Capital Adequacy in Basel III: A Portfolio Perspective

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1 Abstract

We explore the final objectives of bank regulation, and potential enhancements to the existing Basel framework. The main goal of regulation is to prevent a systemic collapse as a result of bank failures rather than to prevent the failure of individual banks. Hence, capital adequacy standards should emphasize the dependence of the system on individual banks in times of distress. We investigate capital adequacy by modeling a bank's balance sheet as a portfolio. In our baseline scenario, a bank maximizes its return-on-equity subject to Basel III's capital requirements. Our results show that imposing an internal capital buffer based on mean shortfall (CVaR) leads to a meaningful reduction in the proportion of risky assets on the balance sheet. Another interesting observation is that switching from an individual bank's risk metric to a systemic risk metric dramatically constrains the proportion of risky assets on the balance sheet. Finally, we implement a method to forecast the CoVaR-based systematic risk measure at an institution-level based on the empirical distribution of bank equity returns. Our out-of-sample forecasts are effective in predicting recent crises and provide evidence that the approach of measuring systematic risk in this paper is valid.

2 Introduction

The Basel Committee on Banking Supervision or BCBS [9] has provided guidelines for bank regulations through the Basel III accord [13, 14, 6]. These guidelines are scheduled to be introduced starting in 2013. Basel III tries to address the deficiencies of older bank regulations. Banks must meet higher capital requirements and maintain a required Leverage Ratio, Liquidity Coverage Ratio and Net Stable Funding Ratio. Measures are also introduced to manage counterparty risk, model risk, proyclicality, and other risks highlighted by the recent banking crisis.

The goal of this paper is to find ways to improve Basel III. In this regard, the limitations of bank regulations can be broadly classified as follows. First, regulations may be inadequate. Basel I is often criticized for its failure to avert the last major banking crisis.

The second and more common criticism is that regulations bear the right intentions but fall short on execution. It is argued in [10] that increased capital requirements may drive traditional banking activity into the "shadow banking" sector, which therefore must be monitored. Failing to do so would leave credit markets exposed while making individual banks safer. This distinction between individual bank risk and systemic risk, emphasized in [2, 1, 4], is one of the cornerstones of our paper. The lack of emphasis on diversification and banks' ability to get favorable treatment by transferring risks from one bucket to another bucket are some other weaknesses of Basel III that are highlighted in [6]. The authors of [20, 18] point out that the Risk-Weighted Assets (RWA) calculation differs across banks, and innovation designed to circumvent regulation based on the treatment of RWA has the potential to undermine Basel III.

The final criticism is that, in the wake of a particularly painful crisis, regulations can sometimes be severely restrictive, and in the process lower overall social utility. This stance is taken by several banks [15, 17, 5], who criticize the new regulations on grounds that they will lead to reduced economic output. Disagreeing with the banks' view, the authors of [3] state that banks' equity may be expensive to private entities but not to society as a whole. According to [3], the abundance of arguments opposing higher capital requirements comes from the incentives that bank managers and shareholders have for maintaining higher leverage.

While there are many views on regulations, one key point deserves to be highlighted. As stated in [1] "Systemic risk should not be described in terms of a financial firm's failure per se but in the context of a firm's overall contribution to system wide failure." The authors go on to characterize systemic risk in terms of expected capital shortfall in a crisis, which they show is a good substitute for stress tests. Another innovative way of measuring systemic risk uses CoVaR [4], defined as the value-at-risk (VaR) of the financial system conditional on banks being under distress.

We investigate capital adequacy by viewing a bank's balance sheet as a portfolio with assets (reserves, loans, and traded assets), liabilities (debt), and equity (capital). Our baseline scenario is the one where a bank maximizes its return-on-equity subject to Basel III's capital requirement. Our results show that requiring an internal capital buffer based on mean shortfall (CVaR), which is something an internal risk manager might recommend, leads to a meaningful reduction in the proportion of risky assets on the balance sheet. Next, we replace an individual bank's risk metric with a systemic risk metric based on CoVaR [4]. Doing so dramatically constrains the proportion of risky assets on the balance sheet, even for a bank that has limited leverage.

