario are critical. The OFHEO stress tests assumed that the GSEs would have no new business during the scenario. This served to limit the base of loans to suffer losses, and it also interacted with the profile of loss rates by mortgage vintage to further decrease estimated losses. These three lessons should be applied to more recent stress testing, as we discuss in more depth below.

Developments Since the Crisis: 2008–Present

The financial crisis dramatically accelerated both the use of stress testing by regulators and research on the topic. Because the first major stress test conducted during the crisis, the Federal Reserve’s Supervisory Capital Assessment Program (SCAP), was widely perceived as successful, it has served as the basis for the techniques and scale of stress-testing exercises performed since then.¹⁰

Conducted in early 2009, the SCAP was intended both to estimate the scale of recapitalization needed by the financial sector and to reduce asymmetric information, which was elevated during the peak of the crisis (FRB, 2009a, 2009b, 2009c). The SCAP covered the 19 U.S. bank holding companies (BHCs) with at least \$100 billion of consolidated assets. These 19 institutions held about two-thirds of the assets in the U.S. banking system. The supervisory agencies and BHCs estimated credit losses on 12 portfolios within the banking book and on investment securities (both held-to-maturity and available-for-sale) for each bank. They also estimated pre-provision net revenue and, for institutions with trading book assets in excess of \$100 billion, market and counterparty credit losses on their trading books. Bank liquidity was not stressed. Projections for these variables were made at the annual frequency for 2009 and 2010, though appropriate measurement of the allowance for loan and lease losses required loss estimates for 2011 as well. The projections of financial institution health were made for two hypothetical scenarios, “baseline” and “more adverse,” provided by the regulators. The scenarios comprised paths for real GDP growth, the national unemployment rate, and a house price index. Firms

¹⁰ For an early survey of alternative methods for stress testing credit risk, see Foglia (2009).

were encouraged to develop paths for additional macroeconomic variables, consistent with the three regulator-provided series, as needed. Banks whose capital was forecast to fall below the threshold were required to raise additional capital.¹¹ Firms were encouraged to obtain additional private capital, such as by common stock issuance. However, any firm failing to recapitalize privately by November 2009 would have to receive a capital injection from the Treasury and would be disallowed from making dividend distributions. Of the 19 firms tested, 10 were found to have a capital deficiency totaling \$75 billion.

Though the aims of the SCAP were relatively narrow, the program's architecture provides a solid basis for stress tests for several reasons. First, the techniques to provide credible assessments of stress losses and capitalization are equally necessary for estimating recapitalization needs or for mitigating disaster myopia. More generally, the modeling, supervisory oversight, and disclosure practices of the SCAP were designed to ensure clarity, accountability, and the reduction of bank opacity. Finally, the SCAP laid the groundwork for wider and systematic data collection and analysis by banks and their regulators. This data collection is useful for many purposes, including the development of highly granular stress-test models. We argue below that these highly granular models seem more promising than highly aggregated models. We also maintain that, suitably redacted, loan-level data gathered for stress testing should be made available to researchers to spur further development of bottom-up models.

Subsequent stress tests in the United States have fallen under several programs; Table 1 enumerates the U.S. and European stress tests and provides summary information.¹² Bank holding companies with consolidated assets in excess of \$50 billion, as well as nonbank financial institutions designated as systemically important by the Financial Stability Oversight Council (FSOC), are required to undergo the Comprehensive Capital Analysis and Review (CCAR) annually (FRB, 2014d, 2015a). CCAR includes a quantitative stress test of BHCs' credit risk in the banking book and market risk in the trading book, conducted by the Federal Reserve. It also includes a qualitative review of BHCs' capital planning and stress-testing procedures.¹³ BHCs can fail CCAR on either quantitative or qualitative grounds, with failure typically implying restrictions on BHCs' planned dividend payouts or share repurchases. The basic stress-testing paradigm for CCAR is quite similar to the SCAP architecture, though modeling, data collection, and disclosure have improved as the process has evolved. The CCAR exercise is a useful financial stability tool beyond the benefits derived from the SCAP. Specifically, because regulators can restrict firms' capital plans, CCAR is clearly a useful forward-looking approach to assessing capital adequacy and assigning capital requirements, complementing Basel regulation. Moreover, the emphasis on the qualitative aspects of capital planning and risk management ensures that CCAR is useful for

¹¹ As noted by Hirtle and Lehnert (2014), the requirement that the BHCs raise a particular dollar value of capital, as opposed to meeting a minimum capital ratio, ensured that the banks could not simply shed assets to address the capital shortfall. Regulators arguably wished to discourage such deleveraging during the crisis.

¹² Of course, many other supervisory organizations conduct stress tests, beyond the instances in the U.S., EU, and UK that we discuss here. Among others, CBol (2011, 2012) discuss the Irish stress tests; IMF (2012b), Oliver Wyman (2012), and Roland Berger (2012) discuss Spanish stress tests.

¹³ These stress tests are also intended to capture bank operational risks, though these risks are measured using rather simple, reduced-form techniques. Because operational risk is largely unrelated to the state of the macroeconomy, it cannot be easily integrated into a macro-driven stress test in any deep or structural way.

incentivizing improved data collection and risk management, our fourth dimension of value for stress testing.

