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Transparency and Model Evolution in Stress Testing

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All models are wrong … but some are useful.
(George Box, Professor of Statistics)

1. Introduction

Based on the positive perceived effects of the *ad hoc* Supervisory Capital Assessment Program (SCAP) in 2009, the 2010 Dodd-Frank Act (DFA) mandated that large banks[1] and their regulators undertake periodic stress tests to determine whether the bank holding companies (BHCs) could continue providing new credit even during a very poor economic cycle.[2] The Dodd-Frank Act Stress Test (DFAST) projects quarterly values for each bank's revenues, loan losses, operational losses, securities valuation losses, and (for the largest institutions[3]) trading account and counterparty losses. The focus is a set of projected capital ratios, which reflect both estimated losses and a standardized set of assumptions about the BHCs' capital distributions.[4]

Some of the DFAST results feed into a new, formal approach to assessing the capital planning processes of large institutions, the Comprehensive Capital Analysis and Review (CCAR) that began in 2011. CCAR combines the estimated DFAST losses with each bank's own capital

[1] Throughout this paper I will use the words "bank" and bank holding company" interchangeably.

[2] The 2018 Economic Growth, Regulatory Relief and Consumer Protection Act (EGRRCPA) dialed back some of the DFA requirements, raising the minimum asset size for required stress tests, cancelling the "Adverse" stress scenario, and subjecting large, but not complex, BHCs to stress tests only in alternate years.

[3] Footnote 7 of Board of Governors (2019a) explains:

> The global market shock component applies to a firm that is subject to the supervisory stress test and that has aggregate trading assets and liabilities of $50 billion or more, or aggregate trading assets and liabilities equal to 10 percent or more of total consolidated assets, and is not a large and noncomplex firm under the Board's capital plan rule (12 CFR 225.8).

[4] Specifically, the DFAST assumes that each bank's common stock dividends are paid at the same level as in the prior year and that there are no share repurchases or (with a very few exceptions) issuances. (Board of Governors, 2018c, Box 2, page 10).

distribution plans: dividend payments and net share repurchases. The predicted CCAR capital ratios thus differ from those in DFAST, and the CCAR requires that each bank's lowest predicted capital ratios exceed specified minima. A bank whose capital plans yield inadequate predicted capital at any point in the 9-quarter DFAST simulation must reduce its planned dividends or net share repurchases. There appears to be no penalty for revising the capital plan in this manner.[5]

Stress test results have become the dominant influence on capital standards for large U.S. BHCs. These tests estimate, for each bank, a cost-adjusted revenue concept called pre-provision net revenue (PPNR), credit losses from eight types of loans and AFS securities holdings for all the tested BHCs. The stress test also estimates trading losses due to an instantaneous set of market shocks to the trading accounts of selected large institutions. To the extent that total losses exceed PPNR, a bank's projected capital account declines, in which case the bank may need to hold more capital at the start of the test. The test's minimum required capital ratios combine a forward-looking assessment of downside risk exposures with Basel's static (or backward-looking) risk weights (Greenwood *et al.*, 2017, p. 490). This shift in perspective is a clear conceptual improvement in capital supervision. Banks must hold sufficient capital today to cover anticipated (stress test) net losses while retaining enough earnings to remain above the specified minimum values for several capital ratios. Effective risk weights reflect the Fed's dynamic expectations about each BHC's PPNR and losses under the severely adverse scenario (Greenwood *et al.* (2017)).

[5] This option is colloquially described as taking a "second bit of the apple." That second bite does not seem very costly. For example, the Fed reports that "There is no restriction imposed by the Board if a firm adjusts its capital plan." (Board of Governors (2018c), p. 11). Moreover, under some circumstances, firms "may re-submit their capital plans before the next stress test cycle and request additional distributions." (*ibid*.)

Because stress tests have become such a prominent component of capital regulation, the regulated firms have sought detailed information about the CCAR modelling process. The ClearingHouse takes an extreme position on transparency in responding to the Fed's December 2017 proposal to increase stress test transparency: "the Federal Reserve should disclose all material aspects of its models, including underlying formulas and equations, and should do so for all models it uses in its stress testing and capital planning framework." (ClearingHouse (2018), page 2). Greater foreknowledge of stress scenarios and models would provide regulated BHCs with "a more certain and precise stress testing and capital planning framework [that] … would promote lending, investment, vibrant capital markets and the efficient allocation of capital." (ClearingHouse (2018), page 3). I take this to mean that BHCs could hold a smaller capital buffer if they did not need to compensate for uncertainty about their assigned minimum capital level. Greater lending and investment would derive from levering the resulting "released" capital. Although greater transparency about DFAST models undoubtedly produces private benefits to CCAR banks, the social value of reducing bank capital depends on the extent to which non-CCAR lending institutions substitute for CCAR bank lending.[6]

In response to requests for enhanced transparency, the Fed has provided general information about its scenario design process and stress test models. (See, for example, equation (1) below.) However, the Fed has strongly resisted publicizing equation specifications or parameter values that would help BHCs anticipate stressed loss estimates. In March 2019, the Fed provided a new type of information about DFAST models, in the form of projected credit card and commercial loan default losses for portfolios with specified loan

[6] For example, Cortés *et al.* (2018) find stress tested banks either raised small business loan rates or (if they had no local offices) cut back loans. They also conclude that smaller banks fill the loan gap created by stress-tested banks' withdrawal, leaving the total amount of bank credit to small business unchanged.

