# Online Appendix for "A Market-Based Measure of Credit Portfolio Quality and Banks' Performance During the Subprime Crisis"

## Appendix A: Bias in the CRI When the Value of Equity is a Function of Asset Risk

In this appendix we allow for the possibility that asset risk has an effect on the value of equity (through the option value of equity). While in the model of Section 3 there was a one-to-one relationship between changes in the value of the loan portfolio and the return on equity, we now relax this assumption. In particular, we also allow the relationship to depend on asset risk.

To this end suppose that the bank only holds loans in its portfolio. The value of equity can then be expressed by a function $f = f(V(Loans), \sigma)$, where $f$ is continuous and $\sigma$ is the volatility of the loan portfolio. We have that $\frac{\partial f}{\partial V(Loans)} > 0$ and under the Merton-model also that $\frac{\partial f}{\partial \sigma} > 0$. We assume that the volatility of the loan portfolio is the market-value weighted-average of the volatility of the high risk and the low risk loans, $\sigma^H$ and $\sigma^L$, respectively:

$$\sigma = \frac{V(H)}{V(Loans)}\sigma^H + \frac{V(L)}{V(Loans)}\sigma^L. \tag{16}$$

Noting that $\frac{V(H)}{V(Loans)} = CRI$ and $\frac{V(L)}{V(Loans)} = 1 - CRI$ we see that asset risk is a function of the CRI.

We have for the total derivative of the value of equity with respect to $V(H)$ and $V(L)$:

$$\frac{df}{dV(H)} = \frac{\partial f}{\partial V(H)} + \frac{\partial f}{\partial \sigma}\frac{\partial \sigma}{\partial V(H)} = \frac{\partial f}{\partial V(Loans)} + \frac{\partial f}{\partial \sigma}(1 - CRI)\frac{\sigma^H - \sigma^L}{V(Loans)} \tag{17}$$

$$\frac{df}{dV(L)} = \frac{\partial f}{\partial V(L)} + \frac{\partial f}{\partial \sigma}\frac{\partial \sigma}{\partial V(L)} = \frac{\partial f}{\partial V(Loans)} - \frac{\partial f}{\partial \sigma}CRI\frac{\sigma^H - \sigma^L}{V(Loans)}. \tag{18}$$

Using these equations we can obtain a first-order approximation of the stock price return ($\frac{\triangle p}{p} = \frac{\triangle f}{Vf}$) caused by changes in the CDS spreads:

$$\frac{\triangle p}{p} \approx -\left(\frac{\partial f}{\partial V(Loans)} + \frac{\partial f}{\partial \sigma}(1 - CRI)\frac{\sigma^H - \sigma^L}{V(Loans)}\right)\frac{V(H)}{V(Loans)}\frac{\triangle CDS^H}{1 - CDS^H} \tag{19}$$

$$-\left(\frac{\partial f}{\partial V(Loans)} - \frac{\partial f}{\partial \sigma}CRI\frac{\sigma^H - \sigma^L}{V(Loans)}\right)\frac{V(L)}{V(Loans)}\frac{\triangle CDS^L}{1 - CDS^L} \tag{20}$$

The estimated CDS-sensitivities, $\gamma$ and $\delta$, will hence be

$$\gamma = -\left(\frac{\partial f}{\partial V(Loans)} + \frac{\partial f}{\partial \sigma}(1 - CRI)\frac{\sigma^H - \sigma^L}{V(Loans)}\right)\frac{V(H)}{V(Loans)} \tag{21}$$

and

$$\delta = -\left(\frac{\partial f}{\partial V(Loans)} - \frac{\partial f}{\partial \sigma}CRI\frac{\sigma^H - \sigma^L}{V(Loans)}\right)\frac{V(L)}{V(Loans)}. \tag{22}$$

If we compute the CRI based on these estimated sensitivities we obtain (after dividing by $-\left(\frac{\partial f}{\partial V(Loans)} + \frac{\partial f}{\partial \sigma}(1 - CRI)\frac{\sigma^H - \sigma^L}{V(Loans)}\right)$):

$$\widetilde{CRI} = \frac{\gamma}{\gamma + \delta} = \frac{V(H)}{V(H) + \frac{\frac{\partial f}{\partial V(Loans)} - \frac{\partial f}{\partial \sigma}CRI\frac{\sigma^H - \sigma^L}{V(Loans)}}{\frac{\partial f}{\partial V(Loans)} + \frac{\partial f}{\partial \sigma}(1-CRI)\frac{\sigma^H - \sigma^L}{V(Loans)}}V(L)}. \tag{23}$$