Two other U.S. stress-test programs closely resemble CCAR and SCAP. First, Dodd-Frank Act Stress Testing (DFAST) requires all federally regulated financial institutions with assets in excess of \$10 billion to conduct company-run stress tests (FRB, 2014b, 2015b). Covered institutions submit their stress tests to their primary regulators for review and are required to disclose the results.¹⁴ While DFAST is quite similar to CCAR and thus serves many of the same core purposes, the tests are applied to a much larger set of firms and are not directly used to set capital requirements, though they are used to inform supervisory oversight and enforcement actions. Figure 1 describes the evolution of the share of assets belonging to banks undergoing stress testing in total banking assets. This share has increased from about 60 percent under SCAP to more than 85 percent under the 2015 CCAR and DFAST. Finally, though not required by any specific legislation, the National Credit Union Administration (NCUA) has begun stress testing credit unions with assets exceeding \$10 billion (NCUA, 2014, 2015). The first stress test was conducted in 2014, and the results were not disclosed; however, the broad structure appears similar to the CCAR stress tests, and the NCUA may disclose results in the future.

Also summarized in Table 1 is the EU-wide stress-testing program (CEBS, 2009, 2010; EBA, 2011a; ECB, 2014). The first EU-wide stress test, conducted by the Committee of European Banking Supervisors (CEBS) in 2009, covered only 22 cross-border banks and disclosed very little information. As such, these early stress tests were of relatively limited financial stability value. Subsequent stress tests, conducted by the CEBS's successor agencies—the European Banking Authority (EBA) followed by the European Central Bank (ECB)—have applied to a wider number of banks and have been much more thoroughly disclosed. In broad terms, the EU-wide stress tests are similar to their U.S. counterparts, emphasizing credit and market risk. Recent scenarios have featured some elements of sovereign risk, though they fall short of fully assessing the impacts of sovereign default.¹⁵ The tests are coordinated by the EU banking regulators but are largely overseen by country-level regulators. In addition to any direct financial stability benefits, EU-wide stress testing fosters testing by national authorities, such as the Bank of England (2014a, 2014b). These national level tests are often structured to roughly coincide with the EU-wide stress tests, in terms of timing, model structures, and variables, but often include additional scenarios, banks, or risks assessed.

Finally, none of these stress-testing regimes include stress tests of bank liquidity, an area of particular concern that we discuss below. Several central banks do conduct separate liquidity stress tests, though. For example, the Federal Reserve conducts the Comprehensive Liquidity Assessment and Review (CLAR; see Tarullo, 2014a), though the data, methodology, and results are confidential. In addition, many central banks have recently developed stress-test models (typically fairly aggregated

¹⁴ The DFAST program is newer than the CCAR, having started only in 2013. The first year of DFAST covered only CCAR firms. Coverage of institutions and disclosure requirements have been phased in to match those described above and required by law. In addition, the conduct and disclosure of DFAST is more fragmented than the CCAR, reflecting the fact that it is overseen by multiple supervisory agencies.

¹⁵ Schuermann (2014) and Goldstein (2014) argue that the approach to stressing sovereign exposures in the EU-wide stress tests has not been sufficiently rigorous.

models) that include liquidity and solvency interaction. However, these models are generally separate from the primary, large-scale stress tests whose results are publicized and studied by private sector analysts. The models are so far mainly used for internal policy analysis. In general, liquidity stress testing is too often conducted confidentially and separately from other forms of stress testing. Given the substantial interaction of liquidity and solvency risks, this is a major area for future work.

2b Current Modeling Approaches

With the historical context in mind, we now turn to the technical aspects of stress-test implementation. Today, there are two general modeling paradigms for conducting capital adequacy stress tests: direct and reverse stress testing. We discuss these methods, dedicating the most attention to direct stress testing, since it has been the main method used for regulatory compliance purposes.

Direct Stress Testing

Direct stress testing, which includes the stress-testing regimes developed since the crisis, is essentially a three-step process. First, empirical relationships between a banking variable and exogenous stressors, such as macroeconomic variables or financial indexes, are estimated. Second, a stress scenario for the exogenous stressors is produced by a researcher or risk manager, or delivered by a regulator or third-party consultant. The scenario may replicate a historical episode or may be hypothetical, intended to assess a particular risk. Third, the stress scenario is applied to the empirical models to understand the effect on the banking variable of interest. The process may be repeated for several banking variables, and additional, possibly assumption-based calculations may be performed to obtain results for final measures, such as capitalization levels. Banks and regulators both follow this general procedure in their stress-testing activities, though with a high degree of heterogeneity in the particular banking variables modeled, the modeling approaches, and even the scenarios considered.

Two empirical methods fall under the direct stress-testing umbrella: *top-down* and *bottom-up*.¹⁶ In the top-down approach, the empirical relationship between a banking variable and an exogenous stressor is assumed at the portfolio level of low granularity. A bank's chargeoff rates on an entire portfolio of loans may depend on the unemployment rate, for example.¹⁷ In the bottom-up approach, the empirical relationship is estimated at the highest possible level of granularity of a banking variable. For example, this model may capture the effect of the local unemployment rate on the probability of borrower default for individual loans. The main advantages of the top-down approach are that it requires only readily available bank-level data and that it allows for the horizontal comparison of stress scenarios for many institutions. The main disadvantage of the top-down approach—and the main advantage of the bottom-up approach—is that idiosyncratic aspects of a bank may be lost at the aggregate level but may be more easily modeled when using granular data. Importantly, under both of

¹⁶ In this paper, we follow the U.S. definitions for these concepts, whereas in Europe “top-down” may refer to stress testing conducted by regulators and “bottom-up” by banks. Burrows, Learmonth, and McKeown (2012) suggest that direct stress testing may include other options along the tradeoff between theoretical coherence and empirical detail, such as dynamic stochastic general equilibrium (DSGE) models. While potentially useful, we are not aware of stress tests being incorporated into these models; hence, we do not discuss them in this paper.

¹⁷ Sangha and Lin (2013) critique such direct stress-testing models from the risk management perspective.

the direct stress-testing approaches, the number of stress scenarios is typically small, which may limit the sources of risk considered, both for individual banks and the financial system as a whole.

