Predicting Operational Loss Exposure Using Past Losses*

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Abstract
Operational risk models, such as the loss distribution approach, frequently use past internal losses to forecast operational loss exposure. However, the ability of past losses to predict exposure, particularly tail exposure, has not been thoroughly examined in the literature. In this paper, we test whether simple metrics derived from past loss experience are predictive of future tail operational loss exposure using quantile regression. We find evidence that past losses are predictive of future exposure, particularly metrics related to loss frequency.

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1 Introduction

International regulatory capital rules (i.e., the Basel Accords) require internationally active banks to hold capital for operational risk.\(^1\) In the US, large, internationally active bank holding companies (BHCs) are required to calculate their operational risk capital according to the Advanced Measurement Approach (AMA), which relies on banks’ internal models to estimate exposure at the 99.9% confidence level.\(^2\) As of the end of June 2017, the ten US BHCs with approved AMA models held capital against operational risk that, on average, amounted to 29% of total risk-weighted assets. This amount is significant when compared to capital held against market and credit risk (7% and 64% of risk-weighted assets, respectively).\(^3,4\) In addition, large US BHCs are required to estimate operational losses under stressed conditions for the annual Comprehensive Capital Analysis and Review (CCAR) required by the Federal Reserve.\(^5\)

To estimate operational loss exposure for AMA and CCAR, bank holding companies typically use models that assume past operational losses are predictive of future operational loss exposure.\(^6\) For this assumption to be sensible, past operational losses should proxy for the underlying factors driving operational loss exposure, such as risk management quality, risk appetite, business model, and size. Given the relative stability of the central moments of the operational loss distribution, such as the expected value, past averages are likely good predictors of future average losses (analysis in this paper confirms that past average losses are good predictors of expected losses - see Table 3).

\(^1\) Basel Committee on Banking Supervision (2006), "International Convergence of Capital Measurement and Capital Standards."
\(^2\) Board of Governors of the Federal Reserve System (2015a), Code of Federal Regulations, Title 12, Part 217, Subpart E.
\(^3\) Risk-weighted assets is an international regulatory concept used to calculate how much loss-absorbing capital a bank needs to endure stressful markets. See Basel Committee on Banking Supervision (2006) for more details.
\(^4\) These estimates are gathered from the FFIEC 101 form as of 2017Q2 for the following eleven bank holding companies: Bank of America, BNY Mellon, Citigroup, Goldman Sachs, JPMorgan Chase, Morgan Stanley, Northern Trust, State Street, US Bancorp, and Wells Fargo.
\(^5\) Board of Governors of the Federal Reserve System (2016), "Comprehensive Capital Analysis and Review 2016 Summary Instructions."
\(^6\) For example, the loss distribution approach, frequently used by AMA banks, and regression techniques that use past losses to forecast future stressed losses, used by multiple CCAR banks.
On the other hand, in the tail of the distribution, exposure is dominated by large and infrequent events; thus, estimates of tail exposure suffer from significant uncertainty and instability. Moreover, the adequacy of past losses as proxies for the often idiosyncratic drivers of tail events is not obvious. So, whether past losses add value in forecasting tail exposure over other proxies, such as income or assets, should be assessed.

Using data from all US bank holding companies subject to CCAR 2016, this paper studies whether past losses are predictive of tail exposure. To this end, we perform quantile regressions where the high quantiles of the industry distribution of banks’ annual operational losses are forecasted using metrics calculated from past losses and other financial variables. We used a variety of alternative explanatory variables (such as controls for size, risk appetite, and risk management quality) and specifications, and we found that loss metrics help forecast tail operational loss exposure. In particular, we found that average loss frequency is a robust predictor of future losses; a one unit increase in average frequency of losses above $100k is associated with approximately a $4Mln increase in the 95th quantile of future annual operational losses.

An extensive literature focuses on the performance of models relying on past loss experience in credit risk. Hillegeist et al. (2004) compare accounting-based models (Z-Score and O-Score) with market-based models (Black-Scholes-Merton model) for probability of default and find that market-based models perform better; while Agarwal and Taffler (2008) compare the Z-score model with the Merton model and find that they have similar ability to predict default. Bharath and Shumway (2008) compare the Merton distance to default model with simpler alternatives and find that the Merton model does not significantly improve upon them. Altman and Sabato (2007) compare a distress prediction model specific to small and medium sized enterprises (SME) with a generic corporate model and find that the SME model outperforms the generic model. Gupton (2005) shows that Moody’s LossCalc model for loss given default outperforms multiple benchmarks. Finally, Lopez and Saidenberg (2000) examine the challenges in validating and backtesting credit models and propose evaluations methods.
Likewise, an extensive literature focuses on the performance of market risk models. Berkowitz and O'Brien (2002) evaluate the performance of banks’ Value-at-Risk (VaR) models and find that VaR models do not outperform simple time-series models based on banks’ trading P&L. Perignon et al. (2008) assess the VaR models of Canadian banks and find that these models systematically overestimate exposure. Bao et al. (2006) compare multiple VaR models, including Riskmetrics and EVT models, and find that EVT models perform best during crisis periods. Escanciano and Olmo (2011) discuss how model risk presents challenges for the backtesting of VaR models and show that block-bootstrapping techniques produce more accurate backtesting. Finally, Gaglianone et al. (2012) illustrate how backtesting of VaR models can be performed using quantile regression.

However, similar studies are lacking for operational risk. To our knowledge, this is the first article to show that metrics of past loss experience are predictive of operational loss exposure. By identifying the loss metrics that best predict exposure, this paper contributes to the literature on factors predictive of operational loss exposure. This literature includes Chernobai et al. (2011), who find that operational loss frequency is higher for firms that are younger, more complex, and more exposed to credit risk; Cope et al. (2012), who find that banks’ likelihood of experiencing certain types of operational losses is highly correlated with constraints on executive power, insider trading, shareholder protection laws and supervisory power; Wang and Hsu (2013), who find that board size and the fraction of independent directions are negatively related with the likelihood of operational loss events; and Abdymomunov et al. (2015), who find that banks suffer higher operational losses during weak macro environments.

Our study coincides with substantial revisions to the Basel framework for operational risk capital. In December 2017, the Basel Committee replaced the previous standardized approaches and the AMA with a new standardized approach. Under the new standardized approach, large bank holding companies are required to calculate operational risk capital according to a fixed formula that relies on the Business
Indicator, an income statement proxy for operational loss exposure, and on past losses. The results of this paper support the combination of size and loss metrics in the calculation of operational risk capital and can inform future work on improvement of the operational risk capital requirements.

The remainder of this paper is organized as follows: Section 2 describes the data used; Section 3 describes the quantile regression methodology and presents the main empirical results; Section 4 provides multiple robustness checks; finally, Section 5 concludes.

2 Data

The analysis in this paper relies on operational loss event data, financial statements, and other supervisory information of 31 bank holding companies that participated in CCAR 2015. We have chosen to end our sample at the end of 2015 because operational losses are often not fully captured as a year ends, and thus banks reported 2016 operational losses are likely still underestimated. Loss information, including loss amounts and counts, is used from 2000Q1 or as far back as available in the Federal Reserve’s Y-14Q reports. Liabilities, equity, total assets, net interest income, and total noninterest income are obtained from Y-9C reports when available and supplemented with data from Bloomberg otherwise. Risk management and internal controls ratings are obtained from confidential supervisory assessments. In addition to firm-specific information, a NBER recession indicator is used.

The dependent variable in the regressions of this paper is the total amount of

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7 List provided in Appendix A.
8 Some banks have reported losses before 2000Q1. However, such data is likely incomplete, and so we opted to start our sample in 2000Q1.
9 Some firms in our sample, such as Goldman Sachs and Morgan Stanley, did not become bank holding companies until late in our sample period and so were not required to fill the Y-9C report for the earlier portion of our sample. Also, some non-bank holding companies (e.g., Countrywide Financial) merged with or were acquired by bank holding companies in our sample. For consistency between the loss datasets and the financial statement variables used for these companies, Y-9C data was augmented by Bloomberg data where appropriate.
operational losses suffered by a bank holding company over a calendar year. Banks provide multiple dates for their operational loss events on Y-14Q reports: occurrence date, discovery date, and accounting date; we rely on the accounting date because it reflects when losses enter the firms’ financial statements and, thus, when capital is needed to cushion losses. In some cases, operational loss events result in multiple loss impacts through time, which are recorded separately in the Y-14Q report (for example, losses resulting from a litigation event may be spread through multiple years). However, reporting practices of losses with multiple impacts are not consistent across banks - some banks aggregate most impacts to one date, while others provide extensive temporal disaggregation; for consistency, we opted to aggregate all impacts of a loss event to its first accounting date. Thus, our loss event dataset includes a single entry for each loss event, which sums all loss impacts of the loss event. Total operational losses for year $t$ are the sum of the loss amounts of all events with a loss amount of at least $20k$ and with the first accounting date in year $t$. Our loss aggregation choice likely works against significance of variables in our regression analysis because it results in lumpier and more volatile loss totals, which are likely harder to predict than smoother loss totals.

Multiple loss metrics are constructed to use as explanatory variables;\textsuperscript{10} in all cases, loss metrics for year $t$ are calculated using bank data from the beginning of the sample until year $t$ (e.g., 2012 average annual losses for a bank whose loss history started in 2000 correspond to the average of total annual losses between 2000 and 2012), but we only calculate the metrics if at least three years are available (e.g., for a bank whose first year of loss data is 2005, the first year explanatory loss metrics are available is 2007). We use the maximum available period to calculate the loss metrics to increase the stability of explanatory loss metrics. We construct four types of loss metrics: 1) average total annual losses only including losses above given thresholds or between two thresholds (e.g., average total annual losses only including loss events above $20k$, average total annual losses only including loss events between $20k$ and $1Mln$; 2) average loss frequency only

\textsuperscript{10} Full list of explanatory variables provided in Appendix B.
including loss events above given thresholds or between two thresholds (e.g., average frequency only including loss events above $100k, average frequency only including loss events between $100k and $1Mln); 3) average loss severity only including loss events above a given threshold (only $100k is used);\textsuperscript{11} and 4) estimates of the 95\textsuperscript{th} quantile of the operational loss distribution obtained through empirical bootstrapping.\textsuperscript{12}

We also use financial statement metrics as explanatory variables: total equity, total liabilities, net interest income, and non-interest income. To increase stability, these metrics are calculated according to a rolling average of three calendar years. For total liabilities and equity, values at the end of the calendar year are averaged for three years (e.g., when using total equity to predict operational losses in 2013, we use the average of total equity at the end of 2012, 2011 and 2010); while for net interest income and non-interest income, values of the full calendar year income statement are averaged for three years.

In addition to loss metrics and financial statement metrics, we also use supervisory assessments of the quality of management. Specifically, the rating constitutes an assessment of the ability of BHCs’ board of directors and senior management, as appropriate for their respective position, to identify, measure, monitor and control risk. The ratings range on a numeric scale from 1 to 5, with a rating of 1 being the strongest (good) and a rating of 5 being the weakest (bad).\textsuperscript{13} Finally, we use an indicator of recession in the US economy, obtained from the NBER, as an explanatory variable.

Table 1 presents the descriptive statistics of the loss metrics, financial statement metrics, supervisory assessment of management quality, and the recession dummy. Each

\textsuperscript{11}Regression results using other loss thresholds (e.g., $1M) are available upon request.

\textsuperscript{12}To estimate the 95\textsuperscript{th} quantile of the operational loss distribution of a bank using past losses, we use an empirical bootstrapping approach. The empirical bootstrap is recommended as a benchmark for operational risk capital models in US Advanced Measurement Approach guidance - see Board of Governors of the Federal Reserve System (2014), Basel Coordination Committee Bulletin 14-1. This approach follows the loss distribution approach and, thus, loss severity and frequency are estimated separately. Frequency is assumed to follow a Poisson distribution; while severity is assumed to follow the historical empirical distribution. Loss events are pooled to a single unit of measure and annual loss distribution is obtained through Monte Carlo simulation convolution of the frequency and severity distributions.

\textsuperscript{13}A detailed description of the Bank Holding Company Rating System can be found at: http://www.federalreserve.gov/boarddocs/srletters/2004/sr0418.htm.
bank-year combination is an independent observation.

Operational risk is substantial for large US BHCs. On average, large US BHCs face operational risk losses above $800Mln per year that represents almost 0.10% of their total assets. Once in ten years, BHCs in our sample, lose around $2Billion representing more than 0.22% of their total assets. Given that large US BHCs are highly leveraged, this can represent a significant hit to their capital base. On average, large US BHCs funded 8.8% of their total assets with tier 1 capital in 2014Q3.\textsuperscript{14} Thus, once every ten years, a BHC in our sample suffered operational losses that would erode more than 2.5% of their capital base if their tier 1 to assets ratio stood at the industry average.

### 3 Empirical Results

To test the predictive ability of past losses, we run several OLS and quantile regressions.\textsuperscript{15} Losses from all CCAR bank holding companies are pooled in these regressions; however, due to the significant differences across banks in our sample, the conditional distribution of annual operational losses is likely heteroscedastic.\textsuperscript{16} To reduce the heteroscedasticity of data, we considered scaling the dependent variable as well as some of the explanatory variables including the loss metrics, total equity, total liabilities, and income measures by total assets. However, we believe that such transformation inherently biases estimation towards finding statistically significant effects. For example, in a simple model of losses at time t as a function of average losses up to time t-1, if losses at time t are unrelated to losses at time t-1, but assets at time t are related to assets at time t-1, we would find a correlation after scaling, although there was no correlation prior to scaling. We calculated the results using assets scaling instead of the methodology we employed in this paper to reduce heteroscedasticity, and generally effects are more likely to be statistically significant when scaling by total assets is used.

\textsuperscript{14} Board of Governors of the Federal Reserve System (2015b), "Comprehensive Capital Analysis and Review 2015: Assessment Framework and Results."

\textsuperscript{15} See Koenker and Bassett (1978), Koenker and Hallock (2001) and Koenker (2005) for descriptions of the theory and use of quantile regression.

\textsuperscript{16} To reduce the heteroscedasticity of data, we considered scaling the dependent variable as well as some of the explanatory variables including the loss metrics, total equity, total liabilities, and income measures by total assets. However, we believe that such transformation inherently biases estimation towards finding statistically significant effects. For example, in a simple model of losses at time t as a function of average losses up to time t-1, if losses at time t are unrelated to losses at time t-1, but assets at time t are related to assets at time t-1, we would find a correlation after scaling, although there was no correlation prior to scaling. We calculated the results using assets scaling instead of the methodology we employed in this paper to reduce heteroscedasticity, and generally effects are more likely to be statistically significant when scaling by total assets is used.
mitigate the heteroscedasticity and increase estimation efficiency, we follow a methodology proposed by Jung et al. (2015) to deal with heteroscedasticity in quantile regressions (for consistency, we also apply the same methodology to our OLS regressions): first, using a fixed set of explanatory variables (equity, liabilities, risk management rating, risk management rating times total assets, crisis indicator, and crisis indicator times total assets), we estimate 25th quantile and 75th quantile regressions; second, we retrieve the fitted values of these 25th and 75th quantile regressions; third, we calculate the weight of each observation, which corresponds to one divided by the fitted interquartile range (i.e., 1/(Fitted value of the 75th quantile regression - Fitted value of the 25th quantile regression); finally, we multiply the dependent and the explanatory variables of each observation by their corresponding weight.

Coefficient estimates are unlikely to be normally distributed in a small sample such as ours; thus, to appropriately test the significance of estimated effects, we use empirical bootstrapping. We employ the (x,y)-pair bootstrap technique, whereby (x,y) pairs of observations from the original sample are sampled with replacement and model parameters are re-estimated multiple times. To obtain coefficient p-values, first we calculate the proportion of coefficient estimates above and below zero; then, we multiply the smaller of these proportions by two to obtain the p-value for the two-sided test of statistical significance. Our p-value estimates are based on 10,000 re-samples.

17 Rather than use the different explanatory variables in each of regressions considered in this paper to set the weights, we always used the weights obtained from these two quantile regression for consistency. Having the same weights throughout is necessary to allow comparison of R^2 statistics.