characteristics (Board of Governors (2019c, pp. 63ff.)). While still not revealing equation specifications or parameter values, this information should improve BHC estimates of DFAST loss projections on these loan types. The trend toward enhanced transparency has, however, proceeded without much attention to the costs and benefits of that transparency. Even if the regulated banks are helped by greater transparency, we must also consider potential effects on the Fed's ability to revise tests. Stress test models must evolve as financial sector institutions and potential risks change over time. Sharing too much model information might bring test revisions under the Administrative Procedures Act (APA), as suggested by the Committee on Capital Market Reform (2016). The delays associated with the proposal-and-comments cycle will impede efforts to revise the tests to reflect evolving conditions in the financial sector. (See OFHEO discussion below.) This must be counted as a large social cost.[7]

This paper evaluates how stress test transparency will affect its value as a supervisory tool. Section 2 discusses the costs and benefits of publicizing detailed information about the test procedures: the model details, BHC-specific test results, or the stress scenarios. Surely, transparency has some social value: regulators must be accountable to the public and Congress, and we should be cognizant of BHCs' compliance costs. At the same time, releasing too much model detail seems likely to degrade the supervisor's ability to assess capital adequacy, and might have deleterious effects on the banking system's overall risk exposure. In Section 3, I suggest some methods for making the stress tests more flexible and innovative. Some additional threats cannot be incorporated into DFAST tests through scenario specifications but require modifying the computation of PPNR and revising the equation parameters that predict losses. Finally, the

[7] The Fed has already agreed (in 2018) to reduce required capital uncertainties, by phasing in across two sequential test years any model change with material effects on required capital.

test's macroprudential dimension can be expanded by making greater use of the trading account information provided by the largest trading and custodial banks. Section 4 offers two suggestions for improving the DFAST model's overall performance, and the final section concludes.

2. Stress test transparency

The Fed has created principle-based models to estimate the individual BHCs' net credit and trading losses under stress. Over time, regulators have also provided increasing amounts of qualitative information about the models underlying DFAST. (For example, see Board of Governors (2019c, pp. 19-63).) Recently, the Fed distributed quantitative information about sample portfolios of commercial and credit card loans, along with DFAST loss estimates on those portfolios. The affected banks have continued to press for more details about the stress testing process, most often claiming that expanded DFAST knowledge would permit better capital planning.

Before the stress tests became such an important component in defining adequate capital, a large BHC's required capital was determined by its risk-weighted assets in place, computed according to the "standard" approach or using the bank's own (Fed-approved) risk models. CCAR changed the game. Tying a BHC's capital requirement to the Fed's (unknown) loss models creates additional uncertainty for the BHC planning processes, presumably forcing the banks to hold more capital against the possibility that their actual requirements exceed what they were expecting. That "excess" capital could be used to support additional, profitable business. Note, however, that large banks have frequently held capital above their minimum required levels, presumably to protect against falling below those required minima. In the late 1990s, for example, the 100 largest BHCs' mean capital ratios exceeded their minimum required ratios by 75%. (Flannery and Rangan

(2008), page 391). The CCAR process for determining adequate capital also changed the urgency of a perceived capital shortfall. Previously, banks and their regulators undertook lengthy discussions about adequate capital, in part because regulatory capital was measured using slow-moving, GAAP accounting standards. Going forward, any capital deficit must be rectified promptly, during the week between DFAST and CCAR.

By design, CCAR accompanied a marked increase in required capital. Minimum capital ratios and funding costs have risen more for the largest (CCAR) banks. Although regulated banks probably hope to address the level of their capital requirements through a discussion of DFAST model characteristics, the value of transparency is more commonly connected expressed in terms of the banks' uncertainty about capital requirements.

The 2019 schedule of stress test events suggests how the Fed might enhance transparency about the CCAR process:

Stress Scenarios Announced: February 13, 2019 Board of Governors (2019a)[8]

BHC Data Submission: February 21, 2019 FR Y-14Q containing loan-level information for the prior December 31. (More generally, FR Y-14Q data are due 52 calendar days after the end of the December quarter.)

As-of date: The as-of date for global (market) shocks varies, to avoid BHC gaming. For 2019, the relevant date (November 5, 2018) was announced with the Summary Instructions in March 2019 (Board of Governors (2019b)).

BHC capital plans and their predicted quarterly results under the stress scenario: April 5, 2019.

DFAST results announced: June 21, 2019: Report results for each individual BHC.

Banks may submit (downwardly) revised capital plans – the "second bite at the apple".

CCAR results announced: June 27, 2019: Report results for each individual BHC.

[8] This document was initially released on February 5. The February 13 release corrected some data errors in the initial version.

This schedule permits three types of additional transparency: about the models, the results or the stress scenarios.

a) **Model transparency**

It is certainly true that DFAST credit loss estimates might differ from those implied by a BHC's own, bespoke models. Grundke *et al.* (2019) and Kupiec (2019) both show that plausible variations in model specification or data assumptions can substantially affect a model's estimated loan losses. Grundke *et al.* (2019, page 25) note further that model differences become more substantial under stress conditions. Given this potential, the BHCs would like to know in advance the Fed model's loss estimates for their December 31 portfolio. "Transparency" sounds like an obvious feature of good government, but what does it mean? In the context of stress tests, I think "transparency" means providing the tested BHC with information permitting them to predict their required capital ratio, which requires specific information about the DFAST models used to generate that requirement. Banks facing greater uncertainty about their total capital requirement must hold a larger capital cushion as protection against being under-capitalized according to CCAR.[9] But how much planning cost can be saved with more information about the Fed's models? In other words, how great is this uncertainty, really?

