CAPITAL SHORTFALL: A NEW APPROACH TO RANKING and REGULATING SYSTEMIC RISKS

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ABSTRACT

The financial crisis of 2007-2009 has given way to the sovereign debt crisis of 2010-2012, yet many of the banking issues remain the same. We discuss a method to estimate the capital that a financial firm would need to raise if we have another financial crisis. This measure of capital shortfall is based on publicly available information but is conceptually similar to the stress tests conducted by US and European regulators. We argue that this measure summarizes the major characteristics of systemic risk and provides a reliable interpretation of the past and current financial crises.

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ABSTRACT

The financial crisis of 2007-2009 has given way to the sovereign debt crisis of 2010-2012, yet many of the banking issues remain the same. We discuss a method to estimate the capital that a financial firm would need to raise if we have another financial crisis. This measure of capital shortfall is based on publicly available information but is conceptually similar to the stress tests conducted by US and European regulators. We argue that this measure summarizes the major characteristics of systemic risk and provides a reliable interpretation of the past and current financial crises.

The most severe impacts of the financial crisis of 2007-9 arose immediately after the failure of Lehman Brothers on September 15, 2008. It is natural to wonder whether the United States should have arranged for an orderly rescue of Lehman as it did for Fannie Mae and Freddie Mac the week before and as it did for AIG, Merrill Lynch, Citigroup, Bank of America, Morgan Stanley, Goldman Sachs, Washington Mutual and Wachovia as well as many smaller and foreign banks over the next days and weeks. How much capital would have been necessary ex post to arrange such an orderly rescue? Another policy recommendation of the Dodd Frank Act of 2010 is to facilitate orderly liquidation and/or resolution, and require living wills of financial institutions so that no future bailouts will be necessary. Will this work when we need it? There is, however, also a third choice. Rather than discuss whether to rescue or not, it is sensible to regulate *ex ante* financial institutions whose failure is likely to have major impacts on the financial and real sectors of the economy; for instance, regulate them to reduce their risk, and consequently the probability that taxpayers will face this choice.

Effective and efficient regulation of this type requires identification of systemically important financial institutions (SIFIs). A typical definition has been provided by Federal Reserve Governor Daniel Tarullo[1]: "*Financial institutions are systemically important if the failure of the firm to meet its obligations to creditors and customers would have significant adverse consequences for the financial system and the broader economy*." This definition is useful because it highlights two important ideas. The first is that the core problem is a firm's difficulty in performing financial services when it fails, i.e., when its capital falls short. The second is that

[1] "*Regulatory Restructuring*," Testimony before the Committee on Banking, Housing, and Urban Affairs, U.S. Senate, Washington, D.C., July 23, 2009.

systemic risk matters only to the extent there is an impact on the broader economy. There is a large theoretical and empirical literature that supports these two ideas (see, for example, Thakor (1996) and Holmstrom and Tirole (1997) on the theoretical side, and Bernanke (1983), Slovin, Sushka and Polonchek (1993) and Gibson (1995) for empirical observations).

The definition, however, misses a key feature of systemic risk. 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 intuition is straightforward. When only an individual financial firm's capital is low, the firm can no longer financially intermediate. This has minimal consequences though because other financial firms can fill in for the failed firm's void. When capital is low in the aggregate, however, it is not possible for other financial firms to step into the breach. This breakdown in aggregate financial intermediation is the reason there are severe consequences for the broader economy.

Motivated from this one economic point, it is possible to provide a precise definition of the systemic risk of a financial firm. Acharya, Pedersen, Philippon and Richardson (2010) develop a simple model in which a group of banks set leverage levels and choose asset positions in a broader economic environment with systemic risk emerging when aggregate bank capital drops below a given threshold. Within this framework, they show that the systemic risk of a firm is equal to the product of three components:

$$\begin{aligned} \text{Real systemic risk of a firm} = {} & \text{Real social costs of a crisis per dollar of capital shortage} \\ & \times \text{Probability of a crisis } (\text{i.e., an aggregate capital shortfall}) \\ & \times \text{Expected capital shortfall of the firm in a crisis} \end{aligned} \tag{1}$$

The focus of this paper is on the third component, namely the expected capital shortfall of a firm in a crisis. Expected capital shortfall captures in a single measure many of the characteristics considered important for systemic risk such as size, leverage, and interconnectedness (e.g., see the 2011 annual report of the Financial Stability Oversight Council (FSOC), formed in the United States following the Dodd Frank Act of 2010, for the determined regulatory factors for assessing systemic risk of financial firms). All of these characteristics tend to increase a firm's capital shortfall when there are widespread losses in the financial sector. But a firm's expected capital shortfall also provides an important addition, most notably the *co-movement* of the financial firm's assets with the aggregate financial sector in a crisis.