Much of the academic literature on stress testing has focused on the direct top-down approach, while some of the stress-test regimes discussed above, such as CCAR, are bottom-up, creating a substantive gap between academic research and supervisory implementation of stress testing. This disparity likely exists because macroeconomic and portfolio-level data are publicly available, whereas loan-level data, necessary for bottom-up modeling, are available only from commercial sources and within supervisory agencies. Hirtle, Kovner, Vickery, and Bhanot (2014) and Kapinos and Mitnik (2015) provide examples of top-down models that have attempted to replicate regulatory analyses. While Hirtle et al. (2014) assume that all banks are equally sensitive to exogenous stressors, Kapinos and Mitnik (2015) and Covas, Rump, and Zakrajsek (2014) describe ways of modeling heterogeneity of this sensitivity. This latter is important because it yields stronger banking distress for a given macroeconomic stress scenario. As was mentioned earlier, Frame et al. (2015) describe the bottom-up model used by the OFHEO to stress test the GSEs in the run-up to the most recent crisis. Relatedly, integrated liquidity stress testing is an idea that has become relatively developed in the academic (and, typically, top-down) literature, but whose practical implementation is incomplete.

Reverse Stress Testing

An alternative paradigm to the direct approaches is *reverse stress testing*. The main objective is to determine the range of exogenous driver scenarios that may “break the bank.” Breuer, Jandacka, Rheinberger, and Summer (2012) and Glasserman, Kang, and Kang (2015) provide alternative methods for conducting reverse stress tests. While it may be difficult to envision a significant regulatory application of the reverse stress-testing paradigm, it is likely to be a useful tool for identifying the types of stress scenarios that may be used for regulatory direct stress-testing purposes.

3 Continuing Technical Challenges

Although the theoretical and empirical research has advanced modeling various income statement and balance sheet items and projecting them forward under hypothetical stress scenarios, several technical and qualitative challenges remain. Further efforts to address them must be made for stress testing to realize its full potential as a financial stability tool. Below, we describe some of the more significant issues in order to motivate future work.

First, stress testing currently stops short of analyzing systemic stress. Although it analyzes the impact of a macro scenario on each firm’s capitalization, mainly through credit losses and income, stress testing does not allow the firm’s results to affect other firms or the real economy. This approach leaves several important questions open. Suppose a firm that does poorly in the stress scenario actually failed. What would happen to the other firms? Would they face liquidity runs? Would the macroeconomic scenario worsen? If so, would this further affect financial stability? Even barring a major bank failure, what effects does lower capitalization have on an institution’s interaction with other players? How might banks react in an effort to mitigate their risk? As banks become less capitalized without breaching regulatory thresholds, do they become more likely merger targets, which may lead to higher concentration and increase systemic risk? These questions regarding the feedback between tested

institutions' results and between their results and the macro scenario must be answered in order to understand the full system-wide effects of a particular stress scenario.

Focusing on the transmission of stress among tested firms, recent experience suggests that transmission largely occurs through liquidity channels.¹⁸ When firms face steep losses and declining capital, they frequently lose funding sources, precipitating fire sales of assets. These fire sales in turn depress asset (and collateral) prices for all institutions and drive liquidity hoarding. Even in the absence of fire sales, loss of confidence in either firm or market liquidity may lead to rapidly rising collateral haircuts and loss of funding capacity or liquidity. In this manner, solvency and liquidity stress is quickly transmitted to other firms.¹⁹ Indeed, recent empirical evidence points to strong links between bank liquidity positions and the ability of banks to meet capitalization requirements. For example, Pierret (2015) finds that banks experience liquidity problems when markets expect their insolvency in a crisis. Similarly, Schmieder, Hesse, Neudorfer, Pühr, and Schmitz (2012) provide simulation-based evidence for a nonlinear relationship between liquidity and solvency risks triggered by an adverse funding shock. Finally, Distinguin, Roulet, and Tarazi (2013) find that, on average, large U.S. and European banks decrease their regulatory capital ratios when faced with higher illiquidity, whereas small banks strengthen their solvency standards in this situation.

In addition to this empirical evidence, policymakers clearly believed during the 2008–2009 crisis that the risks posed by illiquidity at least rivaled the risks stemming from bank insolvency. This belief is supported by the scale of the official liquidity intervention during the crisis. The Federal Reserve reports that the peak value for the total of its emergency liquidity facilities in the U.S. during the crisis was \$1.5 trillion.²⁰ It is worth noting that this amount does not include several prominent liquidity programs such as the FDIC's Temporary Liquidity Guarantee Program, the Treasury's Temporary Guarantee Program for money market mutual funds, or deposit insurance, which can obviously be viewed as a form of liquidity provision. In comparison, official solvency interventions were comparatively small: the combined size of the Treasury's Troubled Asset Relief Program's components directed at recapitalizing the banking industry, the Capital Purchase Program and the Targeted Investment Program, was \$245 billion. Moreover, Kapinos and Mitnik (2015) highlight the fact that the book capitalization levels of banks that either failed or underwent assisted takeovers during the financial crisis were typically well above regulatory minimums in the last quarter before their failure. This raises the concern that current stress tests, which focus almost exclusively on book equity, may yield relatively benign outcomes by not explicitly considering liquidity risk. In part, this may reflect the fact that book and market equity values tend to diverge during times of stress, and that declining market capitalization drives liquidity stress. Thus, incorporating liquidity and systemic stress may require a more thorough treatment of market equity.