The BHCs are constrained by the overall projected capital minimum, not the effective risk weight attached to any single type of loan. Because the projected capital requirement reflects multiple model outputs, there should be some regression toward the mean in the total projected losses. Deloitte (2018) reports that no BHC failed the quantitative portion of CCAR between 2014 and 2018. This could reflect high excess capital holdings in compensation for the Fed model risk,

[9] The BHCs perceive private losses associated with holding "excess" capital. The corresponding social cost depends on externalities associated with bank failures and the extent to which other lenders can substitute effectively for the stress-tested institutions.

or it could reflect the BHCs' ability to predict DFAST results pretty accurately. Gallardo *et al.* (2016) provide evidence consistent with the latter. They find that stress test results became more predictable over the first six CCAR years (2011 – 2016), permitting the banks to manage their capital more tightly. Recent DFAST test results also suggest that the BHC are pretty good at predicting required capital: in 2018, only six of the 35 tested BHC reduced their planned capital distributions following the DFAST (Board of Governors, 2018b, Tables 6A and 6B). All six could satisfy their minimum capital requirements by adjusting their capital distribution plans.[10] Following the 2019 DFAST results, only two (out of 18) tested holding companies revised their capital plans.

In short, I see no strong evidence that stress test uncertainties impose unmanageably large capital surprises on many of the tested BHCs, although this possibility deserves more extensive analysis.[11] Even if the benefits were large, however, further model transparency would have at least two kinds of offsetting negative effects. First, giving BHC access to DFAST model specifics would likely degrade the value of those tests in identifying risky BHC. Second, BHC will rationally rely more on the Fed's credit loss estimates the more precisely they can predict those estimates, and too much reliance on any one set of loss estimates will induce common risk exposures across many institutions in the financial sector.

The shortcomings of a publicly-known stress test are well illustrated by the capital adequacy tests applied to the two mortgage GSEs between 2002 and 2008. Publicity about these

[10] The Fed announced that these six banks had fallen short of 12 required capital minima, although the shortfalls were not very large. Specifically, the three largest BHCs violated only the leverage ratio, two missed the required CET1 ratio by 0.1% of RWA and the sixth fell short of the required CET1 by 0.5% of its RWA. In 2019, two out of 18 tested BHC revised their capital plans to cure a deficit of 0.6% and 0.1% respectively of RWA (Board of Governors (2019e, page 12).

[11] Kohn and Liang (2019) reach a similar conclusion after examining CCAR results.

tests resulted in inflexible econometric models that gave misleading results about the GSEs' true risk exposures. The Federal Housing Enterprise Safety and Soundness Act of 1992 required a specific, quarterly stress test to assure the two publicly-traded mortgage GSEs held sufficient capital. Crucially, the law required the GSEs' regulator (the "Office of Federal Housing Enterprise Oversight", or OFHEO) "to fully disclose the stress test model; and went so far as to publish all stress scenarios, empirical specifications, and parameter estimates in the *Federal Register*." (Frame *et al.* (2015), p. 3). The stress scenario assumed mortgage default losses equivalent to those experienced during 1983-4 in the contiguous states of Arkansas, Louisiana, Mississippi, and Oklahoma. In addition, the constant maturity 10-year Treasury rate would rise or fall (by up to 600 basis point) and remain at the new level for ten years. (See Frame *et al.* (2015).)

The OFHEO stress tests were first administered in 2002. The default and prepayment models were estimated using data on mortgages originated between 1979 and 1997 and remained unchanged through the GSEs' entry to conservatorship in 2008. Frame *et al.* (2015) show that regularly updating the mortgage models would have identified serious GSE solvency problems nearly two years before the government takeover.[12] They blame OFHEO's failure to update its models on the administrative cost of implementing such changes via the public notice and comment process (page 25).[13] The formulaic interest rate stress also proved to be problematic: Jaffee (2003) contends that elective hedging transactions permitted the GSEs to pass the congressionally-mandated test even while taking on other types of interest rate risk. In short, the

[12] In another paper, Gerardi *et al.* (2008) similarly find that pre-crisis mortgage default models would have predicted the crisis experience well if confronted with the actual path of house prices.

[13] Hirtle (2018a, p. 6) makes the same point: "The more stress test models are 'hard coded' in regulation, the more difficult it is to change them as modeling practices improve or as new risks emerge."

OFHEO's fully transparent stress test provided a very poor window into the enterprises' true risk exposures.

Maintaining DFAST model confidentiality will also limit the extent to which banks reduce their overall diversification, because rational BHCs will incorporate known Fed loss estimates into their loan portfolio choices. Think of an unknown loan loss rate being predicted (with error) by two independent models, one from DFAST and the other from a BHC. An optimal forecast combines the two independent forecasts, in inverse proportion to the forecasts' standard errors. Moreover, profit-maximization will lead the BHCs to expand loans for which they believe the Fed has under-estimated required capital weights. Selecting the banking system's risk exposures according to a single model would be the height of folly. ("All models are wrong …"). If the tested banks assemble portfolios reflecting the Fed's sense of credit risks, the entire banking system's portfolio could become less diversified, increasing systemic risk (Schuermann (2013), Gallardo *et al.* (2016)). Leaving the banks unsure about DFAST estimates will reduce their reliance on the DFAST model in making their own portfolio choices, diversifying the system's risk exposure.[14]

Although it is hard to estimate how large this effect might be, history provides examples. The extremely low risk weight assigned to "AAA-rated" MBS tranches before 2008 almost surely affected the banks' and investment banks' holdings of such instruments. These concentrations left the entire banking system exposed to losses when asset quality doubts arose. As another example, recall that the static (Basel) risk weight was initially zero for lines of credit maturing or cancelable

[14] In addition, the BHCs will be forced to keep their in-house models current, which was an early goal of the CCAR process.

in less than one year. In response, the industry granted many lines with a 364-day maturity until Basel III changed their credit conversion factor.