18 In some cases the fitted 75th quantile can be lower than the fitted 25th quantile for observations at the extreme of the range of values of certain explanatory variables. Also, in other cases, weights can become very large, when the interquartile range is very close to zero. To avoid negative weights and extremely high weights, we employ a two-step procedure: first, we divide the interquartile range for all observations by the average interquartile range – this normalization does not affect relative weights, and so it has no direct impact on regression results; second, we floor the normalized interquartile range to 0.02. We have undertaken sensitivity analysis for this assumption by considering floors ranging from 0.01 to 0.1, and results are not meaningfully affected (see Appendix C).

19 We check the robustness of our results by using the intertertile range and the range between the 10th and the 90th quantiles instead of the interquartile range to set the weights. Results are qualitatively similar (see Appendix D).

20 The bootstrapped estimates often show meaningful asymmetry around the average estimate and, thus, demonstrate the non-normality of regression coefficients.

21 To further assess the statistical robustness of our results we use block bootstrapping, a technique that addresses dependence within clusters of observations by bootstrapping clusters of observations.
To assess whether past operational losses help predict future operational losses, we start by performing regressions that only include past loss metrics as explanatory variables. We consider seven alternative combinations of explanatory variables: 1) average total annual losses only including loss events above $20k; 2) average frequency of loss events above $100k; 3) average severity of losses only including loss events above $100k; 4) the 95th quantile of the operational loss distribution obtained through empirical bootstrapping; 5) average frequency of loss events above $100k and average severity of losses only including loss events above $100k; 6) average total annual losses only including loss events between $20k and $1Mln and average total annual losses only including loss events above $1Mln; and 7) average frequency of loss events between $100k and $1Mln and average frequency of loss events above $1Mln.

Average total annual losses jointly reflect the frequency and severity of operational losses experienced by banks and, so, are an intuitive starting point on a search for a summary metric of past losses; however, loss frequency and loss severity may be more predictive when considered as separate factors, and so we consider regressions where they are considered alone and together as separate factors. In addition, we consider the 95th percentile of the operational loss distribution obtained through empirical bootstrapping to assess how a simplified loss distribution approach (LDA) compares with other simpler metrics in predicting annual operational losses. Finally, we estimate regressions where we separate the effects of body losses and tail losses; in model 6, we do so by separating the average losses resulting from loss events between $20K and $1Mln and loss events above $1Mln; while in model 7, we do so by separating the average frequency resulting from losses events between $100K and $1Mln and loss events above $1Mln.

The loss metrics we use are highly correlated, as pairwise correlations exceed 50% in all cases (see Table 2). For example, average total annual losses have a correlation of as a block, rather than independently (Cameron et al. (2008)). In our implementation of the block bootstrap procedure, in each replication we sampled with replacement from the 31 BHCs for which we have data, until the bootstrap sample included data for 31 firms. Given that the number of years of data available varies across firms, our final bootstrap samples have a variable number of observations but generally close to our total sample size of 220. The statistical significance of regression coefficients does not change meaningfully (see Appendix E for results).
89.9% with average loss frequency and a correlation of 97.5% with the 95th quantile of the loss distribution measured from past losses. Nevertheless, we believe comparing the predictive ability of the different loss measures is relevant. So, to avoid multicollinearity that muddles regression results, we chose to not include multiple loss metrics in the same regression, except for cases where they measure a separate dimension of the loss distribution (e.g., average loss frequency and average loss severity, or average total annual losses only including loss events between $100K and $1Mln and average total annual losses only including loss events above $1Mln).

Table 3 presents coefficients from the regression of operational losses at year \( t \) on loss metrics at year \( t - 1 \). We have chosen to use explanatory variables for one year prior to the dependent variable because we want for our regression to show the ability of loss metrics and other control variables to predict operational losses. Panel A reports OLS estimates according to the following regression:

\[
OL_{i,t} = \alpha + \sum_j \beta^j LossMetric^j_{i,t-1} + \epsilon_{i,t},
\]

(1)

Where \( OL_{i,t} \) are total annual operational losses of bank \( i \) in year \( t \) and \( LossMetric^j_{i,t-1} \) are the \( j \)th loss metric of firm \( i \) calculated at \( t - 1 \). Panel B regressions estimate the following conditional quantile functions:

\[
Quant^\theta(OL_{i,t}|LossMetrics) = \alpha^\theta + \sum_j \beta^{\theta,j} LossMetric^j_{i,t-1},
\]

(2)

Where \( Quant^\theta(OL_{i,t}) \) is the \( \theta \)th quantile of the distribution of annual operational losses of bank \( i \) in year \( t \) and \( LossMetric^j_{i,t-1} \) is the \( j \)th loss metric of firm \( i \) calculated at
$t - 1$. Panel B presents the 95$^{th}$ quantile estimates.\footnote{We use 95$^{th}$ quantile regressions to illustrate the predictive ability of loss metrics and other control variables over future tail losses. This choice of quantile is arbitrary; nevertheless, we believe that using the 95$^{th}$ quantile is sensible because it can be intuitively interpreted as 1 in 20 years losses. To demonstrate the robustness of our results, we provide the results of the 90$^{th}$ and the 99$^{th}$ quantile regressions on Appendix F. Results are consistent in most cases.}

[Insert Table 3 here]

When used as the single explanatory variable, an increase in average total annual losses (model 1), average frequency (model 2), or average severity (model 3) is associated with a statistically significant increase in expected future losses and in the 95$^{th}$ quantile of the distribution of future losses. However, despite the three metrics enjoying statistical significance, their R$^2$ statistics suggest meaningfully different explanatory power.\footnote{We calculate R$^2$ statistics for quantile regressions following the methodology proposed by Koenker and Machado (1999). In short, the quantile regression objection function is calculated under the regression of interest (unrestricted) and under a restricted model that only includes an intercept. Then, the ratio between the unrestricted and restricted objective functions is used as in the OLS case to calculate R$^2$.} Average loss frequency shows more explanatory power than average total annual losses for both the OLS and the 95$^{th}$ quantile regression, while average loss severity shows little explanatory power in both regressions. These results suggest that average loss frequency is the most promising predictor of future loss exposure among the simple loss history metrics.

When average frequency and average severity are considered together in a regression (model 5), an increase in average frequency is associated with a statistically significant increase in expected future losses and in 95$^{th}$ quantile of future losses, while the coefficient associated with average severity is not significant in either regression. Also, the coefficients associated with average frequency are of similar magnitude when average severity is accounted for and when it is not. These results suggest that that accounting for average severity does not enhance prediction of future losses when average frequency
is controlled for.

Separating average total losses coming from small loss events from average total losses coming from large loss events (i.e., loss events above $1Mln are categorized as large) enhances their predictive power both in the OLS and the 95\textsuperscript{th} quantile regressions (model 6). For both the OLS and the 95\textsuperscript{th} quantile regressions and in comparison to the coefficient of average total losses in model 1, the coefficient associated with average total losses coming from small loss events is larger while the coefficient associated with average total losses coming from large loss events is smaller. Also, both of these coefficients are statistically significant in both the OLS and the 95\textsuperscript{th} quantile regressions. These results indicate that when using average total losses to predict future losses, separating between large and small losses is useful. On the other hand, separating frequency of small loss events and frequency of large loss events as predictors does not meaningfully improve predictive power (model 7). When taken separately in the OLS and the 95\textsuperscript{th} quantile regressions, the coefficient of frequency of small events decreases slightly relative to the coefficient of frequency in the regression where frequency of large and small loss events is not taken separately, but remains statistically significant; while the coefficient of frequency of large events increases relative to the coefficient of frequency in the regression where frequency of large and small loss events is not taken separately, but becomes not statistically significant.

Finally, the regressions where the 95\textsuperscript{th} quantile of loss distribution measured from past losses is used to predict future expected losses and the 95\textsuperscript{th} quantile of future losses (model 4), unsurprisingly, show a positive and statistically significant relation between past 95\textsuperscript{th} quantile and future losses. Perhaps surprisingly though, the 95\textsuperscript{th} of the past loss distribution holds less predictive power over the future 95\textsuperscript{th} quantile of annual losses than simpler metrics such as average loss frequency or average total losses. Such results question the usefulness of building complex LDA models to forecast high quantiles of loss distributions.

The regression results discussed so far demonstrate that, when used without
additional covariates, past loss metrics are predictive of loss exposure. To further establish the usefulness of past losses, we assess whether past loss metrics remain predictive of exposure when other variables that proxy for riskiness are considered. We consider three types of variables to proxy for banks riskiness: financial statement variables, supervisory assessments, and a macroeconomic indicator of recession.

Two financial statement variables are considered: total debt and total equity. When summed, total debt and total equity equal total assets; thus, they jointly proxy for bank size. We have chosen to consider debt and equity separately because their mix reflects leverage and risk appetite. Also, we use the Risk Management (R) rating of the Bank Holding Company Rating System to proxy for risk management quality in our regressions; however, risk management quality is unlikely to have the same absolute effect on operational loss totals in a small and a large bank, and so we also include interaction term between the risk management rating and total assets in the regression.

Finally, to account for the effect of macroeconomic shocks on total operational losses, we include an indicator variable that assumes the value of one when the US is in a recession and zero otherwise. Similar to risk management quality, we do not believe the absolute effect of a recession in operational losses is likely to be the same for small and large banks, and so we also include an interaction term between the recession indicator and total assets in our regressions.

Some of these variables are highly correlated with loss metrics (see Table 2). For example, bilateral correlations between total equity and average total annual losses or between total equity and average loss frequency are close to 90%; the correlations between total liabilities and these loss metrics are similarly high. These high correlations raise the question of whether past loss metrics are predictive of exposure even when other risk proxies are considered. Table 4 presents the results of regressions including loss metrics and the other proxy variables described in the previous paragraph as explanatory variables. Panel A reports according to the following regression:
\[ OL_{i,t} = \alpha + \sum_j \beta^j \text{LossMetric}_{i,t-1}^j + \sum_k \beta^k \text{ControlVariable}_{i,t-1}^k + \epsilon_{i,t}, \tag{3} \]

Where \( OL_{i,t} \) are total annual operational losses of bank \( i \) in year \( t \), \( \text{LossMetric}_{i,t-1}^j \) is the \( j^{th} \) loss metric of firm \( i \) calculated at \( t - 1 \), and \( \text{ControlVariable}_{i,t-1}^k \) is the \( k^{th} \) control variable for firm \( i \) at time \( t - 1 \). Panel B regressions estimate the following conditional quantile functions:

\[ \text{Quant}_\theta(OL_{i,t}|\text{LossMetrics, ControlVariables}) = \alpha^\theta + \sum_j \beta^j \text{LossMetric}_{i,t-1}^j + \sum_k \beta^k \text{ControlVariable}_{i,t-1}^k, \tag{4} \]

Where \( \text{Quant}_\theta(OL_{i,t}) \) is the \( \theta^{th} \) quantile of the distribution of annual operational losses of bank \( i \) in year \( t \), \( \text{LossMetric}_{i,t-1}^j \) is the \( j^{th} \) loss metric of firm \( i \) calculated at \( t - 1 \), and \( \text{ControlVariable}_{i,t-1}^k \) is the \( k^{th} \) control variable for firm \( i \) at time \( t - 1 \). Panel B presents the 95\(^{th}\) quantile estimates.

When considered together with other risk proxies, average loss frequency remains a statistically significant predictor of future total operational losses (model 2). A unit increase in the average frequency of losses above $100K is associated with approximately a $1.9Mln increase in future expected losses and a $4.0Mln increase in the 95\(^{th}\) quantile of the distribution of future operational loss distribution. On the other hand, when the control variables are added, average total losses, average loss severity, and the 95\(^{th}\) quantile of the operational loss distribution measured from past losses are no longer
statistically significant in the OLS and the 95\textsuperscript{th} quantile regressions. The superiority of average frequency measures relative to measures based on total losses (such as the average total annual losses or the 95\textsuperscript{th} quantile of the operational loss distribution based on past losses) is likely due to frequency being a more stable proxy for risk exposure, as it does not fluctuate significantly when new tail losses are incurred.\textsuperscript{24}

Similar to the regressions that included only loss metrics as explanatory variables, when average loss frequency and severity are included in the same regression (model 5), the coefficient associated with average loss frequency remains positive and statistically significant both in the OLS and the 95\textsuperscript{th} quantile regressions, while the coefficient associated with average loss severity is not statistically significant in either regression. Also, the magnitude of the coefficients associated with average loss frequency in the OLS and the 95\textsuperscript{th} quantile regressions that include average loss severity is similar to the coefficients obtained in the regressions that only include average loss frequency as a loss metric.

When average frequency of large losses (i.e., loss events above $1\text{Mln}$) is separated from the average frequency of small losses (i.e., loss events between $100\text{K}$ and $1\text{Mln}$), average frequency of small losses retains predictive power while average frequency of large losses becomes not significant (model 7). Nevertheless, the coefficient associated with the frequency of small losses is slightly smaller than the coefficient associated with average frequency in model 2 for both OLS and the 95\textsuperscript{th} regressions. Similarly, when average total annual losses resulting from large loss events are separated from the average total annual losses resulting from small loss events (model 6), an increase in average total annual losses resulting from small loss events is associated with an increase in the future expected losses and 95\textsuperscript{th} quantile of the operational loss distribution, while average total losses coming from large loss events are not statistically predictive of future losses. These results show that when size and other bank characteristics are controlled

\textsuperscript{24} The higher stability of average frequency is demonstrated by its lower coefficient of variation: the coefficient of variation for average frequency above $100\text{K}$ is approximately 149\%, while the coefficient of variation of average total annual losses is approximately 207\% and the coefficient of variation of the 95\textsuperscript{th} quantile of operational loss distribution measured from past losses is approximately 195\%.
for, the volume of small losses retains predictive power over future losses but past large losses are not predictive.

High levels of total equity are negatively associated with future operational loss exposure; this relation is consistent across all specifications we tried both for the OLS and the 95\textsuperscript{th} quantile regressions and statistically significant in all cases. On the other hand, total liabilities are positively associated with future loss exposure and statistically significant. Taken together, the coefficients associated with total equity and total liabilities indicate that more leveraged banks are exposed to more operational risk; also, given the typical equity-liabilities mix of large banks, an increase in total assets is associated with an increase in future operational losses.

Except for one regression where it barely clears 10\% significance, the risk management rating given by regulators to banks has no predictive ability over future losses when other factors such as losses, liabilities, and equity are controlled for. This finding suggests that these ratings may be backward-looking, rather than forward-looking. Finally, the recession dummy and its interaction term with total assets are not statistically significant in the OLS regressions; on the other hand, the recession dummy is statistically significant in the 95\textsuperscript{th} quantile regressions and the interaction term is statistically significant at 10\% in most of these quantile regressions. Taken together, these coefficients imply that the largest banks (i.e., approximately banks with more than $100Bln in assets) saw an increase in their tail losses after crisis years while the smaller CCAR banks saw a decrease in their tail losses after crisis years.

4 Robustness Checks

To assess the robustness of our results, we conduct a variety of alternative regressions.
4.1 Controlling for Income

Gross income was used as a proxy for operational loss exposure in the Basel II standardized approaches for operational risk capital. However, as far as we are aware, the efficacy of gross income as an operational risk proxy has not been directly researched in the literature. The 2014 and 2016 Basel Committee consultative papers on changes to the operational risk capital framework introduced a new operational risk proxy, the Business Indicator, within which sub-components of gross income are treated differently. The data available to us does not allow reliable estimation of the Business Indicator and its subcomponents back beyond 2010, but nevertheless we are interested in assessing whether the major components of gross income relate differently to future operational losses and whether metrics driven by loss history remain significant when measures of income are considered. Thus, we introduce net-interest income and non-interest income as explanatory variables in the regressions of this subsection.

The income measures we use are highly correlated with total liabilities and total equity, and so regression results become very noisy when all four metrics are used. Thus, to research the validity of income metrics as proxies for operational risk and to assess whether loss metrics remain significant when income measures are used as controls, we exclude total liabilities and total equity from the regressions in this subsection. Table 5 presents the regression results.

The coefficient of non-interest income is positive and statistically significant in all the OLS regressions and flirts with statistical significant at 10% in the 95th quantile regressions. On the other hand, net-interest income only reaches statistical significance in some of the OLS specifications, and never for the 95th quantile regressions. These
results indicate that non-interest income, often associated with less traditional banking activities such as trading and fee businesses, are more consistently associated with large future operational risk than net-interest income - which is mostly derived from traditional lending businesses.