Stress tests are a standard device used to determine the capital that an institution will need to raise if there is a financial crisis. Under the Dodd-Frank Act, the regulators in the United States are required to conduct annual stress tests to assess capital adequacy of financial firms. The expected capital shortfall estimation we describe below can be a useful tool or substitute for such stress tests.

I. THE METHODOLOGY

In Brownlees and Engle (2011),[2] a model of this form is implemented based on publicly available data in order to determine which institutions are systemically risky, what the cost of a bailout would be, and how this leads naturally to a regulatory strategy. The results of this analysis are updated weekly and posted at http://vlab.stern.nyu.edu/welcome/risk. Results are

[2] See also Chapter 4 "Measuring Systemic Risk" and Chapter 5 "Taxing Systemic Risk" in *Regulating Wall Street: The Dodd-Frank Act and the New Architecture of Global Finance,* edited by Viral V Acharya, Thomas Cooley, Matthew Richardson, and Ingo Walter, John Wiley & Sons, November 2010.

posted both for approximately 100 US financial firms and for 1200 global financial firms. Information from this website will be described below.

The method to be described computes *SRISK*, which is defined as the capital that a firm is expected to need if we have another financial crisis. Symbolically it can be defined as

$$SRISK_{i,t} = E_{t-1}\left(Capital\ \ Shortfall_i \middle| Crisis\right) \tag{2}$$

This can be estimated with a bivariate daily time series model of equity returns on firm i and on a broad market index (which could be just the financial sector).

$$\begin{aligned} &R_{m,t} = \sigma_{m,t}\varepsilon_{m,t} \\ &R_{i,t} = \sigma_{i,t}\left(\rho_{i,t}\varepsilon_{m,t} + \sqrt{1-\rho_{i,t}^2}\,\xi_{i,t}\right) \\ &\left(\varepsilon_{m,t}, \xi_{i,t}\right) \sim F \end{aligned} \tag{3}$$

In this system, the volatilities are asymmetric GARCH processes and the correlation is estimated by DCC. The joint distribution, *F,* ensures that the random variables are uncorrelated but not independent. It can be parameterized with a copula or simply treated as an empirical cumulative distribution function (cdf). The parameters of this process can be estimated by QMLE using standard techniques. On the web site, recursive estimates are presented so that systemic risk inferences are made at each point using only the information that was available.

To calculate the systemic risk, this system first evaluates the losses that an equity holder would face if there is a future crisis. To do this, the system is simulated for six months into the future many times. This simulation allows volatilities and correlations to change over time and samples from the empirical distribution *F* so that empirical tail dependence is maintained. The most pessimistic scenarios for the market return are treated as Crisis scenarios. To be specific, whenever the broad index falls by 40% over the next six months, this is viewed as a crisis. For these scenarios, the expected loss of equity value of firm *i* is called the Long Run Marginal Expected Shortfall or *LRMES*. This is just the average of the fractional returns of the firm's equity in the crisis scenarios. In versions of the model where the simulation is not yet implemented, *LRMES* is approximated as *1-exp(-18*MES)* where *MES* is the one day loss expected if market returns are less than -2%.

The capital shortfall can be directly calculated by recognizing that the book value of debt will be relatively unchanged during this six-month period while equity values fall by *LRMES*. If a prudential capital ratio is considered to be *k* which we take as 8%, then

$$\begin{aligned} SRISK_{i,t} &= E\left(\left(k\left(Debt+Equity\right)-Equity\right)\middle|Crisis\right) \\ &= k\left(Debt_{i,t}\right)-\left(1-k\right)\left(1-LRMES_{i,t}\right)Equity_{i,t} \end{aligned} \tag{4}$$

where *Equity* is the market value of equity today. The contribution to aggregate *SRISK* by any firm is also tabulated as

$$SRISK\%_{i,t}=\frac{SRISK_{i,t}}{\sum_{j\in J}SRISK_{j,t}},\qquad J=\left\{firms\ \ with\ \ positive\ \ SRISK\right\} \tag{5}$$

An enhanced definition of a Crisis will incorporate additional features into the analysis in the future. A crisis can be defined, e.g., by the undercapitalization of the financial sector. Thus if *E* is the sum of all equity in the financial sector and *D* is the aggregate book value of debt, then a crisis means that

$$E < \frac{k}{1-k} D \tag{6}$$

Thus *LRMES* would be evaluated on scenarios satisfying (6). This solution would allow evaluation of the probability of a crisis in equation (1) and implement the leverage externality whereby the systemic risk due to the leverage of each firm will increase with the leverage of other firms. This definition will also make the policy implementation less pro-cyclical.