The effect of the stress tests on bank portfolio choices has been researched by several authors, all working with a relatively short time series of DFAST observations. Barrett and Berrospide (2018) test whether a "capital gap" – the difference between the DFAST capital estimates and those generated by the banks' own models -- predicts several categories of loan growth. Using data from the 2013 – 2016 DFASTs, they conclude "that the capital gap is not constraining bank loan growth or causing banks to tighten their lending standards." (page 24). Flannery *et al.* (2017) conducted a similar test on data from 2013-2015 and found no evidence that growth in loan categories were correlated with capital gaps.

Covas (2018) argues that the DFAST implicit risk weight on small business loans is too high and stress-tested banks have therefore reduced their portfolio holdings of such loans. He concludes that "by curtailing credit to this key sector of the U.S. economy, stress tests *may be* having an adverse impact on economic growth." (page 31, emphasis added). Other authors have also studied the effect of stressed capital ratios on business loans. Acharya *et al.* (2018) find that balance sheet measures of total loans, commercial real estate loans, and credit card loans fell for stress-tested banks, as did small business loan originations.[15] Business activity subsequently fell in the affected counties. While these conclusions are consistent with increased capital requirements raising large banks' funding costs, Acharya *et al.* (2018) provide no information about whether the Fed's loss estimates affected loan composition.[16] The most complete

[15] They also find that the terms (rate, amount, maturity) on relatively large commercial loans (identified through DealScan) worsened for the borrowers from stress-tested banks.

[16] Chen *et al.* (2017) show that the largest four U.S. BHC cut back sharply on their loans to small businesses (as measured by CRA data) between the crisis and 2014. They offer no simple explanation for this cutback, although they do recognize the stress tests as one possible cause.

investigation of small business lending is Cortés *et al.* (2018), who document that stress-tested banks cut back their loans to small businesses, particularly in counties where they had no physical branches. However, they also show that an elastic loan supply from alternative creditors negated any real effects of the large banks' cutbacks:

> small(er) banks increase their loan originations and claim larger market share in geographies formerly reliant on stress-tested lenders. Overall, our evidence does not support the notion that stress tests contributed to a slower recovery of small business lending. (pp. 1-2)

This important result illustrates how alternative lenders can negate any costs that might otherwise be associated with stress-tested banks' loan cutbacks. Because funding costs have risen more for DFAST BHC, smaller bank and nonbank competitors have a new opportunity to underprice the large banks on some risk exposures. Continued monitoring of these portfolio changes seems important.

The OFHEO example and the potential for systemic credit risk concentrations lead me to conclude that disseminating specific model equations or parameters would substantially reduce the regulatory value of stress tests and impede their dynamism. The March 2019 dissemination of the projected losses on sample credit card and commercial loan portfolios is a step toward dissemination of specific model features. While there is no obvious line between appropriate and inappropriate information to disclose, this release seems like the beginning of a slippery slope.

The EGRRCPA's elimination of the severe scenario from future stress tests does suggest one way that the Fed can at least preserve the BHCs' existing access to model information. Before 2019, a BHC could compare the changes in its own loss estimates between the Adverse and the Severely Adverse scenarios against the change in DFAST estimates. Without providing too much detail, these comparisons gave some insight into the models' workings. To replace this lost information source, the Fed could choose to report bank-specific information about the model's

"Baseline" predictions for PPNR, operational losses, loan losses, and/or trading and counterparty values. With this new information, the banks could continue to infer the impact of the overall stress scenario on DFAST results, without learning specific parameter values.[17] I have no strong opinion about the advisability of this innovation to the DFAST process.

b) Results transparency

It is extremely important to maintain the stress tests' current level of reporting detail, which provides estimated values for PPNR, default and mark-to-market losses, and the effect of global portfolio shocks on each tested bank. These reports constitute an unprecedented sharing of supervisory information, which was introduced when the SCAP first reported results for each of the tested BHCs.[18] In addition, the banks must announce their own estimated losses under the severely adverse scenario. In this section, I first report that stress test results through 2018 continued to provide new, value-relevant information to the market, and then discuss how the existing announcement details limit a tendency for supervisory forbearance.

The earliest evaluations of stress test information had mixed implications for the hypothesis that it was relevant to market investors (for example, Morgan *et al.* (2014) on SCAP, Petrella and Resti 2013, Candelon and Sy 2015, Bird *et al.* 2015, Fernandes *et al*. 2015). Following the 2015 CCAR announcements, Glasserman and Tangirala (2016) showed that the cross-section of estimated loan losses from the 2014 and 2015 DFAST could be predicted from the prior years' values. They concluded that the stress tests had stopped providing new, valuable information to

[17] One might try to infer specific parameter values by regressing the loan loss differences between two scenarios on the changes in real or financial variables that are assumed to affect a particular loan type's loss. Without knowing the equations' functional forms, the implied coefficients would only approximate the true model's partial effects.