The statistical relation between the past loss metrics considered in this paper and future losses in these regressions is generally consistent with the relation found in the regressions that included total liabilities and total equity instead of income metrics. Nevertheless, the statistical significance of loss metrics in the 95th quantile regressions including income metrics is somewhat weakened relative to their significance in the quantile regressions that included equity and liabilities, but the regressions themselves also became less explanatory, as the R² statistics decreased.

4.2 Firm Fixed Effects

We have explored controlling for firm fixed effects together with the other controls used in the previous section. In OLS regressions including firm fixed effects, average loss frequency, average loss frequency from small loss events, and average loss total from small loss events retain statistical significance. But in the 95th quantile regressions no past loss metric retains statistical significance. Firm fixed effects control for idiosyncratic differences across firms that are stable through time. Given that past loss metrics likely proxy for some of these differences, it is unsurprising that their effect loses statistical significance when such firm effects are included. Despite these results, we believe the analysis produced in the remainder of the people remains useful, as it shows that past loss metrics can effectively proxy for firm differences in operational risk profiles (see Appendix G for fixed effects estimates).
5 Conclusion

Operational risk practitioners have typically relied on past operational losses to model the distribution of future operational losses. In this paper we provide evidence that past operational losses are a useful metric to predict operational loss exposure, including tail exposure. Metrics associated with loss frequency and particularly the volume of small loss events prove the most robust in forecasting exposure, likely because they are more stable proxies for risk exposure as they do not fluctuate meaningfully when new tail losses are incurred. However, financial regulators should interpret these findings with caution. Requiring the use of frequency metrics for regulatory purposes can lead to undesirable incentives, as breaking loss events into smaller loss events or aggregating them into larger loss events would have capital implications.

Loss metrics that are significantly affected by large loss events, such as average total annual losses, average loss severity, and the 95th quantile of the operational loss distribution measured from past losses, have an inconsistent relation with future losses. In particular, these variables are positively associated with future exposure when used in a stand-alone basis, but are not statistically significant when combined with other proxies for riskiness. These findings are particularly problematic for the use of LDA models to forecast exposure, as the 95th quantile of operational loss distribution measured according to a simplified LDA framework proved less predictive of future tail exposure than a simpler average frequency metric.

Finally, our analysis shows that increased leverage is associated with increase operational loss exposure, and that economic crises lead to an increase in operational loss exposure for the largest banks but to a decrease for smaller CCAR banks. On the other hand, we do not find evidence that supervisory assessments of the quality of management are statistically significant predictors of operational loss exposure.
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Table 1: Descriptive Statistics
This table presents descriptive statistics. The sample includes 240 bank-year observations. In Panel A, yearly statistics are reported for loss metrics. In Panel B, averages from the beginning of the sample are reported for loss metrics. *Yearly Loss* is the average total annual operational losses up to year $t$. *Yearly Loss > $1M* is the average total annual operational losses up to year $t$, only including operational loss events above $1,000,000$. *Count > $100K* is the average annual operational loss frequency up to year $t$, only including operational loss events above $100,000$. *Count > $1M* is the average severe or operational loss events up to year $t$, only including operational loss events above $1,000,000$. *Severity > $100K* is the average severity of operational loss events up to year $t$, only including operational loss events above $100,000$. *Individual Bootstrap 95* is the estimate of the 95 quantile of the unconditional distribution using empirical bootstrap. In Panel C, yearly statistics are reported for BHCs characteristics. In Panel D, 3 years rolling averages are reported for BHCs characteristics. *Total Assets* is the rolling three-year average of a banks total assets at year end. *Equity* is the rolling three-year average of bank’s equity at year end. *Liabilities* is the rolling three-year average of bank’s liabilities at year end. *Net Interest Income* is the rolling three-year average of bank’s yearly net interest income. *Non - Interest Income* is the rolling three-year average of bank’s yearly non-interest income. *Risk* is the value of the risk management rating given by the Federal Reserve System to BHCs. *Crisis Indicator* is a binary variable that assumes the value of one if the US is deemed to be in recession for at least one month in the year according to the NBER.

Panel A: Yearly loss metrics - $ values are in thousands

| Yearly Observation | N    | Mean   | Std. Dev. | 10th  | 50th  | 90th  | Coeff. Var. |
|--------------------|------|--------|-----------|-------|-------|-------|-------------|
| Yearly Loss        | 220  | 888,308| 2,870,432 | 13,352| 112,182| 2,048,308| 3.23        |
| Yearly Loss > $1M  | 220  | 798,728| 2,802,856 | 4,403 | 63,471 | 1,687,976| 3.50        |
| Count > $100K      | 220  | 250    | 356       | 19    | 86    | 720   | 1.42        |
| Count > $1M        | 220  | 28     | 45        | 2     | 8     | 96    | 1.60        |
| Severity > $100K   | 220  | 3,653  |           | 330   | 1,003 | 4,429 | 1.66        |

Panel B: Loss metrics from sample beginning to year $t$ - $ values are in thousands

| Average from beginning | N    | Mean   | Std. Dev. | 10th  | 50th  | 90th  | Coeff. Var. |
|------------------------|------|--------|-----------|-------|-------|-------|-------------|
| Yearly Loss            | 220  | 723,685| 1,503,896 | 15,525| 93,983| 3,581,316| 2.07        |
| Yearly Loss > $1M      | 220  | 654,361| 1,407,355 | 7,661 | 62,279| 3,330,468| 2.15        |
| Count > $100K          | 220  | 192    | 287       | 14    | 71    | 644   | 1.49        |
| Count > $1M            | 220  | 21     | 32        | 2     | 6     | 85    | 1.47        |
| Severity > $100K       | 220  | 2,246  | 2,495     | 471   | 1,347 | 6,405 | 1.11        |

Panel C: Bootstrap 95

| Yearly Observation | N    | Mean   | Std. Dev. | 10th  | 50th  | 90th  | Coeff. Var. |
|--------------------|------|--------|-----------|-------|-------|-------|-------------|
| Total Assets       | 220  | 2,271,929| 4,440,888 | 73,537| 342,919| 9,892,411| 1.95        |

Panel D: 3 years rolling average BHCs characteristics - $ values are in millions

| Yearly Observation | N    | Mean   | Std. Dev. | 10th  | 50th  | 90th  | Coeff. Var. |
|--------------------|------|--------|-----------|-------|-------|-------|-------------|
| Total Assets       | 220  | 527,059| 713,876   | 62,137| 173,220| 1,882,176| 1.35        |
| Equity             | 220  | 46,993 | 59,690    | 6,350 | 20,854 | 156,704 | 1.27        |
| Liabilities        | 220  | 478,902| 654,628   | 54,654| 152,108| 1,727,766| 1.36        |
| Non-Interest Income| 220  | 18,530 | 26,292    | 2,189 | 6,554 | 64,366 | 1.41        |
| Risk               | 220  | 0.29   | 0.45      | 0.00  | 0.00  | 0.00  | 1.54        |
| Crisis Indicator   | 220  | 0.29   | 0.45      | 0.00  | 0.00  | 0.00  | 1.54        |
Table 2: Correlations
This table presents correlations estimates and the p-values. In Panel A, correlation estimates between yearly observations are presented. In Panel B, correlation between loss metrics’ averages from the beginning and financial’s three year rolling window average are presented. Yearly Loss is the average total annual operational losses up to year \( t \). Count > $100K is the average annual operational loss frequency up to year \( t \), only including operational loss events above $100,000. Severity > $100K is the average severity of operational loss events up to year \( t \), only including operational loss events above $100,000. Individual Bootstrap 95\(^{th}\) is the estimate of the 95\(^{th}\) quantile of the unconditional distribution using empirical bootstrap. Yearly Loss $20k-$1Mln is the average total annual operational losses up to year \( t \), only including operational loss events between between $20,000 and $1,000,000. Yearly Loss > $1Mln is the average total annual operational losses up to year \( t \), only including operational loss events above $1,000,000. Count $100K-$1Mln is the average annual operational loss frequency up to year \( t \), only including operational loss events between between $100,000 and $1,000,000. Count > $1Mln is the average annual operational loss frequency up to year \( t \), only including operational loss events above $1,000,000. Equity is the rolling three-year average of bank’s equity at year end. Liabilities is the rolling three-year average of bank’s liabilities at year end. Net Interest Income is the rolling three-year average of bank’s yearly net interest income. Non – Interest Income is the rolling three-year average of bank’s yearly non-interest income. Risk is the value of the risk management rating given by the Federal Reserve System to BHCs. Crisis Indicator is a binary variable that assumes the value of one if the US is deemed to be in recession for at least one month in the year according to the NBER.

| Panel A: Yearly loss metrics - Yearly BHCs characteristics | Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|-------------------------------------------------------------|----------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 - Yearly Loss                                             |          | 1.000 |
| 2 - Count > $100K                                           |          | 0.489 | 1.000 |
|                                                           |          | (0.00) |   |
| 3 - Severity > $100K                                        |          | 0.783 | 0.314 | 1.000 |
|                                                           |          | (0.00) | (0.00) |   |
| 4 - Individual Bootstrap 95\(^{th}\)                        |          | 0.665 | 0.722 | 0.460 | 1.000 |
|                                                           |          | (0.00) | (0.00) | (0.00) |   |
| 5 - Yearly Loss $20k-$1Mln                                  |          | 0.528 | 0.989 | 0.266 | 0.758 | 1.000 |
|                                                           |          | (0.00) | (0.00) | (0.00) | (0.00) |   |
| 6 - Yearly Loss > $1Mln                                     |          | 0.999 | 0.454 | 0.790 | 0.645 | 0.494 | 1.000 |
|                                                           |          | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |   |
| 7 - Count $100K-$1Mln                                       |          | 0.572 | 0.947 | 0.305 | 0.772 | 0.982 | 0.539 | 1.000 |
|                                                           |          | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |   |
| 8 - Count > $1Mln                                           |          | 0.500 | 0.872 | 0.275 | 0.742 | 0.865 | 0.471 | 0.824 | 1.000 |
|                                                           |          | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |   |
| 9 - Equity                                                  |          | 0.532 | 0.852 | 0.329 | 0.866 | 0.880 | 0.504 | 0.833 | 0.835 | 1.000 |
|                                                           |          | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |   |
| 10- Liabilities                                             |          | 0.605 | 0.857 | 0.391 | 0.888 | 0.887 | 0.577 | 0.896 | 0.830 | 0.968 | 1.000 |
|                                                           |          | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |(0.00) |(0.00) |(0.00) |   |
| 11- Net Interest Income                                     |          | 0.599 | 0.804 | 0.392 | 0.867 | 0.846 | 0.574 | 0.868 | 0.742 | 0.894 | 0.938 | 1.000 |
|                                                           |          | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |   |
| 12- Non-Interest Income                                     |          | 0.364 | 0.785 | 0.225 | 0.702 | 0.797 | 0.335 | 0.782 | 0.764 | 0.881 | 0.876 | 0.783 | 1.000 |
|                                                           |          | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |   |
| 13- Risk                                                    |          | 0.014 | 0.073 | 0.092 | 0.143 | 0.048 | 0.013 | 0.012 | 0.101 | 0.119 | 0.066 | 0.035 | 0.047 | 1.000 |
|                                                           |          | (0.83) | (0.28) | (0.18) | (0.04) | (0.48) | (0.85) | (0.86) | (0.14) | (0.08) | (0.33) | (0.61) | (0.49) |   |
| 14- Crisis Indicator                                        |          | 0.145 | -0.044 | 0.183 | 0.032 | -0.026 | 0.150 | -0.008 | -0.007 | -0.043 | 0.006 | 0.064 | -0.080 | -0.010 | 1.000 |
|                                                           |          | (0.03) | (0.51) | (0.01) | (0.63) | (0.71) | (0.03) | (0.90) | (0.92) | (0.52) | (0.93) | (0.35) | (0.24) | (0.88) |
| Variable | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  | 14  |
|----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1 - Yearly Loss | 1.000 |
| 2 - Count > $100K | 0.899 | 1.000 |
| (0.00) |
| 3 - Severity > $100K | 0.722 | 0.556 | 1.000 |
| (0.00) (0.00) |
| 4 - Individual Bootstrap 95th | 0.975 | 0.866 | 0.723 | 1.000 |
| (0.00) (0.00) (0.00) |
| 5 - Yearly Loss $20k-$1Mln | 0.908 | 0.995 | 0.564 | 0.877 | 1.000 |
| (0.00) (0.00) (0.00) (0.00) |
| 6 - Yearly Loss > $1Mln | 0.990 | 0.885 | 0.729 | 0.975 | 0.894 | 1.000 |
| (0.00) (0.00) (0.00) (0.00) (0.00) |
| 7 - Count $100K-$1Mln | 0.891 | 0.999 | 0.536 | 0.858 | 0.995 | 0.876 | 1.000 |
| (0.00) (0.00) (0.00) (0.00) (0.00) |
| 8 - Count > $1Mln | 0.917 | 0.956 | 0.681 | 0.892 | 0.946 | 0.908 | 0.944 | 1.000 |
| (0.00) (0.00) (0.00) (0.00) (0.00) |
| 9 - Equity | 0.895 | 0.916 | 0.674 | 0.875 | 0.922 | 0.886 | 0.907 | 0.936 | 1.000 |
| (0.00) (0.00) (0.00) (0.00) (0.00) (0.00) (0.00) (0.00) |
| 10 - Liabilities | 0.901 | 0.921 | 0.718 | 0.897 | 0.920 | 0.893 | 0.911 | 0.954 | 0.973 | 1.000 |
| (0.00) (0.00) (0.00) (0.00) (0.00) (0.00) (0.00) (0.00) |
| 11 - Net Interest Income | 0.894 | 0.887 | 0.657 | 0.894 | 0.897 | 0.887 | 0.882 | 0.884 | 0.919 | 0.945 | 1.000 |
| (0.00) (0.00) (0.00) (0.00) (0.00) (0.00) (0.00) (0.00) (0.00) (0.00) |
| 12 - Non-Interest Income | 0.785 | 0.850 | 0.680 | 0.785 | 0.845 | 0.775 | 0.839 | 0.899 | 0.922 | 0.920 | 0.850 | 1.000 |
| (0.00) (0.00) (0.00) (0.00) (0.00) (0.00) (0.00) (0.00) (0.00) (0.00) |
| 13 - Risk | 0.163 | 0.135 | 0.155 | 0.134 | 0.114 | 0.165 | 0.134 | 0.122 | 0.095 | 0.089 | 0.026 | 1.000 |
| (0.02) (0.05) (0.02) (0.04) (0.09) (0.01) (0.05) (0.04) (0.07) (0.16) (0.19) (0.70) |
| 14 - Crisis Indicator | 0.022 | -0.022 | -0.001 | 0.032 | -0.012 | 0.025 | -0.021 | -0.021 | -0.037 | 0.023 | 0.079 | -0.076 | -0.010 | 1.000 |
| (0.74) (0.75) (0.99) (0.63) (0.86) (0.72) (0.75) (0.76) (0.58) (0.73) (0.24) (0.27) (0.88) |
Table 3: OLS and quantile regressions with only loss metrics
This table presents coefficient estimates from the regression of operational losses at year $t$ on loss metrics at year $t - 1$. Panel A presents OLS estimates while Panel B presents estimates from the 95\textsuperscript{th} quantile regressions. *Yearly Loss* is the average total annual operational losses up to year $t$. *Count > $100K* is the average annual operational loss frequency up to year $t$, only including operational loss events above $100,000. *Severity > $100K* is the average severity of operational loss events up to year $t$, only including operational loss events above $100,000. *Individual Bootstrap 95\textsuperscript{th}* is the estimate of the 95\textsuperscript{th} quantile of the unconditional distribution using empirical bootstrap. *Yearly Loss $20k-$1Mln* is the average total annual operational losses up to year $t$, only including operational loss events between between $20,000 and $1,000,000. *Yearly Loss > $1Mln* is the average total annual operational losses up to year $t$, only including operational loss events above $1,000,000. *Count $100K-$1Mln* is the average annual operational loss frequency up to year $t$, only including operational loss events between $100,000 and $1,000,000. *Count > $1Mln* is the average annual operational loss frequency up to year $t$, only including operational loss events above $1,000,000. P-values are presented in parentheses.