¹⁸ Of course, transmission might also occur through other channels, such as counterparty credit risk. Counterparty credit risk, though, is arguably captured to some extent in current stress-testing regimes. For example, in CCAR stress tests, BHCs with large trading or custodial positions must include a counterparty default in their adverse and severely adverse scenarios (FRB, 2014d).

¹⁹ Gorton and Metrick (2012) provide a specific example of this narrative for the securitized banking market in 2007 and 2008.

²⁰ For details of these programs, see http://www.federalreserve.gov/monetarypolicy/bst_recenttrends.htm.

The systemic links between solvency and liquidity risk have prompted some policymakers and analysts to call for a combined approach to the regulation of liquidity and capital adequacy at banks (for instance, Tarullo, 2013). However, as BCBS (2013a) points out, liquidity risk modeling remains underdeveloped, particularly compared to solvency tests driven by macro stress scenarios. In many stress-testing exercises a puzzling disconnect remains between the related concepts of liquidity and capital adequacy stress testing. The clearest examples of this disconnect are the two separate exercises run by the Federal Reserve for the U.S. BHCs: CCAR and its liquidity counterpart, CLAR. While much of the information regarding the former is public, the latter remains shrouded in mystery.

To be fair, some regulators have advanced models that attempt to address these issues, though the models have yet to be integrated into the primary stress-testing regimes.²¹ Several models have emphasized bank heterogeneity and systemic implications of stress. Aikman et al. (2009) and Alessandri, Gai, Kapadia, Mora, and Pühr (2009), for example, do so in the context of the Bank of England's Risk Assessment Model for Systemic Institutions (RAMSI). RAMSI is a top-down stress-testing model that features bank heterogeneity and systemic risk driven by shocks to funding liquidity. It follows earlier work on the Austrian Central Bank's model, discussed in Elsinger, Lehar, and Summer (2006) and OeNB (2006). Gauthier, He, and Souissi (2010) and Anand, Bedard-Page, and Traclet (2014) discuss the Bank of Canada's MacroFinancial Risk Assessment Framework (MFRAF). As a final example of this literature, Van den End (2010) provides a related example of a liquidity stress test where bank heterogeneity and systemic risk exacerbate the level of stress experienced by individual banks for the Dutch banking system. Finally, Basel III bank regulations include liquidity regulation, but, given the above considerations, we maintain that such requirements should be integrated with solvency regulation in a forward-looking and systemic manner.²² Thus, in spite of the empirical links and the developing theoretical basis discussed here, many regulatory exercises still treat liquidity and capital adequacy stress tests as separate. We contend that this is perhaps the most critical area for future work.

Given the complexity of the models and sensitivity of firm-level data required to integrate capital and liquidity stress testing, future assessments of systemic risk may need to be conducted only by regulators. At present, many stress-testing regimes include (or wholly comprise) stress tests conducted by banks and reviewed or benchmarked by regulators. However, capturing systemic feedback at a granular level and in a consistent manner across firms requires such excessive data volumes and extraordinarily complex modeling architecture as to make the exercise very challenging for individual institutions. Instead, regulators can build and run models using data obtained from the banks and make assessment regarding the levels of systemic risk. Indeed, this is the general direction taken in the above-cited papers on such testing.

²¹ For a comprehensive survey of issues related to liquidity stress testing, see BCBS (2013b).

²² Basel III includes the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR). The LCR rule requires that banks hold enough high quality liquid assets to fund 30 days of liquidity needs under a hypothetical liquidity stress scenario. Thus, while the LCR can be thought of as a liquidity stress test, it is not integrated with solvency stress tests. Structured more like traditional Basel capital requirements, the NSFR requires banks to maintain stable funding (defined as a function of the contractual maturity and estimated stability of liabilities) at least equal to the bank's funding needs. These needs are determined by applying weights (analogous to risk weights) to assets and off-balance-sheet exposures. See BCBS (2013c, 2014) for more on the LCR and NSFR.

A second technical issue concerns the fact that some of the key quantities that are essential for obtaining measures of bank capitalization are assumed, rather than modeled explicitly. Moreover, these assumptions can significantly affect the results, but their impact is not fully understood. Specifically, paths for the size of the balance sheet (mainly asset growth) are important for determining capital ratios but are difficult to credibly model as functions of macroeconomic scenarios. Such quantities often depend on bank-level management decisions, making consistent statistical modeling across firms, or even within a given firm, especially challenging. As a result, for regulatory stress tests, these quantities are often set by simple assumptions, such as zero asset growth.²³ U.S. stress tests typically allow assets to grow at a rate chosen by the banks, while EU-wide tests assume no asset growth. The Central Bank of Ireland's Financial Measures Programme and OFHEO's stress testing of the GSEs even assumed that loans were not replaced as they matured.

The extent to which these varying assumptions affect the results or their comparability is not fully understood. Hirtle et al. (2014) and Kapinos and Mitnik (2015) perform sensitivity analysis on asset growth assumptions in top-down models and find that different assumptions have sizeable effects on capital projections. Moreover, as noted in Section 2a, Frame et al. (2015) find that OFHEO's decision to assume no new business during the stress scenario caused a substantial understatement of losses, because the probability of default (PD) is especially high during the first few years of a mortgage's life cycle. This suggests that bottom-up stress tests (such as OFHEO's), where individual assets are modeled, may be especially sensitive to asset growth assumptions. However, reflecting the limited published literature on bottom-up stress testing, an issue we return to shortly, Frame et al. is the only study that assesses this sensitivity in such models. Complicating the issue further, Acharya, Engle, and Pierret (2014) suggest that stress-testing results may be sensitive to the use of total versus risk-weighted assets, which need not grow at the same rate.