[18] The SCAP revelations were reportedly preceded by vigorous debate and disagreement among the experts involved in the analysis.

the market, and recommended that the tests should stress new areas of potential concern about financial stability. Flannery *et al.* (2017) evaluated the market effects of SCAP, DFAST and CCAR announcements through 2015. They began by arguing that the usual sort of event study methodology was inappropriate for identifying abnormal market responses to anticipated events. Instead, the authors emphasize tests based on absolute values of the announcement day share returns and the volume of shares traded for individual BHCs.[19]

Table 1 reports test results for SCAP and subsequent stress test announcement dates, extended by Anna Kovner for three years beyond the results in the original paper's Table 2A. (The extended results are shaded in Table 1.) Column (1) reports the usual sort of 3-day cumulative abnormal returns (CAR), which the authors considered inappropriate for an anticipated announcement. The |CAR| tests in column (2) indicate that the announced DFAST or CCAR test results significantly affected return patterns for the SCAP and for every subsequent stress test through 2018. The measure of abnormal trading volume (CAV) shows less uniform statistical significance on test announcement days, with the CCAR dates are more likely than the DFAST dates to carry significant test statistics. Together, columns (2) and (3) of Table 1 indicate that the stress tests have continued to provide value-relevant information.

What information drives these abnormal effects? Are shareholders reacting to new information about the banks' conditions? Or to new information about how the regulator intends to treat the tested BHC? Flannery *et al.* (2017, Table 2B) evaluate the return pattern of un-tested, large BHCs on the DFAST and CCAR announcement days. These banks' equity reacted significantly to all DFAST announcements and many of the CCAR announcements through 2018,

[19] Unlike Glasserman and Tangirala (2016), Flannery *et al.* (2017) evaluate the impact of both loan losses and trading account losses.

consistent with the hypothesis that stress test results convey information about the state of the overall banking industry.

The greatest single benefit of disclosing detailed information about stress test results may be the pressure it brings for supervisors to address problem situations more promptly. The Basel rules' Pillar 1 specify complex, formulaic minimum capital requirements based on each bank's portfolio. Over time, though, banks' accounting capital ratios rise and fall, and the equity's true loss-absorbing capacity – its market value – changes with its share price. The job of maintaining adequate capital ratios is left to national supervisors by Pillar 2. Historically, some supervisors have done a poor job of maintaining sufficient capital to limit large banks' survival probabilities to the calibrated 99.9% annual rate (Flannery (2014), p. 159). In the U.S. (Europe), the largest banks' equity has often been insufficient to absorb large losses during the 1986-2011 (1997-2011) period. The market value of some banks' equity often implied default probabilities exceeding 1% per year, and multiple individual banks maintained relatively high default probabilities for consecutive years (Flannery (2014), Flannery and Giacomini (2015)). In other words, supervisory discretion seems to have limited the effectiveness of Basel's capital regulations.

How might full transparency about stress test results affect this situation? To date, CCAR announcements have reported primarily positive news about large banks' financial conditions. Although the economic situation has been quite benign since the crisis, eventually the Fed will need to announce negative CCAR news about some large institution. Simply announcing a problem is likely to exacerbate the situation by leading counterparties to pull away from the identified institution. Following a history of granular CCAR disclosures, reducing the amount of information released will only arouse suspicions and create uncertainty. Hence the regulators must

present a plan for improvement at the same time they identify the problem.[20] Forcing supervisors to decide quickly may limit forbearance, which frequently permits the losses at a problem institution to accumulate.

Some researchers (Goldstein and Sapra (2014), Leitner and Williams (2017)) point out that the information in government announcements could displace private efforts to gather information, which they evaluate as a potential drawback to public dissemination. Flannery *et al.* (2017), however, discovered that the number of equity analysts following tested banks increased after stress tests began and their earnings forecasts became more accurate. Thus, the net effect of disclosing stress test results does not seem to have impeded private analyses of the affected BHCs.

c) Scenario transparency

Although the Fed has explained how it selects scenario variable values (Board of Governors (2019b)), some observers continue to press for advance information about the actual stress scenarios. Given the limited number of macro variables that affect predicted PPNR and loan losses, the stress scenario has largely been confined to a "severe recession" with large stock and house price declines (Board of Governors (2019b)). Under current Fed procedure, the recession's severity can be predicted to some extent from the economy's current unemployment rate. When the actual unemployment rate is low, it must rise to at least 10% in the severely adverse scenario. At a high actual unemployment rate, the stressed increase cannot exceed 3 – 5% in order to curtail the procyclical effect on BHC capital requirements. Providing further detail about the stress scenario seems unlikely to provide the banks with much information. However, I don't see much reason to resist releasing the stress scenario so long as the model parameters remain confidential.

[20] Most observers agree that the SCAP succeeded in part because supervisors assured the market that any bank requiring additional capital could obtain it from the government if necessary.

In contrast to the stresses affecting loan losses and PPNR for all tested banks, the largest BHCs might greatly appreciate knowing the instantaneous global/market shocks before the test's "as of" date. With that knowledge, a bank could reduce its trading exposures to stressed events without foregoing the expected return associated with bearing other types of risks. As with OFHEO's interest rate test, advance knowledge of the instantaneous DFAST stresses could lead to a substantial understatement of the BHCs' trading risks. Because the potential for gaming is particularly severe for the global/market shocks, it seems important to preserve their confidentiality.[21]

3. Incorporating new stresses into the DFAST

Essentially, the DFAST process asks whether a serious recession would eliminate "too much" of a bank's initial capital. The model compares PPNR against the aggregate losses from credit defaults, AFS loan and security revaluations, and (for 6 or 8 banks with trading or custodial operations) market value losses from instantaneous shocks.[22] The "recession" stress scenarios are intended to generate quite severe bank losses, although the scenarios themselves have not varied greatly between years. The stress test process would better reflect changing financial sector risks if the stress scenarios could incorporate risks beyond those implied by shocks to real and financial variables. For example, the solvency effects of changing business models or unanticipated changes

[21] The as-of date for trading portfolios varies from year to year in order to prevent this type of gaming.