| Panel A: OLS regression | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 |
|-------------------------|---------|---------|---------|---------|---------|---------|---------|
| Yearly Loss             | 1.0349*** |         |         |         |         |         |         |
|                         | (0.00)   |         |         |         |         |         |         |
| Count > $100K (*1,000)  | 2.447*** | 2.392***|         |         |         |         |         |
|                         | (0.00)   | (0.00)  |         |         |         |         |         |
| Severity > $100K        | 41.22*** |         | 13.25   |         |         |         |         |
|                         | (0.00)   |         | (0.34)  |         |         |         |         |
| Individual Bootstrap 95\textsuperscript{th} | 0.1762*** |         |         |         |         |         |         |
|                         | (0.00)   |         |         |         |         |         |         |
| Yearly Loss $20k-$1Mln  | 4.3845***|         |         |         |         |         |         |
|                         | (0.00)   |         |         |         |         |         |         |
| Yearly Loss > $1Mln     | 0.3806** |         |         |         |         |         |         |
|                         | (0.03)   |         |         |         |         |         |         |
| Count $100K-$1Mln (*1,000) | 1.962*** |         |         |         |         |         |         |
|                         | (0.00)   |         |         |         |         |         |         |
| Count > $1Mln (*1,000)  | 34.880   |         |         |         |         |         |         |
|                         | (0.14)   |         |         |         |         |         |         |
| Bank Fixed Effects      | No       | No      | No      | No      | No      | No      | No      |
| N                      | 220      | 220     | 220     | 220     | 220     | 220     | 220     |
| $R^2$                  | 0.31     | 0.37    | 0.04    | 0.18    | 0.38    | 0.41    | 0.38    |

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Panel B: 95\textsuperscript{th} quantile regression

|                          | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 |
|--------------------------|---------|---------|---------|---------|---------|---------|---------|
| Yearly Loss              | 2.8103*** (0.00) |
| Count > $100K (*1,000)  | 7.132*** (0.00)  | 7.138*** (0.00) |
| Severity > $100K        | 282.48*** (0.00) | (0.85)  |
| Individual Bootstrap 95\textsuperscript{th} | 0.6519*** (0.00) |
| Yearly Loss $20k-$1Mln |                | 14.83*** (0.00) |
| Yearly Loss > $1Mln     |                | 0.8535** (0.03) |
| Count $100K-$1Mln (*1,000) |             | 6.685*** (0.00) |
| Count > $1Mln (*1,000)  |                | 29.202 (0.64)  |
| Bank Fixed Effects      | No      | No      | No      | No      | No      | No      | No      |
| N                       | 220     | 220     | 220     | 220     | 220     | 220     | 220     |
| $R^2$                   | 0.42    | 0.49    | 0.13    | 0.37    | 0.49    | 0.49    | 0.49    |

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Table 4: OLS and quantile regressions with loss metrics and additional controls

This table presents coefficients estimates from regression of operational losses at year $t$ on loss metrics and BHCs characteristics at year $t-1$. Panel A presents OLS estimates while Panel B presents estimates from the 95th quantile regressions. Yearly Loss is the average total annual operational losses up to year $t$. Count > $100K$ is the average annual operational loss frequency up to year $t$, only including operational loss events above $\$100,000$. Severity > $100K$ is the average severity of operational loss events up to year $t$, only including operational loss events above $\$100,000$. Individual Bootstrap 95th is the estimate of the 95th quantile of the unconditional distribution using empirical bootstrap. Yearly Loss $20k$-$1Mln is the average total annual operational losses up to year $t$, only including operational loss events between $\$20,000$ and $\$1,000,000$. Yearly Loss > $1Mln is the average total annual operational losses up to year $t$, only including operational loss events above $\$1,000,000$. Count > $1Mln is the average annual operational loss frequency up to year $t$, only including operational loss events above $\$1,000,000$. Equity is the rolling three-year average of bank’s equity at year end. Liabilities is the rolling three-year average of bank’s liabilities at year end. Risk is the value of the risk management rating given by the Federal Reserve System to BHCs. TA is the value of BHCs total assets at the end of the year. Crisis Indicator is a binary variable that assumes the value of one if the US is deemed to be in recession for at least one month in the year according to the NBER. P-values are presented in parentheses.

| Panel A: OLS regression | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 |
|-------------------------|---------|---------|---------|---------|---------|---------|---------|
| Yearly Loss             | 0.5146* | (0.05)  | 1.856***| 1.839***| (0.00)  | (0.00)  | (0.00)  |
| Count > $100K (*1,000)  |         |         |         |         |         |         |         |
| Severity > $100K        | 12.55   | (0.58)  | 6.9296  | (0.58)  | (0.00)  | (0.00)  | (0.00)  |
| Individual Bootstrap 95th| 0.0362  | (0.33)  |         |         |         |         |         |
| Yearly Loss $20k$-$1Mln |         |         |         |         |         |         | 4.8058***|
| Yearly Loss > $1Mln     |         |         |         |         |         |         | (0.00)  |
| Count > $1Mln (*1,000)  |         |         |         |         |         |         | 0.1622  |
| Equity                  | -0.0056***| (0.00) | -0.0086***| -0.0082***| -0.0056***| -0.0069***| -0.0055***|
| Liabilities             | 0.0017***| (0.02) | 0.0020***| 0.0019***| 0.0015***| 0.0020***| 0.0015***|
| Risk (*1,000)           | -61.00  | (0.85)  | -14.96  | -11.195 | 10.115  | 33.320* | 15.856  |
| Risk*TA                 | -0.0000 | (0.81)  | 0.0002  | 0.0001  | -0.0001 | -0.0003*| -0.0003*|
| Crisis (*1,000)         | -28.446 | (0.20)  | -21.806 | -19.573 | -2.342  | -25.463 | -14.182 |
| Crisis*TA               | 0.0003  | (0.18)  | 0.0002  | 0.0002  | 0.0002  | 0.0003  | 0.0003  |
| Bank Fixed Effects      | No      | No      | No      | No      | No      | No      | No      |
| N                       | 220     | 220     | 220     | 220     | 220     | 220     | 220     |
| $R^2$                   | 0.36    | 0.43    | 0.34    | 0.34    | 0.43    | 0.46    | 0.43    |

*p < 0.10, **p < 0.05, ***p < 0.01
Panel B: 95\textsuperscript{th} quantile regression

|                      | Model 1     | Model 2     | Model 3     | Model 4     | Model 5     | Model 6     | Model 7     |
|----------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Yearly Loss          | 0.9071      |             |             |             |             |             |             |
|                      | (0.57)      |             |             |             |             |             |             |
| Count > $100K (\times 1,000) | 4.010**     | 3.675*      |             |             |             |             |             |
|                      | (0.04)      | (0.05)      |             |             |             |             |             |
| Severity > $100K     | 0.2779      | -12.94      |             |             |             |             |             |
|                      | (0.75)      | (0.84)      |             |             |             |             |             |
| Individual Bootstrap 95\textsuperscript{th} | 0.0301      |             |             |             |             |             |             |
|                      | (0.90)      |             |             |             |             |             |             |
| Yearly Loss $20k-$1Mln |             |             |             |             |             |             | 10.16*      |
|                      |             |             |             |             |             |             | (0.05)      |
| Yearly Loss > $1Mln  |             |             |             |             |             |             | -0.2086     |
|                      |             |             |             |             |             |             | (0.96)      |
| Count $100K-$1Mln (\times 1,000) | 3.219*      |             |             |             |             |             |             |
|                      | (0.09)      |             |             |             |             |             |             |
| Count > $1Mln (\times 1,000) | -23,013     |             |             |             |             |             |             |
|                      | (0.60)      |             |             |             |             |             |             |
| Equity               | -0.0287***  | -0.0237***  | -0.0313***  | -0.0310***  | -0.0249***  | -0.0263***  | -0.0275***  |
|                      | (0.00)      | (0.00)      | (0.00)      | (0.00)      | (0.00)      | (0.00)      | (0.00)      |
| Liabilities          | 0.0081***   | 0.0051**    | 0.0099***   | 0.0096***   | 0.0060**    | 0.0066**    | 0.0072**    |
|                      | (0.00)      | (0.01)      | (0.00)      | (0.00)      | (0.01)      | (0.01)      | (0.02)      |
| Risk (\times 1,000)  | 101.025     | 93.791      | 115.819     | 115.571     | 105.191     | 115.215     | 106.707     |
|                      | (0.26)      | (0.28)      | (0.23)      | (0.24)      | (0.34)      | (0.17)      | (0.48)      |
| Risk*TA              | -0.0006     | -0.0003     | -0.0009     | -0.0009     | -0.0004     | -0.0006     | -0.0005     |
|                      | (0.39)      | (0.49)      | (0.33)      | (0.36)      | (0.67)      | (0.35)      | (0.71)      |
| Crisis (\times 1,000) | -183.591**  | -127.42**   | -208.635**  | -197.99**   | -148.422**  | -162.975**  | -155.693**  |
|                      | (0.03)      | (0.03)      | (0.04)      | (0.02)      | (0.04)      | (0.03)      | (0.07)      |
| Crisis*TA            | 0.0013      | 0.0010*     | 0.0017      | 0.0015      | 0.0011*     | 0.0012*     | 0.0011*     |
|                      | (0.20)      | (0.09)      | (0.28)      | (0.19)      | (0.07)      | (0.05)      | (0.09)      |
| Bank Fixed Effects   | No          | No          | No          | No          | No          | No          | No          |
| N                    | 220         | 220         | 220         | 220         | 220         | 220         | 220         |
| R²                   | 0.56        | 0.58        | 0.55        | 0.55        | 0.58        | 0.59        | 0.59        |

*p < 0.10, **p < 0.05, ***p < 0.01
Table 5: OLS and quantile regressions with loss metrics and income controls
This table presents coefficients estimates from regression of operational losses at year \( t \) on loss metrics and BHCs characteristics at year \( t - 1 \). Panel A presents OLS estimates while Panel B presents estimates from the 95\(^{th} \) quantile regressions. Yearly Loss is the average total annual operational losses up to year \( t \). Count > $100K is the average annual operational loss frequency up to year \( t \), only including operational loss events above $100,000. Severity > $100K is the average severity of operational loss events up to year \( t \), only including operational loss events above $100,000. Individual Bootstrap 95\(^{th} \) is the estimate of the 95\(^{th} \) quantile of the unconditional distribution using empirical bootstrap. Yearly Loss $20k-$1Mln is the average total annual operational losses up to year \( t \), only including operational loss events between $20,000 and $1,000,000. Yearly Loss > $1Mln is the average total annual operational losses up to year \( t \), only including operational loss events above $1,000,000. Count > $1Mln is the average annual operational loss frequency up to year \( t \), only including operational loss events between $100,000 and $1,000,000. Interest Income is the value of the interest income at the end of the year. Net Interest Income is the rolling three-year average of bank’s yearly net interest income. Non – Interest Income is the rolling three-year average of bank’s yearly non-interest income. Risk is the value of the risk management rating given by the Federal Reserve System to BHCs. TA is the rolling three-year average of a bank’s total assets at year end. Crisis Indicator is a binary variable that assumes the value of one if the US is deemed to be in recession for at least one month in the year according to the NBER.

Panel A: OLS regression

|                      | Model 1     | Model 2     | Model 3     | Model 4     | Model 5     | Model 6     | Model 7     |
|----------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Yearly Loss          | 0.4642**    |             |             |             |             |             |             |
|                      | (0.01)      |             |             |             |             |             |             |
| Count > $100K (*1,000) | 1,415***    | 1,414***    |             |             |             |             |             |
|                      | (0.00)      | (0.00)      |             |             |             |             |             |
| Severity > $100K     | 2.7685      | 1.3929      |             |             |             |             |             |
|                      | (0.82)      | (0.81)      |             |             |             |             |             |
| Individual Bootstrap 95\(^{th} \) | 0.0498      |             |             |             |             |             |             |
|                      | (0.24)      |             |             |             |             |             |             |
| Yearly Loss $20k-$1Mln |             |             |             |             |             |             | 3.3470**    |
|                      |             |             |             |             |             |             | (0.01)      |
| Yearly Loss > $1Mln  |             |             |             |             |             |             | 0.2394      |
|                      |             |             |             |             |             |             | (0.25)      |
| Count $100K-$1Mln (*1,000) | 1.460***    |             |             |             |             |             |             |
|                      | (0.00)      |             |             |             |             |             |             |
| Count > $1Mln (*1,000) | -4.505      |             |             |             |             |             |             |
|                      | (0.77)      |             |             |             |             |             |             |
| Net Interest Income  | 0.0059*     | 0.0041*     | 0.0043      | 0.0064      | 0.0042*     | -0.0005     | 0.0044**    |
|                      | (0.06)      | (0.07)      | (0.19)      | (0.11)      | (0.09)      | (0.89)      | (0.02)      |
| Non-Interest Income  | 0.0164***   | 0.0142***   | 0.0188***   | 0.0178***   | 0.0141***   | 0.0130***   | 0.0143***   |
|                      | (0.00)      | (0.00)      | (0.00)      | (0.00)      | (0.00)      | (0.00)      | (0.00)      |
| Risk (*1,000)        | -4,608      | -3,668      | -21,972     | -12,744     | -3,759      | -192.00     | -4,891      |
|                      | (0.75)      | (0.89)      | (0.11)      | (0.35)      | (0.92)      | (0.92)      | (0.82)      |
| Risk*TA              | -0.0000     | -0.0000     | 0.0001      | 0.0000      | -0.0000     | 0.0000      | -0.0000     |
|                      | (0.76)      | (0.88)      | (0.12)      | (0.69)      | (0.89)      | (0.92)      | (0.94)      |
| Crisis (*1,000)      | 5.01        | 25.802      | 26.105      | 19.730      | 25.473      | 15.569      | 27.836      |
|                      | (0.93)      | (0.46)      | (0.61)      | (0.54)      | (0.59)      | (0.69)      | (0.51)      |
| Crisis*TA            | 0.0003      | 0.0002      | 0.0002      | 0.0002      | 0.0002      | 0.0003      | 0.0002      |
|                      | (0.29)      | (0.48)      | (0.55)      | (0.46)      | (0.47)      | (0.34)      | (0.56)      |
| Bank Fixed Effects   | No          | No          | No          | No          | No          | No          | No          |
| N                    | 220         | 220         | 220         | 220         | 220         | 220         | 220         |
| R\(^2\)              | 0.45        | 0.48        | 0.43        | 0.44        | 0.48        | 0.48        | 0.48        |

\* \( p < 0.10 \); \** \( p < 0.05 \); \*** \( p < 0.01 \)
## Panel B: 95th quantile regression

|                      | Model 1     | Model 2     | Model 3     | Model 4     | Model 5     | Model 6     | Model 7     |
|----------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Yearly Loss          | 1.2643      |             |             |             |             |             |             |
|                      | (0.29)      |             |             |             |             |             |             |
| Count > $100K (1,000)| 4.661*      | 4.371*      |             |             |             |             |             |
|                      | (0.05)      | (0.05)      |             |             |             |             |             |
| Severity > $100K     | -39.69      | -26.35      |             |             |             |             |             |
|                      | (0.15)      | (0.26)      |             |             |             |             |             |
| Individual Bootstrap | 0.1012      |             |             |             |             |             |             |
| 95th                 | (0.69)      |             |             |             |             |             |             |
| Yearly Loss $20k-$1Mln | 11.40      |             |             |             |             |             |             |
|                      | (0.32)      |             |             |             |             |             |             |
| Yearly Loss > $1Mln  | -0.1386     |             |             |             |             |             |             |
|                      | (0.57)      |             |             |             |             |             |             |
| Count $100K-$1Mln (1,000) | 4.395*     |             |             |             |             |             |             |
|                      | (0.06)      |             |             |             |             |             |             |
| Count > $1Mln (1,000) | -77.33      |             |             |             |             |             |             |
|                      | (0.74)      |             |             |             |             |             |             |
| Net Interest Income  | 0.0313      | 0.0075      | 0.0072      | 0.0213      | 0.0049      | 0.0180      | -0.0064     |
|                      | (0.80)      | (0.78)      | (0.88)      | (0.87)      | (0.93)      | (0.84)      | (0.89)      |
| Non-Interest Income  | 0.0319      | 0.0440      | 0.0300*     | 0.0439*     | 0.0312      | 0.0399      | 0.0253      |
|                      | (0.11)      | (0.21)      | (0.06)      | (0.07)      | (0.17)      | (0.28)      | (0.20)      |
| Risk (1,000)         | 8.974       | 10.561      | -110,308    | -42,300     | -22,449     | 7.113       | -75,866     |
|                      | (0.53)      | (0.96)      | (0.18)      | (0.37)      | (0.92)      | (0.96)      | (0.78)      |
| Risk*TA              | -0.0000     | -0.0001     | 0.0009*     | 0.0003      | 0.0001      | 0.0000      | 0.0004      |
|                      | (0.62)      | (1.00)      | (0.06)      | (0.40)      | (0.86)      | (0.92)      | (0.75)      |
| Crisis (1,000)       | -144,452    | -113,842*   | -46,970     | -75,136     | -208,516    | -152,808*   | -87,480     |
|                      | (0.14)      | (0.06)      | (0.28)      | (0.15)      | (0.10)      | (0.09)      | (0.16)      |
| Crisis*TA            | 0.0009      | 0.0019*     | 0.0015      | 0.0010      | 0.0036*     | 0.0020      | 0.0019*     |
|                      | (0.21)      | (0.05)      | (0.10)      | (0.17)      | (0.06)      | (0.10)      | (0.06)      |
| Bank Fixed Effects   | No          | No          | No          | No          | No          | No          | No          |
| N                   | 220         | 220         | 220         | 220         | 220         | 220         | 220         |
| R²                  | 0.50        | 0.54        | 0.50        | 0.50        | 0.54        | 0.52        | 0.55        |