This expression will only be equal to the "true" CRI ($= \frac{V(H)}{V(H)+V(L)}$) if $\sigma^H = \sigma^L$. For $\sigma^H > \sigma^L$, there will be an upward bias in the estimated CRI since then $\frac{\frac{\partial f}{\partial V(Loans)} - \frac{\partial f}{\partial \sigma}CRI\frac{\sigma^H - \sigma^L}{V(Loans)}}{\frac{\partial f}{\partial V(Loans)} + \frac{\partial f}{\partial \sigma}(1-CRI)\frac{\sigma^H - \sigma^L}{V(Loans)}} < 1$.

The reason for this bias is the following. Suppose the high risk CDS spread declines. There will be direct positive effect on share prices due to changes in the value of the loan portfolio. At the same time, however, asset risk increases as the market-value of high risk loans in the portfolio increases. This increases the option value of equity and provides for an additional increase in share prices. The direct sensitivity coming from the loan portfolio is thus only a part of the total sensitivity. Not taking this into account when interpreting the estimated sensitivity will lead us to infer a higher direct sensitivity, and hence a higher CRI.

Using the Merton-model we can calculate this bias and, more importantly, we can also calculate how it depends on the CRI (a constant bias is not a problem as it is the cross-sectional ranking across banks that matters for the analysis). We assume that the volatility of the value of the high risk loans is twice as high than that of the low risk loans and set the parameters of the Merton-model such that the credit spread on the bank is around 180bps. Specifically, we assume the following parameters: value of firm: 100, volatility of high risk loans: 40%, volatility of low risk loans: 20%, face value of debt: 90, maturity of debt: 5 years, risk-free rate: 5%. For a CRI of 0.15 (about the mean CRI in our sample) this gives a credit spread of 183bps.

We can then compute biases for different CRIs as follows. Each CRI defines a value of asset risk, $\sigma$, through equation (16). Given the other parameters, this allows us to numerically compute the derivatives $\frac{\partial f}{\partial V(Loans)}$ and $\frac{\partial f}{\partial \sigma}$. After obtaining these derivatives, we can then compute the biased CRI using equation (23). For variations in the CRI from 0.05 to 0.25 we obtain an upward bias in the range of 9-12%. More importantly for our analysis, the correlation between true and biased CRI is essentially one (0.99998). Hence, if one bank has a higher estimated CRI than another one, its true CRI is accordingly similarly higher. The bias thus does not seem to cause a noteworthy distortion in the cross-sectional dispersion of the CRIs.

Finally, note that when we are interested in using the CRI for predicting bank's share price performance in recessions (as we do in Section 4.5), the "biased" CRI is actually the correct concept. This is because the share price changes induced by changes in asset quality arise due to the direct channel, but also due to the indirect one through the option value of equity.

## Appendix B: Failure Forecasting at One Quarter and for a Larger Sample of Banks

This appendix reports and discusses the results for the one-quarter failure forecasting as well as the forecasting for a larger set of banks (both one and two quarters).

Table 6, Panel A, reports the one-quarter results for the original dataset for the preferred orthogonalization method. The CRI is again significant in column (1) and its marginal coefficient is not very different from the one for two-quarter forecasting. The CRI remains significant in some of the other specifications but is not significant in three specifications. The results for one-quarter forecasting are thus less stable. However, we also note that none of the traditional bank risk characteristics are significant in the specification involving all control variables (non-performing loans are significant but with the wrong sign). Only real estate loans and size are consistently significant in the regressions.

Panel B shows the results for the second orthogonalization method. Consistent with the two-quarter results, the CRI is again always insignificant. Only in the specification where the CRI enters a horse-race with the Z-score it enters marginally significant (10% level) and with the correct sign (positive).

It should be kept in mind that our sample comprises only a small number of failed banks. This makes it difficult to identify a significant predictive power for the CRI. To alleviate this issue, we also estimate forecasting regressions for a wider set of banks. For this we started again from the failed bank list of the FDIC, which gives us in total 210 U.S. commercial banks that failed during our sample period. From these banks we exclude banks that have assets of less than one billion USD, which reduces the sample to 45 banks. From these banks we lose 18 since they are not listed on any stock exchange. We lose another 9 because either their shares were very illiquid or their bank holding company survived the failure of the commercial bank. This leaves us with 18 failures, of which 8 are already included in our original sample of 150 large BHCs. Adding the two rescue mergers gives us 20 bank failures. Their mean CRI one month before failure is 0.25 (comparing to a sample mean of 0.15). As for some of these banks we were not able to get all the balance sheet data (some banks are registered as Thrifts and have hence different reporting requirements) we focus in this exercise on probits with the CRI and the distance-to-default measure only.