[22] The trading shocks are said to "involve large and sudden changes in asset prices, interest rates, and spreads, reflecting general market dislocation and heightened uncertainty." (Board of Governors (2018c), page 8). The counterparty shocks are explained as follows: "Firms with substantial trading or custodial operations will be required to incorporate a counterparty default scenario component into their supervisory adverse and severely adverse stress scenarios for CCAR 2019. The counterparty default scenario component involves the instantaneous and un-expected default of the firm's largest counterparty." (Board of Governors (2019a, page 7).

in the risk of some asset class could be evaluated by shocking the PPNR or loss model parameters. The test could also move away from its micro-prudential focus by recognizing the potential for similar trading portfolio exposures across the largest banks.

a) Appling new stresses through PPNR modeling

Hirtle (June 2018) identifies PPNR forecasting as one of the more challenging areas in DFAST modelling, and her point is easy to see. When Frame *et al.* (2015, page 5) considered modeling a similar process for incorporating (hypothetical) new GSE business into the OFHEO stress test, they commented that "adding new business to the stress test is not a trivial task because it requires critical assumptions about the amount, composition, and risk characteristics" of that new business. The DFAST models try to maintain each BHC's asset and liability portfolio shares, and new loans are assumed to have the same underwriting properties as the ones they are replacing. In implementing these assumptions, the stress test models twenty-four separate components of PPNR: eight loan types' interest income, seven types of interest expense, six components of noninterest income, and three components of noninterest expense. PPNR changes translate directly into capital ratio changes over the 9-quarter simulation period.

Interest expense and revenue items change according to a partial adjustment equation of the form:

$$Ratio(b,t) = f\left(Ratio(b,t-j), FE(b), FE(b)*Ind(t \geq 2009{:}Q4), Z(t), X(b,t)\right), \qquad (1)$$

"where *b* represents the firm,

t represents time,

Ratio(b,t) represents the component ratio,

Ratio(b, t-j) represents the component ratio lagged by *j* quarters where $j \geq 1$,

FE(b) represents the fixed effect for firm *b*,

FE(b) Ind(t ≥ 2009:Q4)* represents the fixed effect for the period from 2009:Q4 onwards for firm *b*,

Z(t) represents one or more of the macroeconomic variables included in the supervisory scenarios, and

X(b,t) includes firm characteristics and other controls, including seasonal factors in some equations." (Board of Governors (2019c), page 21.)

The firm fixed effects in (1) permit the estimated PPNR components to vary across otherwise similar-looking BHC, although the estimated adjustment speed is the same for all banks. This adjustment speed is potentially important, particularly for loans with short maturities. The estimated adjustment speed on interest income defines the alacrity with which banks begin repricing loans early in the recessionary scenario. If a bank starts to raise loan rates earlier in the recession, subsequent capital declines will be smaller (and vice versa). Similarly, if deposit rates are reduced earlier in the scenario, subsequent estimated capital ratios will be higher. The PPNR pattern for 2018 is consistent with loan or deposit spreads changing more rapidly in the more stressful scenario: estimated aggregate PPNR in the Severely Adverse scenario exceeded PPNR in the Adverse scenario by $25 billion (5.3%).[23]

The granularity of PPNR modeling makes it a logical place to introduce stresses beyond the past scenarios' shocks to real or financial variables. By shocking parameters in equations like (1), the stress scenario could account for different dimensions of likely bank performance. The following bullet points present some preliminary thoughts about how to introduce new stresses through the PPNR.

- How promptly will banks revise their loan pricing once the stress scenario begins? If they act quickly, the stressed loan losses will be partly covered by higher loan revenue. If they act slowly or if loans have long maturities, capital will be depressed by the

[23] In addition to a higher aggregate mean, nearly all the individual BHCs had higher forecasted PPNR in the Severely Adverse scenario than in the Adverse scenario. The higher PPNR under Severely Adverse assumptions might also reflect that deposit rates decrease fairly rapidly as the market rates fall.

expanded volume of new, default-prone loans extended at old, non-stressed contract rates. The speeds of adjustment for various categories of interest income could be shocked to assess the importance of this effect.

- Interest expense adjustment speeds affect the path of capital ratios analogously.

- PPNR proportions could be adjusted to mimic a depositor run, although this may belong more naturally in the Comprehensive Liquidity Analysis and Review (CLAR).

- It seems likely that BHCs will change their business composition in a recession. Expanding or contracting lines of business could be simulated by shocks to adjustment speed parameters or to model intercept terms.

Other risk patterns would require changes in the loss equations.

- In an effort to "reach for yield", will banks shift their loan portfolios toward riskier, but higher-yielding borrowers?[24]

- Several observers suggest that shocks be applied to loan types that have recently been growing rapidly. Because the recent data from rapidly-growing loan categories is unlikely to exhibit high defaults, potential future stresses must be incorporated into the loss equations for the suspect loan type(s). This could take the form of an intercept shift in the loss model, or an adjustment to the elasticity of default losses to macro shocks in the stress scenario.