*p < 0.10, ** p < 0.05, *** p < 0.01
Appendix A

Table 6: Bank Holding Companies
This table presents the list of all the Bank Holding Companies that were considered in our study.

| Bank Holding Company Name                        |
|-------------------------------------------------|
| Ally Financial Inc.                             |
| American Express Company                        |
| Bank of America Corporation                     |
| The Bank of New York Mellon Corporation         |
| BB&T Corporation                                |
| BBVA Compass Bancshares, Inc.                    |
| BMO Financial Corporation                       |
| Capital One Financial Corporation               |
| Citigroup Inc.                                  |
| Citizens Financial Group, Inc.                  |
| Comerica Inc.                                   |
| Deutsche Bank Trust Corporation                 |
| Discover Financial Services                     |
| Fifth Third Bancorp.                            |
| The Goldman Sachs Group, Inc.                   |
| HSBC North America Holdings, Inc.               |
| Huntington Bancshares Inc.                      |
| JPMorgan Chase & Co.                            |
| KeyCorp                                         |
| M&T Corporation                                 |
| Morgan Stanley                                  |
| MUFG Americas Holding Corporation               |
| Northern Trust Corporation                      |
| The PNC Financial Services Group, Inc.          |
| Regions Financial Corporation                   |
| Santander Holdings USA, Inc.                    |
| State Street Corporation                        |
| SunTrust Banks, Inc.                            |
| U.S. Bancorp.                                   |
| Wells Fargo &Co.                                |
| Zions Bancorp.                                  |

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### Appendix B

Table 7: **Variable Definitions**
This table presents the list and describe all variables used in our study.

| Variable                        | Description                                                                                                                                 |
|---------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| **Yearly Loss**                 | *Yearly Loss* is the average total annual operational losses up to year $t$.                                                                  |
| **Yearly Loss $20k-$1Mln**      | *Yearly Loss* $20k-$1Mln is the average total annual operational losses up to year $t$, only including operational loss events between between $20,000 and $1,000,000. |
| **Yearly Loss > $1Mln**         | *Yearly Loss* > $1Mln is the average total annual operational losses up to year $t$, only including operational loss events above $1,000,000.         |
| **Count > $100K**               | *Count* > $100K is the average annual operational loss frequency up to year $t$, only including operational loss events above $100,000.              |
| **Count $100K-$1Mln**           | *Count* $100K-$1Mln is the average annual operational loss frequency up to year $t$, only including operational loss events between $100,000 and $1,000,000. |
| **Count > $1Mln**               | *Count* > $1Mln is the average annual operational loss frequency up to year $t$, only including operational loss events above $1,000,000.           |
| **Severity > $100K**            | *Severity* > $100K is the average severity of operational loss events up to year $t$, only including operational loss events above $100,000.          |
| **Individual Bootstrap 95th**   | *Individual Bootstrap 95th* is the estimate of the 95th quantile of the unconditional distribution using empirical bootstrap with data from the beginning of the sample. Three full years of data are required to compute the estimate. |
| **Equity**                      | *Equity* is the rolling three-year average of bank’s equity at year end.                                                                     |
| **Liabilities**                 | *Liabilities* is the rolling three-year average of bank’s liabilities at year end.                                                            |
| **Risk**                        | *Risk* is the value of the comprehensive risk management rating given by the Federal Reserve System to banks. The value ranges from 1, strong risk management, to 5, weak risk management. |
| **TA**                          | *TA* is the rolling three-year average of a banks total assets at year end.                                                                    |
| **Crisis Indicator**            | *Crisis Indicator* is a binary variable that assumes the value of one if the US is deemed to be in recession for at least one month in the year according to the NBER. |
| **Net Interest Income**         | *Net Interest Income* is the rolling three-year average of bank’s yearly net interest income.                                                 |
| **Non – Interest Income**       | *Non – Interest Income* is the rolling three-year average of bank’s yearly non-interest income.                                             |
Appendix C

Table 8: OLS and quantile regressions with loss metrics and additional controls - Minimum interquantile range for each observation increased to 0.1

This table presents coefficients estimates from regression of operational losses at year $t$ on loss metrics and BHCs characteristics at year $t-1$. Panel A presents OLS estimates while Panel B presents estimates from the 95th quantile regressions. *Yearly Loss* is the average total annual operational losses up to year $t$. *Count > $100K* is the average annual operational loss frequency up to year $t$, only including operational loss events above $100,000$. *Severity > $100K* is the average severity of operational loss events up to year $t$, only including operational loss events above $100,000$. *Individual Bootstrap 95th* is the estimate of the 95th quantile of the unconditional distribution using empirical bootstrap. *Yearly Loss $20k-$1Mln* is the average total annual operational losses up to year $t$, only including operational loss events between between $20,000$ and $1,000,000$. *Yearly Loss > $1Mln* is the average total annual operational losses up to year $t$, only including operational loss events above $1,000,000$. *Count $100K-$1Mln* is the average annual operational loss frequency up to year $t$, only including operational loss events between $100,000$ and $1,000,000$. *Count > $1Mln* is the average annual operational loss frequency up to year $t$, only including operational loss events above $1,000,000$. *Equity* is the rolling three-year average of bank’s equity at year end. *Liabilities* is the rolling three-year average of a bank’s liabilities at year end. *Risk* is the value of the risk management rating given by the Federal Reserve System to BHCs. *TA* is the rolling three-year average of a bank’s total assets at year end. *Crisis Indicator* is a binary variable that assumes the value of one if the US is deemed to be in recession for at least one month in the year according to the NBER. P-values are presented in parentheses.
Panel A: OLS regression

|                         | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 |
|-------------------------|---------|---------|---------|---------|---------|---------|---------|
| Yearly Loss             | 0.2806  | (0.23)  |         |         |         |         |         |
| Count > $100K (*1,000)  |         | 1.506** | 1.522***|         |         |         |         |
| Severity > $100K        |         | -0.9849 | 5.8758  |         |         |         |         |
| Individual Bootstrap 95th|         | 0.0178  |         |         |         |         |         |
| Yearly Loss $20k-$1Mln  |         |         |         |         |         |         | 5.6915***|
| Yearly Loss > $1Mln     |         |         |         |         |         |         | 0.0149  |
| Count $100K-$1Mln (*1,000)|         |         |         |         |         |         |         |
| Count > $1Mln (*1,000)  |         |         |         |         |         |         | 17.021  |
| Equity                  | -0.0074**| -0.0069**| -0.0088**| -0.0085**| -0.0069**| -0.0091***| -0.0069**| (0.03) |
| Liabilities             | 0.0030***| 0.0026***| 0.0031***| 0.0031***| 0.0027***| 0.0028***| 0.0026***|         |
| Risk (*1,000)           | 18.248  | 21.032  | 7.155   | 10.560  | 21.693  | 37.229  |         | 26.414  |
| Risk*TA                 | -0.0004 | -0.0004 | -0.0003 | -0.0003 | -0.0004 | -0.0005*| -0.0005*|         |
| Crisis (*1,000)         | -55.227*| -37.294 | -52.446*| -53.993*| -37.236 | -36.186 |         | -42.975 |
| Crisis*TA               | 0.0005  | 0.0004  | 0.0004  | 0.0004  | 0.0004  | 0.0004  |         | 0.0005  |
| Bank Fixed Effects      | No      | No      | No      | No      | No      | No      | No      |         |
| N                       | 220     | 220     | 220     | 220     | 220     | 220     | 220     |         |
| R²                      | 0.28    | 0.32    | 0.27    | 0.27    | 0.32    | 0.35    | 0.32    |         |

*p < 0.10, **p < 0.05, ***p <0.01
Panel B: 95th quantile regression

|                      | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 |
|----------------------|---------|---------|---------|---------|---------|---------|---------|
| Yearly Loss          | 0.4133  |         |         |         |         |         |         |
|                      | (0.77)  |         |         |         |         |         |         |
| Count > $100K (*1,000) | 2.845*  | 2.852*  |         |         |         |         |         |
|                      | (0.05)  | (0.08)  |         |         |         |         |         |
| Severity > $100K     |         | 8.6594  | 41.56   |         |         |         |         |
|                      |         | (0.78)  | (0.74)  |         |         |         |         |
| Individual Bootstrap 95th | 0.0535  |         |         |         |         |         |         |
|                      | (0.83)  |         |         |         |         |         |         |
| Yearly Loss $20k-$1Mln| 9.8448* |         |         |         |         |         |         |
|                      | (0.06)  |         |         |         |         |         |         |
| Yearly Loss > $1Mln  | -0.2409 |         |         |         |         |         |         |
|                      | (0.97)  |         |         |         |         |         |         |
| Count $100K-$1Mln (*1,000) | 2.909  |         |         |         |         |         |         |
|                      | (0.17)  |         |         |         |         |         |         |
| Count > $1Mln (*1,000) | -21.43  |         |         |         |         |         |         |
|                      | (0.91)  |         |         |         |         |         |         |
| Equity               | -0.0396*| -0.0302**| -0.0430*| -0.0420*| -0.0258**| -0.0271***| -0.0286**|
|                      | (0.09)  | (0.02)  | (0.05)  | (0.06)  | (0.02)  | (0.00)  | (0.01)  |
| Liabilities          | 0.0123***| 0.0086**| 0.0150***| 0.0135***| 0.0096**| 0.0069***| 0.0081**|
|                      | (0.00)  | (0.01)  | (0.00)  | (0.00)  | (0.02)  | (0.00)  | (0.01)  |
| Risk (*1,000)        | 192.902 | 134.214 | 265.762 | 217.779 | 141.487 | 116.785 | 119.412 |
|                      | (0.45)  | (0.37)  | (0.41)  | (0.50)  | (0.37)  | (0.22)  | (0.58)  |
| Risk*TA              | -0.0014 | -0.0009 | -0.0019 | -0.0016 | -0.0012 | -0.0006 | -0.0007 |
|                      | (0.24)  | (0.35)  | (0.27)  | (0.28)  | (0.36)  | (0.29)  | (0.56)  |
| Crisis (*1,000)      | -287.402| -173.85 | -238.48 | -262.571| -97.599 | -166.826| -166.484|
|                      | (0.17)  | (0.15)  | (0.27)  | (0.19)  | (0.22)  | (0.15)  | (0.21)  |
| Crisis*TA            | 0.0017  | 0.0012  | 0.0011  | 0.0013  | 0.0006  | 0.0012  | 0.0011  |
|                      | (0.39)  | (0.19)  | (0.47)  | (0.42)  | (0.26)  | (0.18)  | (0.22)  |
| Bank Fixed Effects   | No      | No      | No      | No      | No      | No      | No      |
| N                    | 220     | 220     | 220     | 220     | 220     | 220     | 220     |
| R²                   | 0.53    | 0.55    | 0.52    | 0.52    | 0.56    | 0.56    | 0.56    |

*p < 0.10, **p < 0.05, ***p < 0.01
This table presents estimates from regression of operational losses at year \( t \) on loss metrics and BHCs characteristics at year \( t-1 \). Panel A presents OLS estimates while Panel B presents estimates from the 95\(^{th}\) quantile regressions. Yearly Loss is the average total annual operational losses up to year \( t \). Count > $100K is the average annual operational loss frequency up to year \( t \), only including operational loss events above $100,000. Severity > $100K is the average severity of operational loss events up to year \( t \), only including operational loss events above $100,000. Individual Bootstrap 95\(^{th}\) is the estimate of the 95\(^{th}\) quantile of the unconditional distribution using empirical bootstrap. Yearly Loss $20k-$1Mln is the average total annual operational losses up to year \( t \), only including operational loss events between $20,000 and $1,000,000. Yearly Loss > $1Mln is the average total annual operational losses up to year \( t \), only including operational loss events above $1,000,000. Count > $1Mln is the average annual operational loss frequency up to year \( t \), only including operational loss events between $100,000 and $1,000,000. Count > $1Mln is the average annual operational loss frequency up to year \( t \), only including operational loss events above $1,000,000. Equity is the rolling three-year average of bank’s equity at year end. Liabilities is the rolling three-year average of bank’s liabilities at year end. Risk is the value of the risk management rating given by the Federal Reserve System to BHCs. TA is the rolling three-year average of a banks total assets at year end. Crisis Indicator is a binary variable that assumes the value of one if the US is deemed to be in recession for at least one month in the year according to the NBER. P-values are presented in parentheses.

|                           | Model 1       | Model 2       | Model 3       | Model 4       | Model 5       | Model 6       | Model 7       |
|---------------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| Yearly Loss               | 0.5492        |               |               |               |               |               |               |
| (0.07)                    |               |               |               |               |               |               |               |
| Count > $100K (*1,000)    | 1.927***      | 1.907***      |               |               |               |               |               |
| (0.00)                    | (0.00)        | (0.00)        |               |               |               |               |               |
| Severity > $100K          | 13.21         | 4.7239        |               |               |               |               |               |
| (0.66)                    | (0.72)        |               |               |               |               |               |               |
| Individual Bootstrap 95\(^{th}\) | 0.0370       |               |               |               |               |               |               |
| (0.42)                    |               |               |               |               |               |               |               |
| Yearly Loss $20k-$1Mln    |               |               |               | 4.7879***     |               |               |               |
| (0.00)                    |               |               |               | (0.00)        |               |               |               |
| Yearly Loss > $1Mln       |               |               |               | 0.2108        |               |               |               |
| (0.35)                    |               |               |               | (0.35)        |               |               |               |
| Count $100K-$1Mln (*1,000) |               |               |               |               | 1.687***      |               |               |
| (0.00)                    |               |               |               | (0.00)        | (0.00)        |               |               |
| Count > $1Mln (*1,000)    |               |               |               |               | 22.550        |               |               |
| (0.33)                    |               |               |               | (0.33)        | (0.28)        |               |               |
| Equity                    | -0.0059**     | -0.0055***    | -0.0073***    | -0.0072***    | -0.0055***    | -0.0055***    | -0.0055***    |
| (0.01)                    | (0.00)        | (0.00)        | (0.00)        | (0.00)        | (0.00)        | (0.00)        | (0.00)        |
| Liabilities               | 0.0003        | 0.0006        | 0.0004        | 0.0005        | 0.0005        | 0.0009**      | 0.0005        |
| (0.53)                    | (0.18)        | (0.37)        | (0.38)        | (0.23)        | (0.23)        | (0.04)        | (0.28)        |
| Risk (*1,000)             | -30.131       | -11.364       | -48.546       | -42.687       | -13.465       | 13.423        | -10.590       |
| (0.51)                    | (0.87)        | (0.34)        | (0.43)        | (0.83)        | (0.83)        | (0.36)        | (0.94)        |
| Risk*TA                   | 0.0005        | 0.0002        | 0.0007        | 0.0006        | 0.0003        | -0.0001       | 0.0002        |
| (0.50)                    | (0.71)        | (0.38)        | (0.44)        | (0.67)        | (0.67)        | (0.58)        | (0.72)        |
| Crisis (*1,000)           | -32.728       | -9.161        | -25.808       | -29.210       | -7.310        | -31.492       | -15.951       |
| (0.23)                    | (0.76)        | (0.43)        | (0.39)        | (0.70)        | (0.70)        | (0.22)        | (0.52)        |
| Crisis*TA                 | 0.0004        | 0.0003        | 0.0003        | 0.0004        | 0.0003        | 0.0004        | 0.0003        |
| (0.19)                    | (0.34)        | (0.30)        | (0.29)        | (0.30)        | (0.30)        | (0.12)        | (0.19)        |
| Bank Fixed Effects        | No            | No            | No            | No            | No            | No            | No            |
| N                         | 220           | 220           | 220           | 220           | 220           | 220           | 220           |
| R^2                       | 0.42          | 0.48          | 0.39          | 0.48          | 0.51          | 0.48          |               |