Third, some seemingly innocuous modeling choices may affect capital projections under stress in unanticipated ways. For example, the standard that has emerged in the top-down modeling literature is to use income quantities as shares of assets and chargeoff quantities as shares of loans. Both sets of assumptions make sense: It would be econometrically flawed to use constantly growing dollar quantities in a regression framework; normalizing income by assets makes the quantities from banks of different size comparable; and chargeoff rates have been the standard metric for the quality of loans. However, they make the modeled ratios insensitive to asset and loan growth assumptions in the stress projection period. One cannot sensibly include the denominator of the ratio as an explanatory variable, so the loss *rate* will be insensitive to asset growth assumptions. This implicitly assumes that the portfolio loan characteristics remain constant in the face of any asset growth rate, which appears implausible. For example, for a bank to grow a portfolio more quickly, it may need to lower underwriting standards, which would be expected to raise loss rates.

Fourth, the focus of the academic stress-testing literature has been on the top-down models that, while useful as a first approximation, have severe limitations. Because they use data at low levels of granularity, the top-down models cannot capture bank portfolio drift or the appearance of new types

²³ Similarly stylized assumptions are often applied to dividend payouts and stock issuance and repurchases.

of assets. While the data necessary for use in top-down models are publicly available, the granular data for the bottom-up approach are not.²⁴ As a result, a substantial disconnect exists between published studies on stress testing that rely on portfolio-level public data and the actual practice of state-of-the-art bottom-up stress testing that employ granular non-public data. Regulators may need to develop a representative, de-identified and possibly synthetic, publicly available dataset at the highest level of granularity to spur research activity in this area and yield more informative stress-testing models.²⁵

Finally, some institutional issues may need to be addressed to make the stress-testing exercise comprehensive and policy-relevant. They primarily concern modeling other sectors related to banking, global, and national macroeconomic conditions, and the feedback mechanisms from the banking sector to these entities. An important sector related to the regulated banking industry is shadow banking. Early theoretical work suggests that increasing the regulatory scrutiny on the formal banking sector may increase the level of risk, including systemic risk, in the shadow banking industry (Kolm, 2015). Further work along these lines, including the feedback effects from the unregulated to the regulated financial sector, is urgently needed.²⁶

4 Critiques of Stress Testing

Abstracting from the technical concerns discussed above, forceful criticism argues against the fundamental appropriateness of stress testing. The argument is that stress testing, or at least the form of regulatory stress testing performed since the 2008–2009 crisis, should not be conducted.²⁷ We consider in this section the most salient of these critiques. While some reflect valid concerns and may warrant additional analysis going forward, we conclude that stress testing remains an appropriate and useful regulatory tool.

The first critique concerns the possibility that stress testing represents an implicit commitment by the regulatory authorities to backstop firms that have previously passed stress tests.²⁸ Market participants may interpret a “pass” as an official endorsement of the health of an institution. If the firm turns out to be unhealthy, participants may expect the regulator to take responsibility. This concern is

²⁴ Currently micro- and loan-level data are available from commercial sources (e.g., CoreLogic for mortgages) and data consortia among banks (e.g., SAS OpRisk VaR and ORX). However, these data are not particularly useful for stress-test modeling because they do not allow for analyzing a bank’s portfolio and, therefore, its risk profile.

²⁵ Development of such a dataset is likely to be technically difficult, as it will entail addressing issues such as the heterogeneity of credit ratings systems for loans as well as the more obvious confidentiality concerns. Providing more detailed portfolio level data may be an intermediate step that is more easily implementable, if less informative. The dataset may be based on the annual submissions for the stress-testing exercise and not entail additional regulatory burden on financial institutions.

²⁶ This can happen even in the absence of extending regulation to the shadow banking sector, as suggested by Fischer (2015), for example.

²⁷ Importantly, at least some large bank executives seem to disagree. Dimon (2015), in his annual letter to JPMorgan Chase shareholders, described CCAR as “good for our industry in that it clearly demonstrates the ability of each and every bank to be properly capitalized, even after an extremely difficult environment” and the stress test’s key assumptions as “appropriately conservative.”

²⁸ Practitioners frequently refer to this concern as creating a “safe harbor” for banks that enables them to thwart the intended purpose of stress-testing regulation.

most clearly present in stress testing during financial crises, when the test may be explicitly aimed at assessing the size of capital shortfalls in preparation for a government recapitalization scheme. Indeed, Schuermann (2014) suggests that one reason for the markets' positive response to SCAP may have been that markets interpreted the stress tests as an implicit assurance that regulators would in some way absorb losses in excess of the stress-test estimates. Flannery (2013) makes a similar point. This critique has also been extended to stress testing outside of financial crises. For example, Kupiec (2014) argues that stress testing (and post-crisis financial regulation more broadly) amounts to regulators operating financial institutions. He goes on to argue that since regulators are effectively operating the institutions, they may face difficulty in allowing equity-holders and creditors to take losses. This critique is accentuated by the potential for financial institutions to "game" the system, designing new products that have low historical sensitivity to macroeconomic variables yet that will suffer losses in a crisis. By designing such products to artificially lower their stress-tested losses, financial institutions may have gained another method to quietly extend their access to implicit government guarantees.

We believe stress testing need not increase the likelihood of future bank bailouts for several reasons. First, additional regulatory provisions, such as the DFA requirement for BHCs with more than \$50 billion in assets to have an updated "living will"—the company's strategy for a rapid and orderly resolution under the Bankruptcy Code—substantially mitigate these concerns.²⁹ In addition to serving as contingency plans, these living wills are useful tools for regulators to encourage firms to conduct operations in a manner that facilitates resolution through bankruptcy and reduces the systemic implications of their failure. Second, stress testing is most widely used in the regulation of firms thought to be systemically important. As such, many market participants already expect that the firms have some form of implicit government support. To the extent that these expectations are true, enhanced supervision, perhaps in the form of stress testing, is warranted to protect the government and society from costs arising from resulting market failures. Third, the worst-case scenario for a bank participating in a stress-test exercise is that it learns nothing new about its risks; the best-case scenario is that the regulator helps identify possible blind spots in the bank's risk management strategy. As we elaborate below, stress tests should be designed with that goal in mind.