- Replacement borrowers are assumed to have the same properties as the borrowers whose loans have run off. But what if a bank cannot find enough such loan applicants during stress period? Would the BHC lower its underwriting standards or shrink its portfolio? If standards are lowered, are contract rates promptly raised?

b) Instantaneous Market Shocks

Summing default and operational losses across tested banks provides a reasonable estimate of the banking system's reaction to stress. Most banks' projected losses are dominated by expected credit defaults. In 2018, the tested BHCs' aggregate loan losses accounted for 72% (81%) of total aggregate losses under the severely adverse (adverse) stress scenario. (These proportions were lower (45% and 36%) for the largest banks, which were subject to instantaneous market and

[24] The stress test's reliance on the standard Basel risk weights limits the effect of risk changes within a loan category on RWA. A revised model could specify that some of the newly-issued loans are more (or less) likely to default than legacy loans.

counterparty shocks.) The tested BHCs have survived a series of "recession" stress tests over the past 8 years, suggesting that loan losses pose limited systemic risk within today's banking system.[25]

The systemic problems in 2008 derived not from the banking book but from the trading book, where many banks held unwise concentrations of (inappropriately valued) residential MBS. The bad assets' widespread trading losses reflected similar exposures across many large institutions. Interbank connections through the largest banks' trading positions could be de-stabilizing in a macro-prudential way that is not captured by the model's one-shot, instantaneous effects. The available stress test data could support a more extensive analysis of trading shocks, which would enhance the tests' macro-prudential implications.[26]

The procedure for computing large banks' trading losses differs from the (relatively straightforward) loan loss models described in Board of Governors (2019c). The banks provide the sensitivity ("greeks") of their trading portfolio components to a variety of market shocks.[27] The Fed then estimates trading losses by combining the reported sensitivities with the vector of shocks and each bank's trading portfolio composition.[28] Once the instantaneous losses are computed, the DFAST model treats them the same way it treats credit losses.

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[25] The banking book losses were likely more consequential in 2007-9 because the banks had less capital.

[26] The extremely large instantaneous market shocks, based on the 2007-9 experience, might be thought to include implicitly some market interaction effects. Incorporating such interaction effects into the simulation calculations would therefore call for less severe instantaneous shocks. I have a more modest goal in proposing greater use of the trading information: merely to identify the most salient risks present in the banks' trading portfolios on the as of date.

[27] The volume of data is apparently quite difficult to handle. Schuermann (2016, page 4) reports that "For CCAR-2015, the Fed specified about 24,000 parameters, across about 20 categories such as equities, FX, rates, energy and commodities, securitized products, credit correlation and so on." The Intermediate Holding Companies, some of which hold substantial trading portfolios, became subject to trading book shocks in 2019.

[28] The Fed's calculation only approximates losses because it ignores the nonlinear effects of some shocks. Each large BHC also reports its own estimated losses from the specified market shocks.

This simple treatment of the voluminous trading data seems to represent a sizeable opportunity loss. To an outsider, at least, it seems that more can be done with the bank trading account data.

- Identify the stresses that have the largest cumulative effects across all the trading banks. The individual BHCs already identify specific shocks that affect them the most. Large sectoral losses or gains would be worth identifying: if the banks are collectively long (short) some risk, the rest of the economy must be short (long).
- Search for "crowded trades" that might be un-wound only with large price effects.

This analysis could be undertaken entirely within the regulatory system. The banks need suffer no further costs or burden. Also, the calculations will not have standard regulatory implications and hence they needn't be completed on the same schedule as the rest of DFAST. Nor must the individual BHCs replicate the analysis. While I recognize that these evaluations would be technically challenging, I think they are worth investigating. Analysis of the banking system's risk exposures would move the stress test toward a more macroprudential exercise.

4. *Model innovations*

I propose one procedural change to the stress testing process and endorse the proposed use of DFAST loss estimates in defining a BHC's Stress Capital Buffer (SCB).

a. Verifying initial asset valuations

The CCAR test predicts changes in a BHC's balance sheet and income under stress, following GAAP accounting procedures. By incrementing the bank's starting capital value, the stress test estimates how much capital the bank will have in each future quarter. But what if the initial capital ratio overstates the bank's ability to absorb losses? This happened during the financial crisis, as regulatory measures of capital far exceeded the market's estimation of firms'

loss-absorbing capacity. Huizinga and Laeven (2012) studied U.S. banks' accounting during the crisis and conclude:

> In 2008, the market value of bank assets was lower than their book value for the majority of US banks. This is *prima facie* evidence that the book value of US banks was inflated. … The discrepancy between market and book values suggests that banks have been slow to adjust book values to reflect market expectations about future asset losses. (page 632)

Today, this possibility seems remote. Yet eventually one or more banks will present misleadingly high regulatory capital ratios that are (nonetheless) consistent with GAAP. Unless the stress tests begins with a reliable estimate of the bank's loss-absorbing capacity, their implications will be suspect (at best). Bulow (2019) and Greenwood *et al.* (2017, page 530) make similar points.[29]

I propose that the stress test procedures begin with a rough assessment of each BHC's loss-absorbing capacity, based on some combination of equity's book and market values.[30] The European Banking Authority followed such a procedure in 2014, when it conducted an extensive "asset quality review" (AQR) before beginning its stress test. I am not suggesting anything as resource intensive as the AQR. Adding a quick, high-level asset quality review to the DFAST process now assures that doing such evaluations in the future will have no negative implications *per se*.[31] A further advantage of this asset quality check is that it will permit (indeed, perhaps force) regulators to address more promptly inadequacies in stressed banks' true loss-absorbing

[29] Greenwood et al. (2017, page 530) argue that "If a CCAR adverse scenario is being drawn up in a mid-2008-like environment, it seems hard to argue that it should not take into account the growing market skepticism about the state of bank balance sheets. Moreover, doing so should serve to heighten the pressure on regulators to push for a rapid recapitalization of the banking system."