\( p < 0.10; \) \( \ast p < 0.05; \) \( \ast\ast p < 0.01 \)
Panel B: 95\textsuperscript{th} quantile regression

|                         | Yearly Loss | Count > $100K (\times1,000) | Severity > $100K | Individual Bootstrap 95\textsuperscript{th} | Yearly Loss $20k-$1Mln | Yearly Loss > $1Mln | Count $100K-$1Mln (\times1,000) | Count > $1Mln (\times1,000) |
|-------------------------|-------------|------------------------------|------------------|---------------------------------------------|------------------------|----------------------|----------------------------------|-------------------------------|
|                         | 0.5913      | 4.429*                       | 12.60            | 0.1057                                       | 11.79**                | -0.0438              | 4.684*                          | -32.146                       |
|                         | (0.43)      | (0.02)                       | (0.76)           | (0.84)                                       | (0.04)                 | (0.97)               | (0.05)                          | (0.51)                        |
| Equity                  | -0.0278***  | -0.0214***                   | -0.0289***       | -0.0224***                                   | -0.0190***             | -0.0190***           | -0.0190***                      | -0.0190***                    |
|                         | (0.00)      | (0.00)                       | (0.00)           | (0.00)                                       | (0.00)                 | (0.00)               | (0.01)                          | (0.01)                        |
| Liabilities             | 0.0079**    | 0.0039**                     | 0.0079***        | 0.0093***                                    | 0.0051**               | 0.0039**             | 0.0039**                        | 0.0039**                      |
|                         | (0.02)      | (0.03)                       | (0.00)           | (0.05)                                       | (0.01)                 | (0.02)               | (0.02)                          | (0.02)                        |
| Risk (\times1,000)     | 77.378      | 79.161                       | 77.867           | 78.883                                       | 107.194                | 76.481               | 76.481                          | 76.481                        |
|                         | (0.30)      | (0.32)                       | (0.27)           | (0.35)                                       | (0.23)                 | (0.48)               | (0.48)                          | (0.48)                        |
| Risk*TA                 | -0.0004     | -0.0000                      | -0.0006          | 0.0000                                       | -0.0005                | 0.0000               | -0.0002                         | -0.0002                       |
|                         | (0.52)      | (0.67)                       | (0.43)           | (0.49)                                       | (0.40)                 | (0.92)               | (0.92)                          | (0.92)                        |
| Crisis (\times1,000)   | -201.120**  | -126.176**                   | -186.129**       | -173.571**                                   | -165.59**              | -192.559**           | -138.608**                      | -138.608**                    |
|                         | (0.02)      | (0.02)                       | (0.01)           | (0.03)                                       | (0.00)                 | (0.04)               | (0.04)                          | (0.04)                        |
| Crisis*TA               | 0.0015      | 0.0013**                     | 0.0011           | 0.0009                                       | 0.0018**               | 0.0021**             | 0.0014*                         | 0.0014*                       |
|                         | (0.16)      | (0.04)                       | (0.14)           | (0.34)                                       | (0.03)                 | (0.05)               | (0.05)                          | (0.05)                        |
| Bank Fixed Effects      | No          | No                           | No               | No                                           | No                     | No                   | No                              | No                            |
| N                       | 220         | 220                          | 220              | 220                                          | 220                    | 220                  | 220                             | 220                           |
| R\textsuperscript{2}    | 0.58        | 0.60                         | 0.57             | 0.60                                         | 0.60                   | 0.60                 | 0.60                            | 0.60                          |

\* p < 0.10, \*\* p < 0.05, \*\*\* p < 0.01
Appendix D

Table 10: OLS and quantile regressions with loss metrics and additional controls - intertertile range used for weighting

This table presents coefficients estimates from regression of operational losses at year $t$ on loss metrics and BHCs characteristics at year $t - 1$. Panel A presents OLS estimates while Panel B presents estimates from the 95th quantile regressions. *Yearly Loss* is the average total annual operational losses up to year $t$. *Count > $100K* is the average annual operational loss frequency up to year $t$, only including operational loss events above $100,000$. *Severity > $100K* is the average severity of operational loss events up to year $t$, only including operational loss events above $100,000$. *Individual Bootstrap 95th* is the estimate of the 95th quantile of the unconditional distribution using empirical bootstrap. *Yearly Loss $20k-$1Mln* is the average total annual operational losses up to year $t$, only including operational loss events between between $20,000 and $1,000,000. *Yearly Loss > $1Mln* is the average total annual operational losses up to year $t$, only including operational loss events above $1,000,000$. *Count $100K-$1Mln* is the average annual operational loss frequency up to year $t$, only including operational loss events between $100,000 and $1,000,000. *Count > $1Mln* is the average annual operational loss frequency up to year $t$, only including operational loss events above $1,000,000$. *Equity* is the rolling three-year average of bank’s equity at year end. *Liabilities* is the rolling three-year average of bank’s liabilities at year end. *Risk* is the value of the risk management rating given by the Federal Reserve System to BHCs. *TA* is the rolling three-year average of a bank’s total assets at year end. *Crisis Indicator* is a binary variable that assumes the value of one if the US is deemed to be in recession for at least one month in the year according to the NBER. P-values are presented in parentheses.
Panel A: OLS regression

|                      | Model 1         | Model 2         | Model 3         | Model 4         | Model 5         | Model 6         | Model 7         |
|----------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| Yearly Loss          | 0.2818         |                |                |                |                |                |                |
|                      | (0.40)         |                |                |                |                |                |                |
| Count > $100K (*1,000) | 2,127***      | 2,082**       |                |                |                |                |                |
|                      | (0.00)         | (0.01)        |                |                |                |                |                |
| Severity > $100K     |                | 24.31         | 12.86          |                |                |                |                |
|                      |                | (0.56)        | (0.62)         |                |                |                |                |
| Individual Bootstrap 95th | 0.0385      |                |                |                |                |                |                |
|                      | (0.57)         |                |                |                |                |                |                |
| Yearly Loss $20k-$1Mln |                |                |                |                |                |                | 5.4716***     |
|                      |                |                |                |                |                |                | (0.00)         |
| Yearly Loss > $1Mln  |                |                |                |                |                |                | -0.0560        |
|                      |                |                |                |                |                |                | (0.94)         |
| Count $100K-$1Mln (*1,000) |                |                |                |                |                |                | 1.478**       |
|                      |                |                |                |                |                |                | (0.04)         |
| Count > $1Mln (*1,000) |                |                |                |                |                |                | 65.376         |
|                      |                |                |                |                |                |                | (0.19)         |
| Equity               | -0.0069**      | -0.0050**      | -0.0075***     | -0.0068**      | -0.0046*       | -0.0093***     | -0.0063**      |
|                      | (0.01)         | (0.04)        | (0.01)         | (0.01)         | (0.07)         | (0.00)         | (0.01)         |
| Liabilities          | -0.0017        | -0.0023        | -0.0015        | -0.0017        | -0.0025        | -0.0010        | -0.0021        |
|                      | (0.84)         | (0.69)        | (0.88)         | (0.68)         | (0.85)         |                | (0.74)         |
| Risk (*1,000)        | -102,839       | -90,661        | -105,468       | -104,852       | -95,661        | -55,120        | -67,245        |
|                      | (0.61)         | (0.63)        | (0.86)         | (0.68)         | (0.85)         |                | (0.67)         |
| Risk*TA              | 0.0013         | 0.0012         | 0.0013         | 0.0013         | 0.0012         | 0.0009         | 0.0011         |
|                      | (0.65)         | (0.67)        | (0.50)         | (0.58)         | (0.62)         | (0.68)         | (0.69)         |
| Crisis (*1,000)      | -93,335*       | -65,870*       | -89,469*       | -92,639*       | -61,454        | -69,404        | -79,560*       |
|                      | (0.05)         | (0.09)        | (0.08)         | (0.06)         | (0.13)         | (0.11)         | (0.05)         |
| Crisis*TA            | 0.0008**       | 0.0006*        | 0.0008*        | 0.0009**       | 0.0006*        | 0.0003         | 0.0006*        |
|                      | (0.04)         | (0.09)        | (0.05)         | (0.04)         | (0.08)         | (0.40)         | (0.07)         |
| Bank Fixed Effects   | No             | No             | No             | No             | No             | No             | No             |
| N                    | 220            | 220            | 220            | 220            | 220            | 220            | 220            |
| R²                   | 0.43           | 0.50           | 0.43           | 0.44           | 0.50           | 0.54           | 0.52           |

*p < 0.10, **p < 0.05, ***p < 0.01
Panel B: 95\textsuperscript{th} quantile regression

|                      |                |                |                |                |                |                |                |                |                |
|----------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| Yearly Loss          | 0.4126         |                |                |                |                |                |                |                |                |
| (0.42)               |                |                |                |                |                |                |                |                |                |
| Count > $100K (\times 1,000) | 4.494\textsuperscript{**} | 4.582\textsuperscript{**} |                |                |                |                |                |                |                |
| (0.04)               | (0.04)         |                |                |                |                |                |                |                |                |
| Severity > $100K     | 22.68          | -20.29         |                |                |                |                |                |                |                |
| (0.72)               | (0.87)         |                |                |                |                |                |                |                |                |
| Individual Bootstrap 95\textsuperscript{th} |                | -0.0285        |                |                |                |                |                |                |                |
| (0.97)               |                |                |                |                |                |                |                |                |                |
| Yearly Loss $20k-$1Mln | 10.85\textsuperscript{*} |                |                |                |                |                |                |                |                |
| (0.08)               |                |                |                |                |                |                |                |                |                |
| Yearly Loss > $1Mln  | 0.2170         |                |                |                |                |                |                |                |                |
| (0.98)               |                |                |                |                |                |                |                |                |                |
| Count $100K-$1Mln (\times 1,000) | 4.334\textsuperscript{*} |                |                |                |                |                |                |                |                |
| (0.07)               |                |                |                |                |                |                |                |                |                |
| Count > $1Mln (\times 1,000) |                | -96,802        |                |                |                |                |                |                |                |
| (0.58)               |                |                |                |                |                |                |                |                |                |
| Equity               | -0.0328\textsuperscript{***} | -0.0248\textsuperscript{***} | -0.0347\textsuperscript{***} | -0.0298\textsuperscript{***} | -0.0235\textsuperscript{***} | -0.0262\textsuperscript{***} | -0.0240\textsuperscript{***} |                |                |
| (0.00)               | (0.00)         | (0.00)         | (0.00)         | (0.00)         | (0.00)         | (0.00)         | (0.00)         |                |                |
| Liabilities          | 0.0060\textsuperscript{*} | 0.0029\textsuperscript{*} | 0.0073\textsuperscript{**} | 0.0043\textsuperscript{**} | 0.0023\textsuperscript{*} | 0.0044\textsuperscript{**} | 0.0021         |                |                |
| (0.05)               | (0.09)         | (0.02)         | (0.02)         | (0.08)         | (0.03)         |                | (0.11)         |                |                |
| Risk (\times 1,000)  | -32,307        | 8,953          | -12,510        | -81,758        | 1,710          | 33,559         | -53,716        |                |                |
| (0.94)               | (0.87)         | (0.87)         | (0.87)         | (0.85)         | (0.49)         | (0.92)         |                |                |
| Risk*TA              | 0.0001         | 0.0003         | -0.0001        | 0.0006         | 0.0004         | -0.0003        | 0.0009         |                |                |
| (0.86)               | (0.84)         | (0.89)         | (0.79)         | (0.84)         | (0.65)         | (0.72)         |                |                |
| Crisis (\times 1,000) | -240,571\textsuperscript{*} | -244,612\textsuperscript{*} | -183,181\textsuperscript{*} | -232,420\textsuperscript{**} | -267,83        | -279,795\textsuperscript{*} | -162,130       |                |                |
| (0.05)               | (0.05)         | (0.06)         | (0.03)         | (0.10)         | (0.03)         | (0.10)         | (0.10)         |                |
| Crisis*TA            | 0.0011         | 0.0021\textsuperscript{**} | 0.0005         | 0.0014         | 0.0024\textsuperscript{*} | 0.0021\textsuperscript{*} | 0.0015\textsuperscript{*} |                |                |
| (0.16)               | (0.04)         | (0.28)         | (0.16)         | (0.06)         | (0.06)         | (0.09)         | (0.09)         |                |
| Bank Fixed Effects   | No             | No             | No             | No             | No             | No             | No             | No             |                |
| N                    | 220            | 220            | 220            | 220            | 220            | 220            | 220            | 220            |                |
| R\textsuperscript{2} | 0.52           | 0.56           | 0.52           | 0.49           | 0.56           | 0.56           | 0.56           | 0.57           |

\(^* p < 0.10, \quad ^{**} p < 0.05, \quad ^{***} p < 0.01\)
Table 11: OLS and quantile regressions with loss metrics and additional controls - 10th and 90th quantiles used as range for weighting

This table presents coefficients estimates from regression of operational losses at year $t$ on loss metrics and BHCs characteristics at year $t-1$. Panel A presents OLS estimates while Panel B presents estimates from the 95th quantile regressions. Yearly Loss is the average total annual operational losses up to year $t$. Count > $100K is the average annual operational loss frequency up to year $t$, only including operational loss events above $100,000. Severity > $100K is the average severity of operational loss events up to year $t$, only including operational loss events above $100,000. Individual Bootstrap 95th is the estimate of the 95th quantile of the unconditional distribution using empirical bootstrap. Yearly Loss $20k-$1Mln is the average total annual operational losses up to year $t$, only including operational loss events between $20,000 and $1,000,000. Yearly Loss > $1Mln is the average total annual operational losses up to year $t$, only including operational loss events above $1,000,000. Count > $1Mln is the average annual operational loss frequency up to year $t$, only including operational loss events between $100,000 and $1,000,000. Count > $1Mln is the average annual operational loss frequency up to year $t$, only including operational loss events between $100,000 and $1,000,000. Equity is the rolling three-year average of bank’s equity at year end. Liabilities is the rolling three-year average of bank’s liabilities at year end. Risk is the value of the risk management rating given by the Federal Reserve System to BHCs. TA is the rolling three-year average of a banks total assets at year end. Crisis Indicator is a binary variable that assumes the value of one if the US is deemed to be in recession for at least one month in the year according to the NBER. P-values are presented in parentheses.