A closely related concern is that stress testing exposes regulators to reputational risk. If markets perceive that regulators give a particular firm or financial system a passing grade, only for it to fail soon thereafter, the regulators' reputations may be compromised (Hirtle and Lehnert, 2014). Indeed, this seems to have occurred with the EU-wide stress tests of banks in both Ireland and Spain, and as Schuermann (2014) discusses, it was detrimental to the reputation of European banking authorities. We see this as an argument for effective and accountable stress testing rather than an indictment of the practice. Undoubtedly, the choice of scenario severity involves a difficult trade-off akin to the Type I vs. Type II errors in statistics. On one hand, regulators need to be mindful of the large costs (mostly borne by shareholders) associated with falsely determining that a financial institution may be insolvent under stress. Subjecting banks to implausibly severe stress is likely to reduce their operational efficiency and

²⁹ This requirement is mandated by §165(d) of the DFA and also applies to nonbank financial firms designated by the FSOC as systemically important. In addition, the FDIC requires insured depository institutions (rather than BHCs) with assets over \$50 billion to submit comparable resolution plans.

make them, as Smith (2014) puts it, “too-cautious-to-fail.” On the other hand, regulators need to balance those costs with the potential costs to taxpayers (or insurance funds), as well as their own reputation, from failure of an institution that has passed a stress test. Treading this fine line, however, is inherent to the nature of banking regulation in general and not to stress testing in particular.

A third critique is that the requirement to conduct stress testing represents an unreasonable burden on financial institutions, especially smaller and less complex institutions (see Deseret News, 2013, or McLannahan, 2015, for examples). Fundamentally, this critique relies on a (perhaps unstated) value judgment that the benefits of stress testing in terms of financial stability are not worth the costs to banks or regulators. We argue that this value judgment should be formally stated. In that spirit, we contend that the net benefit of stress testing is almost surely positive for the largest financial institutions and declines for successively smaller and less sophisticated banks. At some threshold, the costs outweigh the benefits. The largest institutions pose the greatest systemic risk, require advanced risk management practices consistent with their high degree of complexity, and have the resources to undertake stress tests. In contrast, midsize and smaller institutions are less complex. Because they have limited capabilities to conduct stress tests, many midsize and smaller banks rely on external consultants to conduct tests, both reducing their value in encouraging improved risk management and exposing them to consultant-driven, correlated model risk. Moreover, midsize regional banks and other smaller banks are likely less sensitive to national macroeconomic and financial conditions described in regulatory scenarios, as their stability depends more on local conditions or the health of individual counterparties.

Current supervisory requirements and expectations for the various stress-test regimes are consistent with our assessment of the net benefits: they are graduated to reduce the burden on small institutions, and the smallest are not required to conduct tests. From this perspective, the present critique is really a debate about precisely where the graduations or thresholds should fall, rather than about the practice of stress testing per se.³⁰ Debate on this topic is ongoing among the senior leadership of U.S. regulatory agencies responsible for stress testing. For example, Tarullo (2014b) argues that a higher asset threshold should be used to designate those banks required to participate in CCAR. Further research to assess whether the United States’ current “dual system” of stress testing by bank size can be improved upon seems warranted.

More broadly, this critique highlights the value of additional analysis characterizing the costs and benefits of stress testing. Such research is scarce but would provide rigor to the discussion on the appropriate breadth and depth of stress testing (Cumming, 2015). Available estimates of the cost of the DFA regulation suggest that bank costs related to stress testing are small.³¹ It is necessary to recognize that stress testing does require the resources of banks and that those resources must be leveraged to

³⁰ Recall that Figure 1 provides a visual description of the marginal asset coverage by DFAST over CCAR.

³¹ S&PRS (2012) estimates that compliance with all of the DFA provisions would reduce the pretax earnings of Bank of America, Citigroup, Goldman Sachs, JPMorgan Chase, Morgan Stanley, PNC Financial Services, US Bancorp, and Wells Fargo by \$22 to \$34 billion annually. Stress testing would fall under the higher regulatory compliance expenses whose upper estimate is \$2.5 billion, or about 30 basis points of the earnings estimate. Thus, this report suggests that the cost of stress testing for financial firms is likely to be small.

maximum effect as a risk management tool, rather than for a mere compliance exercise. However, many of the benefits of stress testing, such as improved data collection and risk management, are hard to quantify. Moreover, these benefits are quite relevant even to smaller financial institutions. Insofar as stress testing reduces asymmetric information and mitigates systemic risk, smaller banks receive an additional layer of insulation from adverse industry-wide shocks. Future work to quantify these benefits is highly advisable.

Further, Kupiec (2014) argues that stress testing represents dangerous overreach into bank management, forcing institutions to submit to an opaque process whose outcome-generating model is not known to the banking industry. Making the stress-testing models transparent, however, is likely to generate the same problems experienced by OFHEO, which conducted stress tests under maximum transparency. Further, such transparency is likely to maximize so-called “model risk,” where both the regulators and the entire industry are driven by the results of just one particular model, preventing the identification of blind spots using techniques such as reverse stress testing. Maintaining a certain degree of process opacity, therefore, appears to be appropriate. Moreover, regulators should remain vigilant that the industry not settle for a few consultant-driven stress-testing models known to be given a pass by regulators, thus institutionalizing model risk.