[30] Incorporating equity's market value into the supervisory process has supporters, but even they acknowledge some serious potential problems. Among other things, a bank's equity market value may include some value for conjectured TBTF guarantees and the value of intangibles may evaporate under stress. Still, Greenwood *et al.* (2017, page 530) observe "that the current system, which has no real role for market-based information, is also far from optimal."

[31] The DFAST procedure does include a correction for differences between a BHC's initial ALLL and the model's forecasted losses for the coming four quarters. Any difference is "linearly smoothed into the Federal Reserve's provisions projection over the nine quarters." (Board of Governors (2019d, page 13).

capacities. It is far from obvious how to combine relatively volatile market valuations with more static book valuations. One possibility: set a BHC's initial equity value to min (BVEQ, [γ MVEQ + (1-γ) BVEQ]), where $0 \leq \gamma \leq 1$).

b. Stress capital buffer

The Basel Committee on Bank Supervision agreed that large banks should hold a "capital conservation buffer" equal to at least 2.5% of RWA. Currently, that buffer has the same size across all affected U.S. banks. The Fed has proposed replacing this uniform requirement with a "stress capital buffer" (SCB) equal to "the decrease in a firm's common equity tier 1 (CET1) capital ratio in CCAR plus four quarters of planned common stock dividends". (Board of Governors (2018a), page 2).[32] A risk-sensitive SCB seems clearly superior to the current requirement.

5. Summary and Conclusions

Econometric models required by the 2010 Dodd-Frank Act have taken center stage in defining minimum acceptable capital ratios for the largest U.S. bank holding companies. These models are complex, but they do appear to reflect sound economic and statistical principals. Their prominence in capital adequacy regulation has generated a keen interest in understanding exactly how the models work. The Fed has revealed some important things about the models, but resists sharing the equation specifications or parameters. Nor should they share such specifics. The lessons from OFHEO's stress tests clearly indicate this, along with the danger that the Fed's risk assessments become incorporated into many banks' risk exposures. By contrast, sharing information about the macro and interest rate stressed scenario values seems to pose less risk to

[32] In order to comply with international agreements about the scale of the supplemental buffer, the SCB will have a floor of 2.5%.

the integrity of the overall DFAST model. It is extremely important that the Fed continue to release granular information about individual BHCs' performance under the stress tests. This information is relevant to bank shareholders and, more importantly, the commitment to announce both good and bad test results should help focus supervisory attention on finding prompt solutions to problem situations.

The DFAST models must evolve with changing patterns and risks in the financial sector. Imposing administrative constraints on the Fed's ability to modify its models could seriously compromise the stress tests' validity and usefulness. The U.S. banking agencies have always used their discretion in supervising financial institutions, and I see no reason to interfere with discretion that takes the form of a formal model.

One frequently hears a call for subjecting BHCs to "new" stresses in the DFAST model. Credit and operational losses have derived from a stress scenario that amounts to a "serious recession", and the banks have routinely passed tests based on stressed credit losses. If there are big risks in the banking system, they likely lie outside the loan losses simulated in DFAST. It will be difficult to produce nuanced stress scenarios if our only instruments are the financial and real variables that go into DFAST equations. Other possible sources of stress can be evaluated via parameter changes in the PPNR and credit loss models. These should be considered. Likewise, supervisors should consider ways to broaden their use of the voluminous trading portfolio data provided by the largest institutions. These data can be evaluated without further interaction with the banks, to assess macro-prudential risks.

Finally, I close with a plea for finding a reasonable way to incorporate market information into large banks' supervisory oversight. Taking book capital measures at face value threatens the efficacy of existing stress tests. The question, of course, is how to combine market and accounting

information most appropriately. With the stress tests so tightly focused on accounting variables, I worry that market information will remain a step-child.

Table 1: Market Impact on Stress Tested Firms of Stress Testing Disclosure

Stress Tested Firms

	Event date						Est. Window
	(1) CAR		(2) |CAR|		(3) CAV		(4) |CAR|
SCAP 2009 Before	3.24		9.68		7.22	***	6.31
SCAP 2009 After	3.64	***	9.43	***	10.73	***	2.66
CCAR 2011	-1.92	***	2.12	**	0.77	**	1.58
CCAR 2012	3.59	***	3.60	***	2.72	***	1.77
DFAST 2013	0.73	*	1.64	**	0.23		1.20
CCAR 2013	-0.41		1.45		0.07		1.20
DFAST 2014	-0.71	**	1.91	**	1.02	***	1.01
CCAR 2014	-0.93	***	1.22		0.31	**	1.01
DFAST 2015	1.89	***	2.01	***	0.29	*	1.04
CCAR 2015	1.22	***	1.57	***	0.52	***	1.04
DFAST 2016	-1.97	***	2.49	***	-0.29		1.39
CCAR 2016	-0.64		1.39		0.34		1.39
DFAST 2017	-1.13	***	1.25	*	-0.61	***	0.97
CCAR 2017	0.89	***	1.12		0.33	**	0.97
DFAST 2018	-1.67	***	1.84	***	-0.13		1.05
CCAR 2018	1.35	***	1.37		0.35	***	1.05
All Events (with SCAP before)	0.16		2.18	***	0.75	***	1.70
All Events (with SCAP after)	0.18		2.16	***	0.91	***	1.36
All Events Except 2009	-0.02		1.75	***	0.38	***	1.22

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