Finally, we implement a CoVaR-based method to forecast the systematic risk measure at an institution level based on the empirical distribution of bank equity returns. CoVaR is defined as the VaR of the financial system conditional on an institution being under distress. Information about an institution's contribution to systemic risk is contained in the difference of CoVaR in a crisis and CoVaR in the median state. We call this difference $\triangle CoVaR$. It is illustrated that Citigroup and Bank of America exhibited a higher magnitude of $\triangle CoVaR$ during 2008, while Wells Fargo had a relatively small $\triangle CoVaR$. These patterns are indeed in line with the reality.

Overall, our empirical test shows that $\triangle CoVaR$ is a valid measure of systematic risk at the institution level. Therefore, it can be extended to calibrate a risk capital surcharge in the Basel regulatory framework. By incorporating this approach in calculating risk weighted assets, the new regulatory framework can achieve the effect discussed in Section 4, i.e. limit banks' exposure to assets that contribute the most to systematic risk.

The remainder of the paper is organized as follows. In Section 3, we discuss the framework of our problem, describing the portfolio-based model of a bank's balance sheet, and the various ratios that constrain banks. Section 4 describes our results in detail. Section 5 provides empirical evidence on the effectiveness of a systemic risk measure which we intend to use for deriving improved risk weighting scheme. We conclude in Section 6.

3 Model Framework

We adopt the framework described by [Pokutta and Schmaltz, 2012]. A bank's balance sheet can be viewed as a portfolio with assets (loans, reserves and traded assets), liabilities (deposits) and equity (capital). To make things simple while still being able to draw meaningful conclusions, we model a bank's asset base as a portfolio of loans and two traded asset classes. Log returns on each asset class are assumed to follow normal distribution.

We explore the desirability of banks' capital requirements by aggregating conclusions from different portfolio optimization problems. The answer to each question provides progressively greater insight. Our focus is on capital adequacy. A study of liquidity requirement is beyond the scope of this paper, therefore we do not explicitly consider reserves on the balance sheet, yet it is implicitly allowed when assets are not fully invested in risky securities. For the first three questions, we keep leverage fixed as well. The simplified model allows us to study the interplay of risk and return through the portfolio weights of the bank's assets, before we introduce the effects of endogenous leverage.

According to the different treatments for market risk and credit risk under Basel III, we categorize banks as two types:

1. Broker-dealer, which only has a trading book with liquid market instruments and no banking book; the capital charge on the trading book comes from VaR (Market Risk Requirement, MRR)

2. Savings bank, which has both a banking book and a trading book. The capital charge on the banking book (Loans) is 8% times credit risk weights. The capital charge on the trading book comes from VaR (Market Risk Requirement, MRR). We constrain the business model of the savings bank by restricting its MRR/Total RWA $\leq$ 45%, i.e. at least 55% of its RWA must come from its banking business.

3.1 Q1: Max Return Portfolio with Basel Constraints

The first question seeks the portfolio that will maximize return-on-equity (RoE) with fixed leverage and Basel constraints.

Broker-dealer:
Assume that the broker-dealer's balance sheet contains two risky traded assets, whose return characteristics are known. The market risk capital charge is based on VaR. The formula is

$$MRC_t = Max(k\frac{1}{60}\sum_{i=1}^{70} VaR_{i-1}, VaR_{i-1}) + SRC_t)$$

where VaR stands for 10-day 99% VaR, k is a multiplier between 3 and 4, and SRC is a specific charge concerning counterparties. We assume $SRC = 0$, which is reasonable for exchange-traded instruments. To make the magnitude comparable, we use $2 \times VaR$ as an average market risk charge. The optimization problem can be stated as follows:
Objective:

$$max[\sum(asset\ weight \times asset\ return) - cost\ of\ debt \times (1 - Capital)]$$

Subject to:
Capital constraint:

$$Capital \geq sum(asset\ weight \times capital\ charge)$$

General constraints:

$$0 \leq asset\ weight \leq 1$$

$$sum(asset\ weight) \leq 1$$

We further explore two scenarios, one with high leverage and the other with low leverage:

Leverage constraints:

$$High\ leverage : Capital/Totalasset = 4\%$$

$$Low\ leverage : Capital/Totalasset = 10\%$$

Savings bank/Commercial bank:
In addition to holding the same asset pool in the trading book as the broker dealer does, the savings bank has another asset class of loans in its banking book, which will be charged capital on its credit risk. The formulation of the optimization problem is similar to that of the broker-dealer type. Again we study two scenarios for the savings bank with different levels of fixed leverage, but the level for high leverage case is lower than that for Broker-dealer type.
Objective:

$$max[\sum(asset\ weight \times asset\ return) - cost\ of\ debt \times (1 - Capital)]$$

Subject to:

Capital constraint:

$$Capital \geq sum(asset\ weight \times capital\ charge)$$

General constraints:

$$0 \leq asset\ weight \leq 1$$

$$sum(asset\ weight) \leq 1$$

Leverage constraints:

$$Highleverage : Capital/Totalasset = 5\%$$

$$Lowleverage : Capital/Totalasset = 10\%$$

3.2 Q2: Optimal Portfolio for Internal Risk Manager

The second question also seeks an RoE-maximizing portfolio with fixed leverage and Basel constraints like Q1, but in addition it also requires an internal capital buffer. It is the internal risk manager's responsibility to prevent capital from falling below a regulated level when losses occur in the trading book. We adopt 99% CVaR (conditional VaR or mean shortfall) of each asset as the level for its capital buffer, as this is commonly used for determining the economic capital. The idea is to hold an amount of capital equal to the expected loss in big drawdowns in excess of regulated capital. The optimization therefore maximizes return by keeping the capital charge plus capital buffer below a predetermined threshold. The optimization problem can be formally stated as follows:
Objective:

$$max[sum(asset\ weight \times asset\ return) - cost\ of\ debt \times (1 - Capital)]$$

Subject to:
Capital constraint:

$$Capital \geq sum(asset\ weight \times capital\ charge) + CVaR(Total\ assets)$$

plus General constraints and Leverage constraints

3.3 Q3: Optimal Portfolio for Regulators

Regulators have a similar but somewhat different objective than internal risk manager in banks. Capital shortfall in a bank concerns regulators when it has a contagion effect that puts pressure on other bank's balance sheet and threatens the viability of the entire banking system, which was exactly what happened in the global financial crisis. To address this issue, we need to relate the capital charge on bank assets to a measure of such risk. The Basel regulation and internal risk control both purely focus on standalone risk at the institution level. Yet from a regulator's perspective, the isolated failure of a bank is of little consequence if it does not result in systemic risk. Therefore, it is more appropriate to weight risk based on the contribution to systemic risk. The concept is analogous to the Markowitz portfolio theory, in which asset risk is measured by beta with respect to market portfolio.

We studied two such measures, MES (Marginal Expected Shortfall) from [1] and CoVaR [4]. These two metrics essentially measure the loss of an instrument/asset conditional on significant market drawdown. Under normality assumption, it can be shown that these loss measures are proportional to correlation, while MES also depends on volatility of the asset. These measures can be translated to risk weights by requiring that the loss in market distress does not lead to a shortfall in regulated capital. [1]

In order for correlation to make sense, we also need a hypothetical portfolio of the entire banking system. The financial sector equity index is used for this purpose. The optimization problem in Q3 replaces the risk weights in Q1 and Q2 with weights based on systemic risk measures (specifically MES in this problem):
Objective:

$$max[sum(asset\ weight \times asset\ return) - cost\ of\ debt \times (1 - Capital)]$$

Subject to:

Capital constraints:

$$Capital \geq sum(systematic\ risk\ weights \times asset\ return)$$

Or

$$Capital \geq sum(systematic\ risk\ weights \times asset\ return) + CVaR(Total\ assets)$$

plus General constraints and Leverage constraints

3.4 Q4: Cases for Endogenous Leverage

In this subsection we study the cases where banks have the liberty and ability to alter capital structure. Here we do not enforce fixed leverage, but incorporate the leverage ratio requirement from Basel III that requires banks to hold at least 3% of non-risk weighted assets as capital. The optimization problem for Q4 is therefore:
Objective:

$$max[\sum(asset\ weight \times asset\ return) - cost\ of\ debt \times (1 - Capital)]$$

Subject to:

Capital constraint: follows Q1, Q2 and Q3
Leverage constraints:

$$Capital/Total\ assets \geq 3\%$$

plus General constraints.