Table 7 contains the results for both forecasting horizons. Panel A reports the results for the first orthogonalization method. Column (1) and (3) shows the results with only the CRI included. The CRI turns out to be positively and very significantly related to future bank failures at both forecasting horizons. The (marginal) coefficients are higher than for the small set of banks. The point estimate for two-quarter forecasting is 0.115, which translates into a 13% higher chance of failing during our sample period for a bank with a CRI that is one standard deviation higher than the mean CRI. Column (2) and (4) report results with the Z-score included. The Z-score is significant with the correct sign at the one-quarter horizon but not so at the two-quarter horizon. The CRI is remains significant. The results for the Merton-based distance-to-default are similar and are not reported. Panel B shows that the results for the second orthogonalization method are unchanged; the CRI is insignificant in all specifications.

**Table 6: Failure Prediction (One Quarter)**

**Panel A (Market Orthogonalization)**

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| CRI | 0.0634** | 0.0226* | 0.0384** | 0.00697 | 0.0382** | 0.0732*** | 0.00818 | 0.000595 |
| | (0.0290) | (0.0141) | (0.0170) | (0.0111) | (0.0247) | (0.0292) | (0.00527) | (0.00118) |
| Non-Performing Loans/TL | | -0.0488* | | | | | | -0.00299** |
| | | (0.0322) | | | | | | (0.00653) |
| Loan Loss Provisions/TL | | 0.0300 | | | | | | 0.000399 |
| | | (0.253) | | | | | | (0.0112) |
| Loan Loss Allowance/TL | | 0.0341 | | | | | | 0.00510 |
| | | (0.152) | | | | | | (0.0185) |
| Net Charge Offs/TL | | 0.306 | | | | | | 0.00894 |
| | | (0.243) | | | | | | (0.0233) |
| Tot. Risk Weight. Assets/TA | | | -0.00576 | | | | | -4.81e-05 |
| | | | (0.00962) | | | | | (0.000560) |
| Loan Growth | | | -0.0691 | | | | | 0.00164 |
| | | | (0.0618) | | | | | (0.00524) |
| Interest from Loans/TL | | | 0.108* | | | | | -0.00221 |
| | | | (0.0649) | | | | | (0.00375) |
| ROA | | | -0.120*** | | | | | 0.00185 |
| | | | (0.0556) | | | | | (0.00406) |
| Debt/TA | | | | 0.166*** | | | | 0.00479 |
| | | | | (0.0673) | | | | (0.0101) |
| Loans/TA | | | | 0.0120** | | | | 0.000521 |
| | | | | (0.00707) | | | | (0.00125) |
| log(TA) | | | | 0.00121** | | | | 0.000124** |
| | | | | (0.000783) | | | | (0.000267) |
| Real Estate Loans/TL | | | | | 0.0268** | | | 0.000871** |
| | | | | | (0.0104) | | | (0.00196) |
| Dummy Sec. Real Est. Loans | | | | | 0.000305 | | | -0.000180 |
| | | | | | (0.00377) | | | (0.000435) |
| Beta | | | | | | 0.00667*** | | 0.000160 |
| | | | | | | (0.00268) | | (0.000320) |
| Z-score | | | | | | | -0.00116*** | -7.77e-05* |
| | | | | | | | (0.000578) | (0.000150) |
| Observations | 1453 | 1453 | 1453 | 1453 | 1453 | 1453 | 1453 | 1453 |
| pseudo $R^2$ | 0.0307 | 0.226 | 0.157 | 0.183 | 0.0803 | 0.0879 | 0.223 | 0.393 |

The dependent variable is the bank specific failure indicator for each quarter. All regressions are based on equation (14) and report marginal effects. Clustered standard errors (at the bank level) are reported in parentheses. ***, ** and * denote significance for the underlying coefficient at the 1%, 5% and 10% level respectively.