Another frequently made critique argues that historical data will not be informative in predicting the next crisis. This shortcoming of historical data may arise from the fact that new products will be developed with little history; loan underwriting standards may change; or historical data may be contaminated with events that may not repeat, such as a government capital and liquidity support; among other things. In addition, as Bookstaber et al. (2014) and Jacobides, Drexler, and Rico (2014) point out, stressful events are infrequent, compounded by the fact that institutions and their interconnections, positions, and leverage change over time. As a result of these limitations, stress testing might provide a false sense of security without actually addressing risks. This is a legitimate concern, and addressing it calls for granular, loan-level modeling to reduce the model risks posed by new products or business practices. It also calls for a stress-testing program that evolves over time and avoids converging to a model monoculture.

A related, fundamental concern involves the implementation of stress testing as a tool to attenuate disaster myopia. We have argued that stress testing is useful in this regard because it provides a rigorous structure within which market participants can consider unlikely adverse events. For this to be true, regulators must avoid becoming complacent and myopic, which will require an ongoing commitment to rigorous modeling and strenuous scenario selection. The OFHEO experience suggests that maintaining up-to-date models and providing sufficiently stressful scenarios are critical to the success of stress testing. These activities should not simply “fight the last war” but should instead proactively study emerging risks. So far, regulators performance in this regard is mixed.³² While modeling techniques are advancing, the importance of scenario design is not widely emphasized. For example, the most stressful scenarios in U.S. stress tests have borne substantial resemblance to the

³² Hirtle and Lehnert (2014) and Schuermann (2014) suggest that if sufficiently detailed data on the banks are released, market participants can effectively conduct their own stress tests using their own scenarios.

2008–2009 crisis. We hope that the scenarios tested will become more diverse and exploratory as the crisis fades into history. Also noted above, the EU-wide stress tests have stopped short of including an actual sovereign default in their stress scenarios. This has harmed the usefulness of the tests and likely points to significant political limitations within the EU banking regulatory system. Going forward, regulators must continue to design stressful scenarios, perhaps relying on reverse stress-testing techniques to uncover the emerging sources of risk. Continued effort is also required to ensure that both models and scenarios retain some heterogeneity and do not progress to a state of monoculture.

A final, fundamental concern is that financial shocks, rather than macroeconomic shocks, may represent the greater risk to financial stability. In short, the concern is that stress testing is looking in the wrong place. For the most part, current stress tests are driven primarily by a macroeconomic scenario, which is then translated into financial distress. An alternative narrative for financial stress might be that it originates as a shock to the financial system, which then causes macroeconomic stress. Whether macroeconomic or financial shocks drive financial cycles is the subject of a large literature beyond the scope of this paper.³³ This preliminary discussion, however, suggests that a more comprehensive modeling approach is strongly warranted.

5 Concluding Remarks and Recommendations for the Future of Stress Testing

This paper has provided an overview of the theory and practice of stress testing banks. On balance, we argue that stress-testing exercises are a useful addition to the toolkit of bank risk managers and their regulators. From a supervisory perspective, stress testing serves as a forward-looking complement to Basel regulations that can more effectively capture systemic risk while encouraging more holistic risk management. From a more fundamental perspective, stress testing may be viewed as a means of reducing disaster myopia in the sense of Guttentag and Herring (1986) and preventing financial fragility that results in a so-called Minsky moment of financial collapse and a subsequent severe macroeconomic slump.

Regulatory implementation of stress testing in the wake of the most recent crisis has arguably already delivered substantial benefits to the banking industry and the public. Wider availability of banking data and their more rigorous scrutiny have curbed bank opaqueness, improved governance, and led to better risk management practices than those that were in place before the 2008–2009 crisis. Equipped with more detailed data and improved risk modeling techniques, many bank executives are now forced to think through forward-looking risk management issues; an analytical framework addressing them was largely absent prior to the crisis.

While substantial progress has been made, some important issues remain unresolved. First, public availability of some form of granular data needs to be expanded to give researchers the opportunity to develop more precise stress-testing models. Also, given the strong empirical link

³³ This question is closely related to a large literature that includes Bernanke, Gertler, and Gilchrist (1999), Gertler and Kiyotaki (2010), and Jermann and Quadrini (2012).

between liquidity stress and capital adequacy, we recommend that these two types of stress-testing exercises be merged. In addition, modeling the interaction of banks with other banks and financial institutions, including the shadow banking sector, and, ultimately, the broader macroeconomy is likely to yield important insights into additional sources of liquidity and capital adequacy stress. Further, the reverse stress-testing paradigm needs to encompass banking, financial, macroeconomic, and international sources of extreme yet plausible shocks to identify the potential blind spots in bank risk management. Finally, research on the benefits and costs of stress testing may help to better tailor this regulatory tool. While this program is undoubtedly quite challenging, it promises to reap substantial rewards.