4 Implementation and Results

To implement the optimizations outlined in Section 3, we create two hypothetical bank assets mimic equity and fixed income. Their returns are normally distributed with mean [10%, 6%] and standard deviation [10.72%, 3.45%]. Their correlation with financial sector index is [89.75%, -40.61%]. So basically their risk profiles contrast each other. We denote the first asset "High risk" and the latter one "Low risk". Moreover, we assume average return of loans on the banking book is 4.5%, cost of debt equals 4%, and the average risk weight of bank loans is 0.5 following [Pokutta and Schmaltz, 2012].
Table 1 and 2 present the results for problem Q1, Q2 and Q3.

Q1: The solution for Broker-dealer is extremely sensitive to leverage. When leverage is forced to be low (capital=10% of assets), the RoE-maximizing portfolio puts over 90% in High risk asset in our particular example. When leverage is high, the solution becomes conservative, assigning only 9% in High risk. On the other hand, due the business model constraints, Savings bank has substantial holdings of loans compared to risky assets. Especially in the low leverage case, the abundant capital forces loans to be overloaded in order to meet the constraint. Overall, we can see Basel capital requirements constrain bank's ability to take risk, as in most cases banks in our examples cannot fully load on high risk assets.

Q2: Not surprisingly, the optimal portfolios for Q2 assign higher weights to lower risk assets compared to Q1, except in the case of low leverage Savings bank where almost all assets are loans. These results show that an internal capital buffer unambiguously reduces risk taking and profitability. As in reality, the risk manager's objective contradicts the purely profit-seeking objective in Q1.

Q3: The optimal portfolios for Q3 is of particular interest to us as they resulted from an untraditional measure. Firstly, we observe that the effect of using systematic risk weights is independent of leverage, suggesting that any risk reduction from introducing such risk weights cannot be achieved by simply limiting leverage, as proposed in Basel III. More importantly, these results show that using systemic risk weights significantly reduces loading in High risk assets when banks are risky (i.e. have relatively large holding in High risk assets), while keep or midly increase risk taking when banks are at low risk. This works ideally for us - we want a capital regulation that heavily penalize risk taking for high risk institutions with potential to cause systematic event, but also encourage profitability for safe banks rather than forcing them to hold unnecessary capital. The framework of deploying risk weights based on systemic risk measures exactly meets such objective.

Table 3 reports the results for Q4. When banks are free to alter capital structure, the effects of Basel requirements, internal capital buffer and systemic risk weights are still highly visible. It's worthwhile to point out that in this setting, all Broker-dealers will presumaly choose the same capital structure and similarly for Savings banks, therefore the entire banking system becomes more homogeneous.

Again using systemic risk weights nicely fullfills our goal. In the case of the Broker-dealer, it pushes them to enhance capital base as they are usually highly levered. In the case of the savings bank, imposing a systematic risk measure leads to a focus on lending, reducing its exposure to traded markets, and enhancing the capital base.

5 Empirical Tests of Systemic Risk Measure

In this section we present the estimation of the systemic risk measure that leads to the risk weights for determining the capital surcharge. It is the natural step from the results above as we need a viable approach to compute systemic risk weights in order to incorporate it in a regulatory framework. The essence of a systemic risk measure is to capture time-varying dependence of bank and the system. Following [2], we describe the estimation of time-varying CoVaR conditional on state variables. Based on the methodology in [2], we calculated $CoVaR$ for major banks conforming to Basel. Specifically, $\triangle CoVaR$ means the VaR of the Financial System conditional on the event that one specific institution is at its VaR level. Mathematically, we have:

$$\triangle CoVaR_q^{System|i} = CoVaR_q^{System|X^i=VaR_q^i} - CoVaR_q^{System|X^i=Median^i}$$

$$Pr(X^{System} \leq CoVaR_q^{System|X^i=VaR_{q'}^i} | X^i = VaR_{q'}^i) = q$$

Empirically, we used Quantile Regression on the following two equations:

$$X_t^i = \alpha^i + \gamma^i M_{t-1} + \epsilon_t^i \quad (1)$$

$$X_t^{System} = \alpha^{System|i} + \beta^{System|i} X_t^i + \gamma^{System|i} M_{t-1} + \epsilon_t^{System|i} \quad (2)$$