**Table 6: Failure Prediction (One Quarter)**

**Panel B (CDS Orthogonalization)**

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| CRI | 0.000397 | 0.000154 | 0.000224 | 0.000180 | 0.000260 | 0.000331 | 0.000156* | 1.02e-05 |
| | (0.000271) | (0.000106) | (0.000158) | (0.000123) | (0.000169) | (0.000249) | (9.30e-05) | (2.10e-05) |
| Non-Performing Loans/TL | | -0.0511 | | | | | | -0.00264 |
| | | (0.0342) | | | | | | (0.00640) |
| Loan Loss Provisions/TL | | 0.00793 | | | | | | 0.00204 |
| | | (0.279) | | | | | | (0.00987) |
| Loan Loss Allowance/TL | | 0.0446 | | | | | | 0.00351 |
| | | (0.171) | | | | | | (0.0149) |
| Net Charge Offs/TL | | 0.354 | | | | | | 0.00552 |
| | | (0.272) | | | | | | (0.0170) |
| Tot. Risk Weight. Assets/TA | | | -0.00447 | | | | | -3.56e-06 |
| | | | (0.0118) | | | | | (0.000448) |
| Loan Growth | | | -0.0592 | | | | | 0.00161 |
| | | | (0.0693) | | | | | (0.00512) |
| Interest from Loans/TL | | | 0.143* | | | | | -0.00119 |
| | | | (0.0751) | | | | | (0.00258) |
| ROA | | | -0.126** | | | | | 0.00207 |
| | | | (0.0572) | | | | | (0.00462) |
| Debt/TA | | | | 0.167*** | | | | 0.00361 |
| | | | | (0.0638) | | | | (0.00877) |
| Loans/TA | | | | 0.0125 | | | | 0.000441 |
| | | | | (0.00778) | | | | (0.00113) |
| log(TA) | | | | 0.00132 | | | | 0.000109 |
| | | | | (0.000813) | | | | (0.000254) |
| Real Estate Loans/TL | | | | | 0.0305*** | | | 0.000779 |
| | | | | | (0.0105) | | | (0.00190) |
| Dummy Sec. Real Est. Loans | | | | | 0.000289 | | | -0.000154 |
| | | | | | (0.00394) | | | (0.000405) |
| Beta | | | | | | 0.00629* | | 0.000119 |
| | | | | | | (0.00364) | | (0.000272) |
| Z-score | | | | | | | -0.00123** | -7.73e-05 |
| | | | | | | | (0.000562) | (0.000162) |
| Observations | 1453 | 1453 | 1453 | 1453 | 1453 | 1453 | 1453 | 1453 |
| pseudo $R^2$ | 0.00292 | 0.214 | 0.130 | 0.170 | 0.0604 | 0.0360 | 0.215 | 0.385 |

The dependent variable is the bank specific failure indicator for each quarter. All regressions are based on equation (14) and report marginal effects. Clustered standard errors (at the bank level) are reported in parentheses. ***, ** and * denote significance for the underlying coefficient at the 1%, 5% and 10% level respectively.

**Table 7: Failure Prediction with Enlarged Sample**

| | Panel A (Market Orthogonalization) | | | | Panel B (CDS Orthogonalization) | | | |
|---|---|---|---|---|---|---|---|---|
| | Failure in 2 Quarters | | Failure in 1 Quarter | | Failure in 2 Quarters | | Failure in 1 Quarter | |
| | (1) | (2) | (3) | (4) | (1) | (2) | (3) | (4) |
| CRI | 0.115*** | 0.0881*** | 0.105*** | 0.0563*** | -9.51e-05 | -0.000116 | -0.000173 | -0.000151 |
| | (0.0249) | (0.0313) | (0.0236) | (0.0269) | (0.000356) | (0.000274) | (0.000507) | (0.000331) |
| Z-score | | -0.00162 | | -0.00229** | | -0.00258*** | | -0.00288*** |
| | | (0.000891) | | (0.000600) | | (0.000857) | | (0.000647) |
| Observations | 1510 | 1510 | 1510 | 1510 | 1510 | 1510 | 1510 | 1510 |
| pseudo $R^2$ | 0.118 | 0.146 | 0.0837 | 0.148 | 4.34e-05 | 0.0520 | 0.000163 | 0.0890 |

The dependent variable is the bank specific failure indicator for each quarter. All regressions are based on equation (14) and report marginal effects. Clustered standard errors (at the bank level) are reported in parentheses. ***, ** and * denote significance for the underlying coefficient at the 1%, 5% and 10% level respectively.