Panel A: OLS regression

|                      | Model 1     | Model 2     | Model 3     | Model 4     | Model 5     | Model 6     | Model 7     |
|----------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Yearly Loss          | 0.2892**    |             |             |             |             |             |             |
|                      | (0.05)      |             |             |             |             |             |             |
| Count > $100K (*1,000) | 621.00**   | 709.00**   |             |             |             |             |             |
|                      | (0.02)      | (0.02)      |             |             |             |             |             |
| Severity > $100K     | 7.9136      | 11.68*      |             |             |             |             |             |
|                      | (0.19)      | (0.05)      |             |             |             |             |             |
| Individual Bootstrap 95th | 0.0518*     |             |             |             |             |             |             |
|                      | (0.05)      |             |             |             |             |             |             |
| Yearly Loss $20k-$1Mln |             |             |             |             |             | 2.0716**   |             |
|                      |             |             |             |             |             | (0.01)      |             |
| Yearly Loss > $1Mln  |             |             |             |             |             | 0.2131      |             |
|                      |             |             |             |             |             | (0.20)      |             |
| Count $100K-$1Mln (*1,000) |             |             |             |             |             |             | 564.00**   |
|                      |             |             |             |             |             |             | (0.04)      |
| Count > $1Mln (*1,000) |             |             |             |             |             |             | 18.529      |
|                      |             |             |             |             |             |             | (0.28)      |
| Equity               | -0.0064***  | -0.0066***  | -0.0075***  | -0.0069***  | -0.0066***  | -0.0062***  | -0.0065***  |
|                      | (0.00)      | (0.00)      | (0.00)      | (0.00)      | (0.00)      | (0.00)      | (0.00)      |
| Liabilities          | 0.0020***   | 0.0020***   | 0.0025***   | 0.0022***   | 0.0022***   | 0.0018***   | 0.0019***   |
|                      | (0.00)      | (0.00)      | (0.00)      | (0.00)      | (0.00)      | (0.00)      | (0.00)      |
| Risk (*1,000)        | 15.876      | 12.556      | 13.477      | 16.713      | 20.177      | 19.264      | 18.436      |
|                      | (0.34)      | (0.45)      | (0.46)      | (0.26)      | (0.24)      | (0.25)      | (0.23)      |
| Risk*TA              | -0.0001     | -0.0001     | -0.0001     | -0.0001     | -0.0002     | -0.0001     | -0.0001     |
|                      | (0.35)      | (0.53)      | (0.40)      | (0.31)      | (0.20)      | (0.33)      | (0.40)      |
| Crisis (*1,000)      | -63.870**   | -58.904**   | -57.132**   | -59.285**   | -53.940**   | -60.810**   | -61.905**   |
|                      | (0.01)      | (0.02)      | (0.04)      | (0.02)      | (0.04)      | (0.03)      | (0.03)      |
| Crisis*TA            | 0.0007**    | 0.0006**    | 0.0006**    | 0.0006**    | 0.0006**    | 0.0006**    | 0.0007**    |
|                      | (0.01)      | (0.02)      | (0.04)      | (0.02)      | (0.03)      | (0.04)      | (0.03)      |
| Bank Fixed Effects   | No          | No          | No          | No          | No          | No          | No          |
| N                    | 220         | 220         | 220         | 220         | 220         | 220         | 220         |
| R²                   | 0.35        | 0.35        | 0.35        | 0.35        | 0.36        | 0.36        | 0.36        |

*p < 0.10, **p < 0.05, ***p < 0.01
Panel B: 95th quantile regression

|                      | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 |
|----------------------|---------|---------|---------|---------|---------|---------|---------|
| Yearly Loss          | 0.4657  | (0.62)  |         |         |         |         |         |
| Count > $100K (1,000) | 1,494   | (0.16)  | 2,646   |         |         |         |         |
| Severity > $100K     | -9.1375 | (0.65)  | 40.03   |         |         |         |         |
| Individual Bootstrap 95th | 0.0719  | (0.94)  |         |         |         |         |         |
| Yearly Loss $20k-$1Mln |         |         |         |         |         |         | 8.4483* |
| Yearly Loss > $1Mln  |         |         |         |         |         |         | -0.3373 |
| Count $100K-$1Mln (1,000) |         |         |         |         |         |         | 2,918   |
| Count > $1Mln (1,000) |         |         |         |         |         |         | -22,411 |
| Equity               | -0.0282*** | (0.00) | -0.0280*** | (0.00) | -0.0344*** | (0.00) | -0.0309*** | (0.00) | -0.0249*** | (0.00) | -0.0297*** | (0.00) | -0.0292*** | (0.00) |
| Liabilities          | 0.0078** | (0.01)  | 0.0086*** | (0.00) | 0.0087*** | (0.01) | 0.0089**  | (0.00) | 0.0079*** | (0.00) | 0.0081*** | (0.00) |         |         |
| Risk (1,000)         | 80,266  | (0.54)  | 106,536  | (0.37)  | 44,304   | (0.48)  | 92,921    | (0.46)  | 138,312   | (0.31)  | 121,729   | (0.36)  | 118,124   | (0.47)  |
| Risk*TA              | -0.0005 | (0.44)  | -0.0006  | (0.40)  | -0.0004  | (0.28)  | -0.0005   | (0.28)  | -0.0012   | (0.41)  | -0.0007   | (0.26)  | -0.0007   | (0.44)  |
| Crisis (1,000)       | -205,279| (0.15)  | -185,51* | (0.09)  | -262,719 | (0.18)  | -177,269  | (0.16)  | -98,817   | (0.13)  | -181,187  | (0.13)  | -169,705  | (0.13)  |
| Crisis*TA            | 0.0015  | (0.28)  | 0.0014   | (0.19)  | 0.0018   | (0.35)  | 0.0010    | (0.37)  | 0.0006    | (0.20)  | 0.0013    | (0.15)  | 0.0011    | (0.22)  |
| Bank Fixed Effects   | No      |         | No      |         | No      |         | No       |         | No      |         | No       |         | No       |         |
| N                    | 220     |         | 220     |         | 220     |         | 220      |         | 220     |         | 220      |         | 220      |         |
| R²                   | 0.60    |         | 0.60    |         | 0.59    |         | 0.60     |         | 0.60    |         | 0.60     |         | 0.60     |         |

* p < 0.10, ** p < 0.05, *** p < 0.01
Appendix E

Table 12: OLS and quantile regressions with loss metrics and additional controls - Block bootstrap

This table presents coefficients estimates from regression of operational losses at year $t$ on loss metrics and BHCs characteristics at year $t-1$. Panel A presents OLS estimates while Panel B presents estimates from the 95th quantile regressions. *Yearly Loss* is the average total annual operational losses up to year $t$. *Count > $100K* is the average annual operational loss frequency up to year $t$, only including operational loss events above $100,000$. *Severity > $100K* is the average severity of operational loss events up to year $t$, only including operational loss events above $100,000$. *Individual Bootstrap 95th* is the estimate of the 95th quantile of the unconditional distribution using empirical bootstrap. *Yearly Loss $20k-$1Mln* is the average total annual operational losses up to year $t$, only including operational loss events between between $20,000$ and $1,000,000$. *Yearly Loss > $1Mln* is the average total annual operational losses up to year $t$, only including operational loss events above $1,000,000$. *Count $100K-$1Mln* is the average annual operational loss frequency up to year $t$, only including operational loss events between $100,000$ and $1,000,000$. *Count > $1Mln* is the average annual operational loss frequency up to year $t$, only including operational loss events above $1,000,000$. *Equity* is the rolling three-year average of bank’s equity at year end. *Liabilities* is the rolling three-year average of bank’s liabilities at year end. *Risk* is the value of the risk management rating given by the Federal Reserve System to BHCs. *TA* is the rolling three-year average of a bank’s total assets at year end. *Crisis Indicator* is a binary variable that assumes the value of one if the US is deemed to be in recession for at least one month in the year according to the NBER. P-values are presented in parentheses.
### Panel A: OLS regression

|                        | Model 1          | Model 2          | Model 3          | Model 4          | Model 5          | Model 6          | Model 7          |
|------------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| Yearly Loss            | 0.5146*          |                  |                  |                  |                  |                  |                  |
|                        | (0.06)           |                  |                  |                  |                  |                  |                  |
| Count > $100K (*1,000) |                  | 1.856***         |                  | 1.839***         |                  |                  |                  |
|                        |                  | (0.00)           |                  | (0.00)           |                  |                  |                  |
| Severity > $100K       |                  | 12.55            |                  | 6.9296           |                  |                  |                  |
|                        |                  | (0.53)           |                  | (0.70)           |                  |                  |                  |
| Individual Bootstrap 95th |                | 0.0362           |                  |                  |                  |                  |                  |
|                        |                  | (0.33)           |                  |                  |                  |                  |                  |
| Yearly Loss $20k-$1Mln |                  |                  |                  | 4.8058***        |                  |                  |                  |
|                        |                  |                  |                  | (0.00)           |                  |                  |                  |
| Yearly Loss > $1Mln    |                  |                  |                  | 0.1622           |                  |                  |                  |
|                        |                  |                  |                  | (0.64)           |                  |                  |                  |
| Count $100K-$1Mln (*1,000) |              |                  |                  |                  |                  |                  | 1.602***         |
|                        |                  |                  |                  |                  |                  |                  | (0.00)           |
| Count > $1Mln (*1,000) |                  |                  |                  |                  |                  |                  | 25.463           |
|                        |                  |                  |                  |                  |                  |                  | (0.47)           |
| Equity                 | -0.0067*         | -0.0056*         | -0.0086**        | -0.0082**        | -0.0056**        | -0.0069**        | -0.0058**        |
|                        | (0.05)           | (0.06)           | (0.03)           | (0.03)           | (0.04)           | (0.02)           | (0.04)           |
| Liabilities            | 0.0017*          | 0.0016**         | 0.0020**         | 0.0019**         | 0.0015**         | 0.0020**         | 0.0015**         |
|                        | (0.09)           | (0.03)           | (0.04)           | (0.04)           | (0.03)           | (0.01)           | (0.04)           |
| Risk (*1,000)          | -61.00           | 10,701           | -14.96           | -11.195          | 10,115           | 33,320           | 15.856           |
|                        | (0.76)           | (0.69)           | (0.99)           | (0.93)           | (0.68)           | (0.37)           | (0.63)           |
| Risk*TA                | -0.0000          | -0.0001          | 0.0002           | 0.0001           | -0.0001          | -0.0003          | -0.0001          |
|                        | (0.66)           | (0.52)           | (0.93)           | (0.77)           | (0.52)           | (0.19)           | (0.51)           |
| Crisis (*1,000)        | -28,446          | -634.00          | -21,806          | -19,573          | -2,342           | -25,463          | -14,182          |
|                        | (0.21)           | (0.77)           | (0.40)           | (0.51)           | (0.68)           | (0.40)           | (0.60)           |
| Crisis*TA              | 0.0003           | 0.0002           | 0.0002           | 0.0002           | 0.0002           | 0.0003           | 0.0003           |
|                        | (0.18)           | (0.40)           | (0.30)           | (0.35)           | (0.35)           | (0.28)           | (0.32)           |
| Bank Fixed Effects     | No               | No               | No               | No               | No               | No               | No               |
| N                      | 220              | 220              | 220              | 220              | 220              | 220              | 220              |
| R²                     | 0.36             | 0.43             | 0.34             | 0.34             | 0.43             | 0.46             | 0.43             |

*p < 0.10, **p < 0.05, ***p < 0.01
### Panel B: 95th quantile regression

|                        | Model 1         | Model 2         | Model 3         | Model 4         | Model 5         | Model 6         | Model 7         |
|------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| **Yearly Loss**        | 0.9071 (0.59)  |                |                |                |                |                |                |
| Count > $100K (*1,000) | 4.010* (0.08)  |                |                |                |                |                |                |
| **Severity** > $100K   | 0.2779 (0.96)  |                |                |                |                |                |                |
| Individual Bootstrap 95th | 0.0301 (0.98)  |                |                |                |                |                |                |
| **Yearly Loss** $20k-$1Mln | 10.16 (0.12)  |                |                |                |                |                |                |
| **Yearly Loss** > $1Mln |                |                |                |                |                |                |                |
| Count $100K-$1Mln (*1,000) |                |                |                |                |                |                | 3.219* (0.08)  |
| Count > $1Mln (*1,000) |                |                |                |                |                |                | -23.0 (0.56)   |
| **Equity**             | -0.0287* (0.06) | -0.0237** (0.01) | -0.0313** (0.02) | -0.0310** (0.02) | -0.0249** (0.01) | -0.0263*** (0.02) | -0.0275** (0.02) |
| Liabilities            | 0.0081** (0.01) | 0.0051** (0.01) | 0.0099*** (0.02) | 0.0096*** (0.02) | 0.0060** (0.01) | 0.0066** (0.01) | 0.0072** (0.01) |
| Risk (*1,000)          | 101.025 (0.41)  | 93.791 (0.36)  | 115.819 (0.49)  | 115.571 (0.48)  | 105.191 (0.43) | 115.215 (0.43) | 106.707 (0.61)  |
| Risk*TA                | -0.0006 (0.55)  | -0.0003 (0.64) | -0.0009 (0.61)  | -0.0009 (0.62)  | -0.0004 (0.60) | -0.0006 (0.65) | -0.0005 (0.65)  |
| Crisis (*1,000)        | -183,591*** (0.04) | -127.42* (0.06) | -208,635* (0.07) | -197.99* (0.05) | -148,422* (0.05) | -162,975* (0.05) | -155,693* (0.08) |
| Crisis*TA              | 0.0013 (0.19)   | 0.0010 (0.11)  | 0.0017 (0.27)   | 0.0015 (0.21)   | 0.0011* (0.09) | 0.0012* (0.09) | 0.0011* (0.09)  |
| Bank Fixed Effects      | No             | No             | No             | No             | No             | No             | No             |
| N                      | 220            | 220            | 220            | 220            | 220            | 220            | 220            |
| R²                     | 0.56           | 0.58           | 0.55           | 0.55           | 0.58           | 0.59           | 0.59           |

*p < 0.10,  **p < 0.05,  ***p < 0.01
Appendix F

Table 13: OLS and quantile regressions with only loss metrics - 90th and 99th quantile regressions

This table presents coefficient estimates from the regression of operational losses at year $t$ on loss metrics at year $t - 1$. Panel A presents estimates of the 90th quantile regression while Panel B presents estimates from the 99th quantile regressions. Yearly Loss is the average total annual operational losses up to year $t$. Count > $100K is the average annual operational loss frequency up to year $t$, only including operational loss events above $100,000. Severity > $100K is the average severity of operational loss events up to year $t$, only including operational loss events above $100,000. Individual Bootstrap 95th is the estimate of the 95th quantile of the unconditional distribution using empirical bootstrap. Yearly Loss $20k-$1Mln is the average total annual operational losses up to year $t$, only including operational loss events between $20,000 and $1,000,000. Yearly Loss > $1Mln is the average total annual operational losses up to year $t$, only including operational loss events above $1,000,000. Count $100K-$1Mln is the average annual operational loss frequency up to year $t$, only including operational loss events between $100,000 and $1,000,000. Count > $1Mln is the average annual operational loss frequency up to year $t$, only including operational loss events above $1,000,000. P-values are presented in parentheses.

| Panel A: 90th quantile regression | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 |
|-----------------------------------|---------|---------|---------|---------|---------|---------|---------|
| Yearly Loss                       | 2.2852*** |         |         |         |         |         |         |
| Count > $100K (*1,000)            | 5.535*** | 5.537*** |         |         |         |         |         |
| Severity > $100K                  | 229.43*** | -0.7514 |         |         |         |         |         |
| Individual Bootstrap 95th         | 0.5893*** |         |         |         |         |         |         |
| Yearly Loss $20k-$1Mln            | 9.8751*** |         |         |         |         |         |         |
| Yearly Loss > $1Mln               | 0.9166**  |         |         |         |         |         |         |
| Count $100K-$1Mln (*1,000)        |         |         |         |         |         |         | 5.539*** |
| Count > $1Mln (*1,000)            |         |         |         |         |         |         | -3.529  |
| Bank Fixed Effects                | No      | No      | No      | No      | No      | No      | No      |
| N                                 | 220     | 220     | 220     | 220     | 220     | 220     | 220     |
| $R^2$                             | 0.39    | 0.43    | 0.11    | 0.30    | 0.43    | 0.43    | 0.43    |

*p < 0.10, **p < 0.05, ***p < 0.01
Panel B: 99\textsuperscript{th} quantile regression

|                       | Model 1   | Model 2   | Model 3   | Model 4   | Model 5   | Model 6   | Model 7   |
|-----------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Yearly Loss $\geq$ 7.2693***<br>(0.00) |           |           |           |           |           |           |           |
| Count > $100K$ (*1,000) | 20,104***<br>(0.00) | 18,192***<br>(0.00) |           |           |           |           |           |
| Severity > $100K$ | 1.0000***<br>(0.00) | 67.26<br>(0.97) |           |           |           |           |           |
| Individual Bootstrap 95\textsuperscript{th} | 2.0912***<br>(0.00) |           |           |           |           |           |           |
| Yearly Loss $\geq$ 46.60**<br>(0.02) |           |           |           |           |           |           |           |
| Yearly Loss > 1.2566<br>(0.66) |           |           |           |           |           |           |           |
| Count $\geq$ 18,892***<br>(0.00) |           |           |           |           |           |           |           |
| Count $>1Mln$ (*1,000) |           |           |           |           |           |           |           |
| Bank Fixed Effects | No | No | No | No | No | No | No |
| N | 220 | 220 | 220 | 220 | 220 | 220 | 220 |
| $R^2$ | 0.57 | 0.65 | 0.24 | 0.54 | 0.65 | 0.64 | 0.65 |

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Table 14: OLS and quantile regressions with loss metrics and additional controls - 90th and 99th quantile regressions

This table presents coefficients estimates from regression of operational losses at year $t$ on loss metrics and BHCs characteristics at year $t-1$. Panel A presents estimates of the 90th quantile regression while Panel B presents estimates from the 99th quantile regressions. Yearly Loss is the average total annual operational losses up to year $t$. Count > $100K is the average annual operational loss frequency up to year $t$, only including operational loss events above $100,000. Severity > $100K is the average severity of operational loss events up to year $t$, only including operational loss events above $100,000. Individual Bootstrap 95th is the estimate of the 95th quantile of the unconditional distribution using empirical bootstrap. Yearly Loss $20k-$1Mln is the average total annual operational losses up to year $t$, only including operational loss events between $20,000 and $1,000,000. Yearly Loss > $1Mln is the average total annual operational losses up to year $t$, only including operational loss events above $1,000,000. Count $100K-$1Mln is the average annual operational loss frequency up to year $t$, only including operational loss events between $100,000 and $1,000,000. Count > $1Mln is the average annual operational loss frequency up to year $t$, only including operational loss events above $1,000,000. Equity is the rolling three-year average of bank’s equity at year end. Liabilities is the rolling three-year average of bank’s liabilities at year end. Risk is the value of the risk management rating given by the Federal Reserve System to BHCs. TA is the rolling three-year average of a bank’s total assets at year end. Crisis Indicator is a binary variable that assumes the value of one if the US is deemed to be in recession for at least one month in the year according to the NBER. P-values are presented in parentheses.