Unlike with [2], X_t^i and X_t^{System} are weekly returns of institutions and the financial sector index, respectively. M_{t-1} is a one-period lagged weekly data of macroeconomics statistics. They are:

(1) VIX, which captures the implied volatility in the stock market reported by the Chicago Board Options Exchange.

(2) A short term "liquidity spread" defined as the difference between the three-month repo rate and the three-month bill rate. This liquidity spread measures short-term liquidity risk. We use the three-month general collateral repo rate that is available on Bloomberg, and obtain the three-month Treasury rate from the Federal Reserve Bank of New York.

(3) The change in the three-month Treasury bill rate from the Federal Reserve Board's H.15. We use the change in the three-month Treasury bill rate because we find that the change, not the level, is most significant in explaining the tails of financial sector market-valued asset returns.

(4) The change in the slope of the yield curve, measured by the yield spread between the ten-year Treasury rate and the three-month bill rate obtained from the Federal Reserve Board's H.15 release.

(5) The change in the credit spread between BAA-rated bonds and the Treasury rate (with the same maturity of ten years) from the Federal Reserve Board's H.15 release.

(6) The weekly equity market return from CRSP.

(7) The weekly real estate sector return in excess of the market return (from the real estate companies with SIC code 65-66).

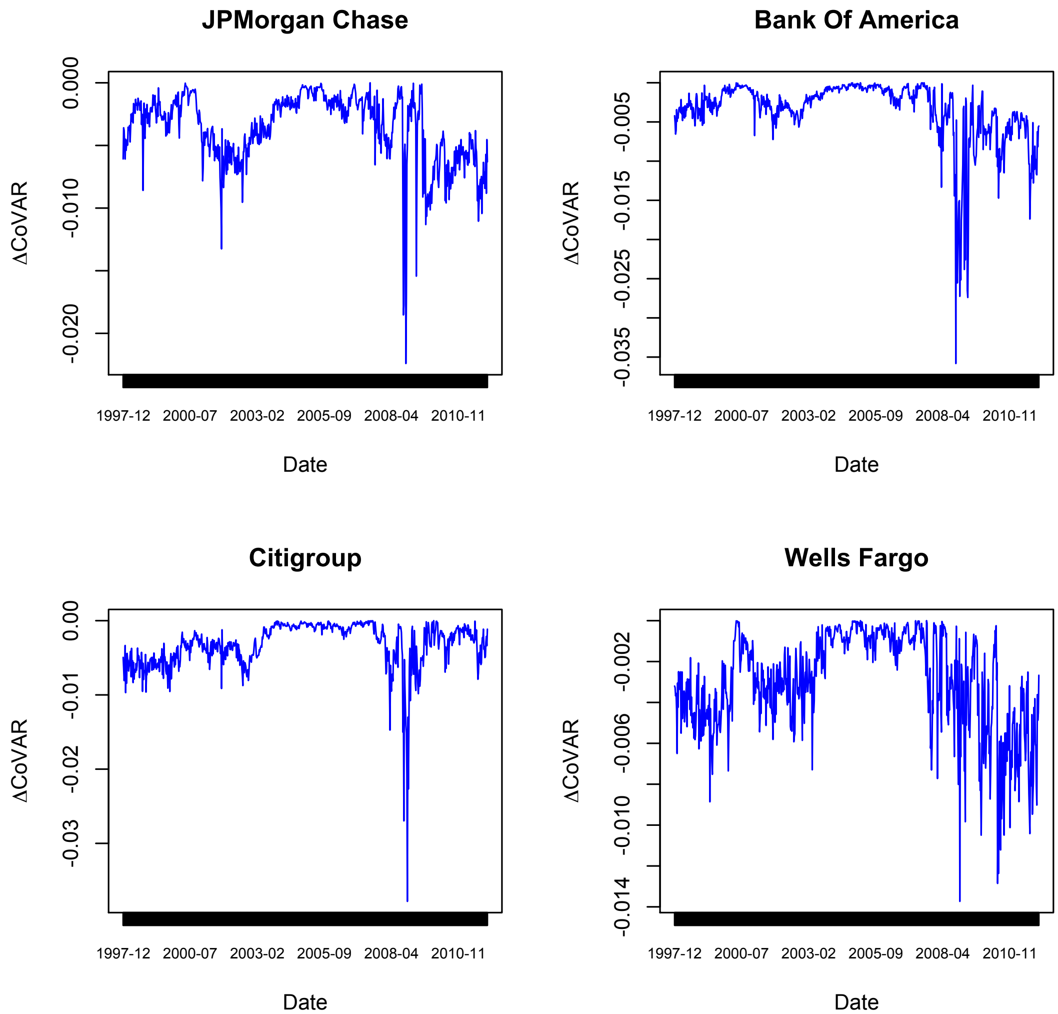
After estimating the parameters in (1) and (2) via Quantile Regression, we can follow these equations to get the $\triangle CoVaR^{System|i}$:

$$VaR_t^i(q) = \hat{\alpha}_q^i + \hat{\gamma}_q^i M_{t-1} \tag{3}$$

$$CoVaR_t^i(q) = \hat{\alpha}^{system|i} + \hat{\beta}^{system|i} VaR_t^i(q) + \hat{\gamma}^{system|i} M_{t-1} \tag{4}$$

$$\triangle CoVaR_q^{system|i} = CoVaR_t^i(q) - CoVaR_t^i(50\%) = \hat{\beta}_q^i (VaR_q^i - VaR_{50\%}^i) \tag{5}$$

Thereby we can see the plots:



In the figures above, we plot $\triangle CoVaR$ for four representative banks over our sample horizon. In each case, $\triangle CoVaR$ slumped during the dot-com bubble in early 2000, subprime crisis in 2008, and Eurozone crisis in 2011. Notably, Citigroup and Bank of America exhibit higher magnitude in $\triangle CoVaR$ during 2008, while Wells Fargo has relatively small $\triangle CoVaR$. These patterns are indeed in line with reality. Overall, our empirical test shows $\triangle CoVaR$ is a valid measure of systemic risk at the institution level. Therefore, it can be extended to calibrate the risk capital surcharge in the Basel regulatory framework. By incorporating this approach in calculating risk weighted assets, the new regulatory framework can achieve the effect discussed in Section 4, i.e. limit bank's exposure on assets that contribute the most to systemic risk.

From Table 4, we can see that CoVaR actually is a very good measure of how one single institution impacts on the whole system. Specifically, we can see that during the 2008

Financial Crisis, Lehman Brothers, which later declared bankruptcy, ranked at top while during the 2011 Euro Crisis, most investment banks were ranked higher than commercial ones, due to their higher exposure to European credit markets.

6 Conclusions

We find that the use of different risk metrics leads to significantly different proportions of risky assets on banks' balance sheets. In particular, a bank's internal risk manager may prefer a portfolio that is less risky than what regulations require. We also conclude that there are effective methods for measuring individual institutions' contributions to systemic risk that can be implemented using publicly available information. We implement and test one such method based on CoVaR, and find it to be highly effective. The use of such metrics can help identify institutions that are a potential threat to systemic stability, and induce them to strengthen their capital structure. Such targeted regulations can reduce interference in the operation of stable banks, and help to address concerns that regulations are responsible for widespread reduction in banks' profitability.