Table 1: Summary of Stress-Testing Exercises

Program	Description	Year	Results	Scenario Variables
SCAP	Stress test of 19 U.S. BHCs with greater than \$100 billion in assets. Covered credit risk in banking book and market risk in trading book.	2009	10 BHCs capital deficient, with a total shortfall of \$75 billion. Only one bank used Treasury recapitalization program.	GDP, unemployment, HPI
CCAR	Quantitative stress test and qualitative analysis of capital planning process. Tests in 2011–2013 included only SCAP BHCs; those in 2014–2015 included all U.S. BHCs with assets over \$50 billion plus FSOC designees. Covered credit risk in banking book and market risk in trading book.	2011	Most BHCs forced to lower dividend payouts. Firm-specific results not released.	GDP, unemployment, HPI, CPI, yields, equity prices, income
		2012	Four banks breach capital limit	Same plus CRE prices, VIX, int'l
		2013	Two BHCs failed	Same
		2014	Five BHCs failed	Same
		2015	Two BHCs failed	Same
DFAST ¹	Quantitative stress test and qualitative analysis of capital planning process at all federally regulated U.S. financial companies with assets over \$10 billion.	2013	One BHC drops below 5% tier 1 common ratio	Same
		2014	One BHC drops below 5% tier 1 common ratio	Same
		2015	No BHCs breach 5% threshold	Same
NCUA	Similar to CCAR, but applied to federally insured credit unions.	2014	Results not published	Similar
EU-wide	Test of credit risk in banking book and market risk in trading book. 2009 covered 22 cross-border banks with 60% of EU banking assets. 2010-2011 covered 90 or 91 largest banks to capture at least 50% of banking assets by country. 2014 covered 130 banks.	2009	No bank's Tier 1 ratio falls below 6%	At least EU-wide GDP, unemployment, and RE prices
		2010	Seven banks failed	Country-level GDP, CPI, unemployment, yields, RE prices, int'l
		2011	Eight banks failed	Same
		2014	25 banks failed	Same
UK	Similar to 2014 EU-wide stress test but tailored to UK-specific risks and covered eight banks.	2014	Three banks failed	Same

Sources: Federal Reserve Board (2009a, 2011, 2012, 2013a,b,c, 2014a,b,c, 2015a,b), NCUA (2014, 2015), Committee of European Banking Supervisors (2009, 2010), European Banking Authority (2011a,b), European Central Bank (2011, 2014), European Systemic Risk Board (2014), and Bank of England (2014a,b). ¹As noted in Section 2a, the full institutional coverage and disclosure of DFAST results is fragmented and new. Consequently, the test results presented here reflect only the Federal Reserve's disclosure of the results from its DFAST projections for the same set of institutions subject to CCAR. Wider results for all banks are not centrally available.

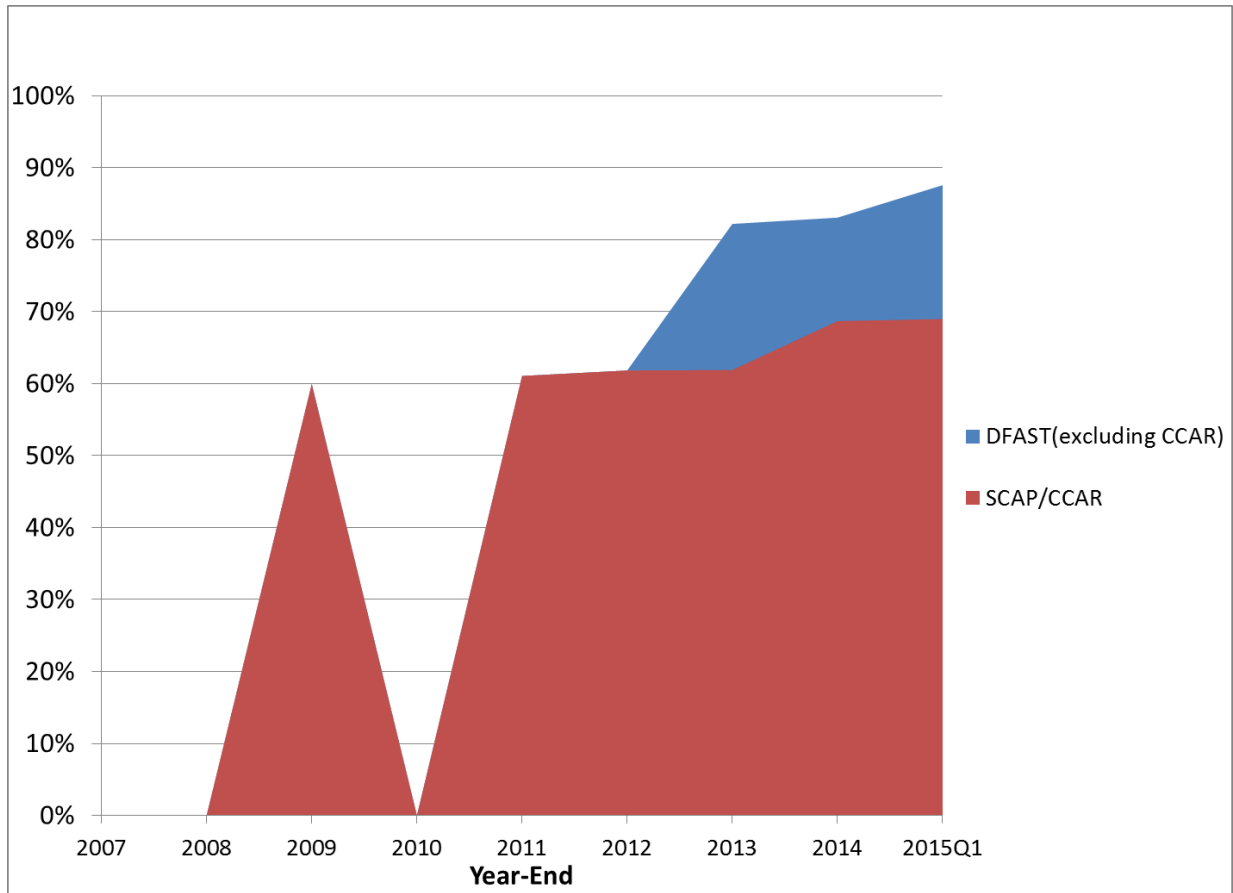


Figure 1: Share of total U.S. banking assets belonging to banks subject to stress-testing exercises.

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