Panel A: 90th quantile regression

|                      | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 |
|----------------------|---------|---------|---------|---------|---------|---------|---------|
| Yearly Loss          | 0.5146** (0.04) |         |         |         |         |         |         |
| Count > $100K        | 1.856*** (0.00) | 1.839*** (0.00) |         |         |         |         |         |
| Severity > $100K     | 12.55 (0.47) | 6.9296 (0.61) |         |         |         |         |         |
| Individual Bootstrap | 0.0362 (0.34) |         |         |         |         |         |         |
| Yearly Loss $20k-$1Mln |         | 4.8058*** (0.00) |         |         |         |         |         |
| Yearly Loss > $1Mln  | 0.1622 (0.43) |         |         |         |         |         |         |
| Count $100K-$1Mln    |         | 1.602*** (0.00) |         |         |         |         |         |
| Count > $1Mln        |         | 25.463 (0.35) |         |         |         |         |         |
| Equity               | -0.0067*** (0.00) | -0.0056*** (0.00) | -0.0086*** (0.00) | -0.0082*** (0.01) | -0.0056*** (0.00) | -0.0069*** (0.00) | -0.0058*** (0.00) |
| Liabilities          | 0.0017** (0.03) | 0.0016** (0.02) | 0.0020** (0.02) | 0.0019** (0.01) | 0.0015** (0.03) | 0.0020*** (0.00) | 0.0015** (0.01) |
| Risk (*1,000)        | -61.00 (0.88) | 10.701 (0.55) | -14.96 (0.55) | -11.195 (0.80) | 10.115 (0.55) | 33.320 (0.10) | 15.856 (0.35) |
| Risk*TA              | -0.0000 (0.84) | -0.0001 (0.54) | 0.0002 (0.77) | 0.0001 (0.84) | -0.0001 (0.84) | -0.0003* (0.59) | -0.0001 (0.52) |
| Crisis (*1,000)      | -28.446 (0.22) | -634.00 (0.22) | -21.806 (0.35) | -19.573 (0.46) | -2.342 (0.68) | -25.463 (0.32) | -14.182 (0.49) |
| Crisis*TA            | 0.0003 (0.17) | 0.0002 (0.37) | 0.0002 (0.28) | 0.0002 (0.35) | 0.0002 (0.34) | 0.0003 (0.21) | 0.0003 (0.24) |
| Bank Fixed Effects    | No       | No       | No       | No       | No       | No       | No       |
| N                    | 220      | 220      | 220      | 220      | 220      | 220      | 220      |
| R²                   | 0.36     | 0.43     | 0.34     | 0.34     | 0.43     | 0.46     | 0.43     |

*p < 0.10, **p < 0.05, ***p < 0.01
Panel B: 99th quantile regression

| Model 1   | Model 2  | Model 3   | Model 4   | Model 5   | Model 6   | Model 7   |
|-----------|----------|-----------|-----------|-----------|-----------|-----------|
| Yearly Loss | 0.8393   |            |           |           |           |           |
|           |          | (0.25)    |           |           |           |           |
| Count > $100K (*1,000) | 3.130**  | 3.204**   |           |           |           |           |
|           |          | (0.02)    |           |           |           |           |
| Severity > $100K | 19.20    | -3.8891   |           |           |           |           |
|           |          | (0.51)    |           |           |           |           |
| Individual Bootstrap 95th | 0.0858   |            |           |           |           |           |
|           |          | (0.67)    |           |           |           |           |
| Yearly Loss $20k-$1Mln | 7.8575** |            |           |           |           |           |
|           |          | (0.02)    |           |           |           |           |
| Yearly Loss > $1Mln | -0.0116  |            |           |           |           |           |
|           |          | (0.99)    |           |           |           |           |
| Count $100K-$1Mln (*1,000) | 3.361*   |            |           |           |           |           |
|           |          | (0.05)    |           |           |           |           |
| Count > $1Mln (*1,000) | -7.687   |            |           |           |           |           |
|           |          | (0.95)    |           |           |           |           |
| Equity | -0.0170*** | -0.0155*** | -0.0218*** | -0.0205*** | -0.0153*** | -0.0164*** |
|          | (0.00)   | (0.00)    | (0.00)    | (0.00)    | (0.00)    | (0.00)    |
| Liabilities | 0.0043** | 0.0032*   | 0.0055**  | 0.0037**  | 0.0031    | 0.0033**  | 0.0031*   |
|           | (0.02)   | (0.08)    | (0.01)    | (0.01)    | (0.10)    | (0.03)    |
| Risk (*1,000) | 42.475   | 59.839    | 39.257    | -9.202    | 61.641    | 57.150    | 60.987    |
|           | (0.40)   | (0.43)    | (0.56)    | (0.64)    | (0.40)    | (0.24)    |
| Risk*TA | -0.0003  | -0.0002   | -0.0000   | 0.0003    | -0.0002   | -0.0001   | -0.0002   |
|           | (0.62)   | (0.75)    | (0.98)    | (0.92)    | (0.89)    | (0.71)    |
| Crisis (*1,000) | -148.261** | -138.712** | -109.673** | -162.325** | -139.925** | -142.714*** | -135.2*   |
|           | (0.01)   | (0.03)    | (0.03)    | (0.02)    | (0.02)    | (0.00)    |
| Crisis*TA | 0.0011   | 0.0015**  | 0.0005    | 0.0012    | 0.0015**  | 0.0014**  | 0.0015*   |
|           | (0.11)   | (0.04)    | (0.19)    | (0.14)    | (0.02)    | (0.02)    |
| Bank Fixed Effects | No       | No        | No        | No        | No        | No        |
| N         | 220      | 220       | 220       | 220       | 220       | 220       |
| R²        | 0.47     | 0.50      | 0.46      | 0.46      | 0.50      | 0.50      | 0.51      |

*p < 0.10, **p < 0.05, ***p < 0.01
Appendix G

Table 15: OLS and quantile regressions with loss metrics, additional controls and bank fixed effects

This table presents coefficients estimates from regression of operational losses at year \( t \) on loss metrics and BHCs characteristics at year \( t - 1 \) with bank fixed effects. Panel A presents OLS estimates while Panel B presents estimates from the 95\(^{th} \) quantile regressions. \( \text{Yearly Loss} \) is the average total annual operational losses up to year \( t \). \( \text{Count} > \$100K \) is the average annual operational loss frequency up to year \( t \), only including operational loss events above \$100,000. \( \text{Severity} > \$100K \) is the average severity of operational loss events up to year \( t \), only including operational loss events above \$100,000. \( \text{Individual Bootstrap} \) is the estimate of the 95\(^{th} \) quantile of the unconditional distribution using empirical bootstrap. \( \text{Yearly Loss} \ $20k-$1Mln \) is the average total annual operational losses up to year \( t \), only including operational loss events between \$20,000 and \$1,000,000. \( \text{Yearly Loss} > \$1Mln \) is the average total annual operational losses up to year \( t \), only including operational loss events above \$1,000,000. \( \text{Count} \ $100K-$1Mln \) is the average annual operational loss frequency up to year \( t \), only including operational loss events between \$100,000 and \$1,000,000. \( \text{Count} > \$1Mln \) is the average annual operational loss frequency up to year \( t \), only including operational loss events above \$1,000,000. \( \text{Equity} \) is the rolling three-year average of bank’s equity at year end. \( \text{Liabilities} \) is the value of the liability at the end of the year. \( \text{Risk} \) is the value of the risk management rating given by the Federal Reserve System to BHCs. \( \text{TA} \) is the rolling three-year average of a banks total assets at year end. \( \text{Crisis Indicator} \) is a binary variable that assumes the value of one if the US is deemed to be in recession for at least one month in the year according to the NBER.

| Panel A: OLS regression | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 |
|-------------------------|---------|---------|---------|---------|---------|---------|---------|
| Yearly Loss             | 0.3442  |         |         |         |         |         |         |
|                         | (0.26)  |         |         |         |         |         |         |
| Count > $100K (*1,000)  | 2.283** | 2.425** |         |         |         |         |         |
|                         | (0.01)  | (0.02)  |         |         |         |         |         |
| Severity > $100K        | -31.63  | -44.99  |         |         |         |         |         |
|                         | (0.21)  | (0.11)  |         |         |         |         |         |
| Individual Bootstrap 95\(^{th}\) | 0.0636  |         |         |         |         |         |         |
|                         | (0.46)  |         |         |         |         |         |         |
| Yearly Loss $20k-$1Mln  |         | 9.5265**|         |         |         |         |         |
|                         |         | (0.03)  |         |         |         |         |         |
| Yearly Loss > $1Mln     | -0.2096 |         |         |         |         |         |         |
|                         | (0.60)  |         |         |         |         |         |         |
| Count $100K-$1Mln (*1,000) |         | 2.992** |         |         |         |         |         |
|                         |         | (0.01)  |         |         |         |         |         |
| Count > $1Mln (*1,000)  |         | -56.628 |         |         |         |         |         |
|                         |         | (0.42)  |         |         |         |         |         |
| Equity                  | -0.0073 | -0.0149**| -0.0046 | -0.0076 | -0.0145**| -0.0164**| -0.0147** |
|                         | (0.17)  | (0.02)  | (0.50)  | (0.21)  | (0.02)  | (0.01)  | (0.02)  |
| Liabilities             | 0.0026***| 0.0027***| 0.0029***| 0.0027***| 0.0030***| 0.0027***| 0.0030*** |
|                         | (0.00)  | (0.00)  | (0.00)  | (0.00)  | (0.00)  | (0.00)  | (0.00)  |
| Risk (*1,000)           | 17.978  | 15.645  | 21.129  | 14.299  | 20.689  | 18.305  | 20.192  |
|                         | (0.62)  | (0.64)  | (0.51)  | (0.75)  | (0.37)  | (0.61)  | (0.54)  |
| Crisis (*1,000)         | -0.0004 | -0.0003 | -0.0004 | -0.0004 | -0.0004 | -0.0003 | -0.0004 |
|                         | (0.23)  | (0.33)  | (0.19)  | (0.30)  | (0.17)  | (0.36)  | (0.24)  |
| Risk*TA                 | -3.985  | -13.804 | 19.206  | 3.337   | 2.555   | -18.582 | -8.37   |
|                         | (0.70)  | (0.38)  | (0.94)  | (0.84)  | (0.72)  | (0.33)  | (0.56)  |
| Crisis*TA               | 0.0002  | 0.0003  | 0.0000  | 0.0001  | 0.0002  | 0.0003  | 0.0002  |
|                         | (0.52)  | (0.29)  | (0.76)  | (0.62)  | (0.45)  | (0.27)  | (0.49)  |
| Bank Fixed Effects       | Yes     | Yes     | Yes     | Yes     | Yes     | Yes     | Yes     |
| N                       | 220     | 220     | 220     | 220     | 220     | 220     | 220     |
| \( R^2 \)               | 0.52    | 0.54    | 0.52    | 0.52    | 0.55    | 0.55    | 0.54    |

* \( p < 0.10 \), ** \( p < 0.05 \), *** \( p < 0.01 \)
## Panel B: 95<sup>th</sup> quantile regression

|                      | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 |
|----------------------|---------|---------|---------|---------|---------|---------|---------|
| Yearly Loss          | -5.4831 |         |         |         |         |         |         |
|                      | (0.15)  |         |         |         |         |         |         |
| Count > $100K (*1,000) | 2.615   | 2.048   |         |         |         |         |         |
|                      | (0.39)  | (0.34)  |         |         |         |         |         |
| Severity > $100K     | -181.80 | -179.57 |         |         |         |         |         |
|                      | (0.17)  | (0.18)  |         |         |         |         |         |
| Individual Bootstrap 95<sup>th</sup> | -0.8452 |         |         |         |         |         |         |
|                      | (0.10)  |         |         |         |         |         |         |
| Yearly Loss > $20k-$1Mln |         |         |         |         |         | 12.20   |         |
|                      |         |         |         |         |         | (0.12)  |         |
| Yearly Loss > $1Mln  |         |         |         |         |         |         | -5.2798 |
|                      |         |         |         |         |         | (0.11)  |         |
| Count $100K-$1Mln (*1,000) |         |         |         |         |         |         | 2.704   |
|                      |         |         |         |         |         | (0.20)  |         |
| Count > $1Mln (*1,000) |         |         |         |         |         | -254.639|         |
|                      |         |         |         |         |         | (0.53)  |         |
| Equity               | 0.0118  | -0.0440 | -0.0203 | -0.0098 | -0.0244 | -0.0088 | -0.0477 |
|                      | (0.87)  | (0.11)  | (0.35)  | (0.66)  | (0.16)  | (0.37)  | (0.11)  |
| Liabilities          | 0.0034  | 0.0036  | 0.0043  | 0.0023  | 0.0026  | 0.0018* | 0.0043* |
|                      | (0.10)  | (0.21)  | (0.19)  | (0.15)  | (0.18)  | (0.07)  | (0.16)  |
| Risk (*1,000)        | 18.834  | -8.857  | 69.552  | -44.351 | 38.361  | 35.880  | -40.766 |
|                      | (0.48)  | (0.61)  | (0.50)  | (0.71)  | (0.50)  | (0.42)  | (0.71)  |
| Risk*TA              | -0.0002 | 0.0007  | -0.0002 | 0.0015  | 0.0002  | 0.0002  | 0.0004  |
|                      | (0.74)  | (0.77)  | (0.86)  | (0.73)  | (0.77)  | (0.85)  | (0.73)  |
| Crisis (*1,000)      | -52.774 | -178.534*** | -24.521* | -50.561** | -48.333* | 25.535  | -142.588** |
|                      | (0.16)  | (0.00)  | (0.07)  | (0.04)  | (0.09)  | (0.24)  | (0.02)  |
| Crisis*TA            | 0.0005  | 0.0018* | 0.0004* | 0.0005* | 0.0009** | 0.0002* | 0.0012** |
|                      | (0.14)  | (0.02)  | (0.05)  | (0.08)  | (0.04)  | (0.08)  | (0.02)  |
| Bank Fixed Effects    | Yes     | Yes     | Yes     | Yes     | Yes     | Yes     | Yes     |
| N                    | 220     | 220     | 220     | 220     | 220     | 220     | 220     |
| R²                   | 0.79    | 0.74    | 0.74    | 0.78    | 0.75    | 0.80    | 0.75    |

*<i>p < 0.10</i>, **<i>p < 0.05</i>, ***<i>p < 0.01</i>