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Table 1: Optimal Portfolio with Fixed Leverage: Broker-dealer

Broker-dealer; High leverage: Capital / Total assets=4%			
	High risk asset	Low risk asset	Return on Capital
Q1	0.0904	0.9096	39.04%
Q2	0.0561	0.9439	35.61%
Q3: replace Q1 with systematic risk weights	0.0701	0.9299	37.01%
Q3: replace Q2 with systematic risk weights	0.0907	0.8426	29.06%
Broker-dealer; Low leverage: Capital / Total assets=10%			
	High risk asset	Low risk asset	Return on Capital
Q1	0.9378	0.0622	52.51%
Q2	0.7298	0.2702	44.19%
Q3: replace Q1 with systematic risk weights	0.0737	0.9263	17.95%
Q3: replace Q2 with systematic risk weights	0.0470	0.9486	16.61%

Table 2: Optimal Portfolio with Fixed Leverage: Savings Bank

Savings bank; MRR/RWA≤45%, High leverage: Capital / Total assets=5%					
	Loans	High risk asset	Low risk asset	Capital/Total assets	Return on Capital
Q1	0.6875	0.1695	0.1430	5%	36.93%
Q2	0.6875	0.1605	0.1520	5%	36.22%
Q3: replace Q1 with systematic risk weights	0.6875	0	0.2988	5%	21.74%
Q3: replace Q2 with systematic risk weights	0.6875	0	0.2952	5%	21.29%
Savings bank; MRR/RWA≤45%, Low leverage: Capital / Total assets=10%					
	Loans	High risk asset	Low risk asset	Capital/Total assets	Return on Capital
Q1	0.9821	0.0179	0	10%	9.98%
Q2	0.9821	0.0179	0	10%	9.98%
Q3: replace Q1 with systematic risk weights	0.9821	0.0179	0	10%	9.98%
Q3: replace Q2 with systematic risk weights	0.9821	0.0179	0	10%	9.98%

Table 3: Optimal Portfolio with Endogenous Leverage

Q4 - Broker dealer; MRR/RWA=100%, Endogenous leverage: Capital / Total assets≥3%					
	Loans	High risk asset	Low risk asset	Capital/Total assets	Return on Capital
Q1		0	0.8930	3%	49.26%
Q2		0	0.3984	3%	49.64%
Q3: replace Q1 with systematic risk weights		0	0.3984	3%	49.64%
Q3: replace Q2 with systematic risk weights		0.7224	0.2776	13.66%	39.80%

Q4 - Savings bank; MRR/RWA≤45%, Endogenous leverage: Capital / Total assets≥3%					
	Loans	High risk asset	Low risk asset	Capital/Total assets	Return on Capital
Q1	0.4230	0	0.5770	4.31%	35.70%
Q2	0.5018	0.0822	0.4159	5.11%	34.85%
Q3: replace Q1 with systemic risk weights	0.7537	0	0.2463	7.67%	28.17%
Q3: replace Q2 with systemic risk weights	0.7630	0.2370	0	7.77%	27.22%

Table 4: Ranking of Systemic Risk Measured by $\triangle$CoVAR in Two Crisises

Rank	2008 Financial Crisis		2011 Euro Crisis	
1	Lehman Brothers	-0.0142	Suntrust Banks Inc	-0.0240
2	Morgan Stanley	-0.0076	Morgan Stanley	-0.0230
3	Goldman Sachs	-0.0075	Bank of America	-0.0174
4	Bank of New York Mellon	-0.0041	Bank of New York Mellon	-0.0147
5	PNC Financial Servies	-0.0030	Goldman Sachs	-0.0136
6	Wells Fargo	-0.0029	PNC Financial Servies	-0.0129
7	Wachovia Corp	-0.0028	State Street Corp	-0.0129
8	Marshall & Ilsley	-0.0024	JPMorgan Chase	-0.0110
9	State Street Corp	-0.0020	Wells Fargo	-0.0104
10	Bank of America	-0.0013	Keycorp	-0.0091
11	Keycorp	-0.0010	Citigroup	-0.0070
12	Citigroup	-0.0010	Wachovia Corp	NA
13	Suntrust Banks Inc	-0.0004	Marshall & Ilsley	NA
14	JPMorgan Chase	-0.0004	Merrill Lynch	NA
15	Merrill Lynch	-0.0003	Lehman Brothers	NA