II. A MARKET BASED ALTERNATIVE TO BASEL RISK WEIGHTS

A reasonable regulatory requirement might be that *SRISK=0*. In this case a firm will not need, at least in expectation, to raise capital in a future crisis of the severity assumed. From (4) this implies that

$$Equity_{i,t} \geq \frac{k\ Debt_{i,t}}{(1-k)\left(1-LRMES_{i,t}\right)} \tag{7}$$

Using numbers from Bank of America in Table 1 below, *LRMES* is 71% and imposing a hard capital requirement of *k*=4%, the firm specific ratio of equity to debt is .14 or maximum leverage ratio of Debt to Equity is 7.1. For Wells Fargo this calculation gives a maximum leverage of 9.6, which is essentially what it has today. Thus, each firm would have individual prudential capital requirements based on the risk profile of their business. Any firm desiring to reduce its capital requirement could de-lever, de-risk, de-merge or decline bets that are highly correlated with the broad market.

Basel capital requirements use risk weights to adjust assets against which capital must be held. This is in a sense equivalent to our approach but with an important difference.

Equation (7) can be rewritten in terms of the quasi-assets of the firm by adding market value of equity to book value of debt.

$$Equity_{i,t} \geq \frac{k}{1-(1-k)LRMES_{i,t}} Assets_{i,t} \tag{8}$$

where *k* is the hard leverage constraint, say 4%, and the fraction $\left(1-(1-k)LRMES_i\right)^{-1}$ can be interpreted as the risk-weight corresponding to our approach.

One can interpret our risk-weight approach as an alternative to the much criticized Basel risk-weights. In theory, the risk-weight based on the systemic measure *LRMES* incorporates the risk of the underlying assets. In terms of the underlying intuition, firms with systemically risky assets and leverage will have higher MES and must hold higher amounts of capital. For example, if the expected return in a crisis is -100%, then the firm would have to be fully capitalized (i.e., no debt). If the expected return is 0%, then the firm would need to hold just 4% of capital. During the recent financial crisis, the average return of the 25% worst performing bank holding companies was -87% versus -17% for the top performing 25%. For *k* = 4%, this would translate to a 24.27% capital requirement for the more systemic firms (as measured by their realized *LRMES* in the crisis) and just 4.78% for the less systemic ones.

III. ALTERNATIVE APPROACHES

Two very interesting alternatives will be discussed here. The *CoVaR* methodology of Adrian and Brunnermeier (2011) can be compared under some simplifying assumptions. Suppose at time t, the joint distribution of returns on one firm and the broad market is conditionally normal and expressed as:

$$\begin{pmatrix} R_{i,t} \\ R_{m,t} \end{pmatrix} \Big| F_{t-1} \sim N\left(0, \begin{pmatrix} \sigma^2{}_{i,t} & \rho_{i,m,t}\sigma_{m,t}\sigma_{i,t} \\ \rho_{i,m,t}\sigma_{m,t}\sigma_{i,t} & \sigma^2{}_{m,t} \end{pmatrix}\right) \tag{9}$$

VaR(q) and *CoVaR(q,p)* are defined as

$$P_{t-1}\left(R_{i,t} < -VaR^q{}_{i,t}\right) = q = P_{t-1}\left(R_{m,t} < -VaR^q{}_{m,t}\right) = P_{t-1}\left(R_{m,t} < -CoVaR^{q,p}{}_{i,t} \,\middle|\, R_{i,t} = -VaR^p{}_{i,t}\right) \tag{10}$$

and the contribution to systemic risk, which measures the increased risk to the system when one firm is at its extreme, is called

$$\Delta CoVaR_t = CoVaR^{q,q}{}_{i,t} - CoVaR^{q,.5}{}_{i,t} \tag{11}$$

Evaluating (11) under (9) yields a simple closed form expression

$$\Delta CoVaR_t = \rho_{i,m,t}\sigma_{m,t}\Phi^{-1}(q) \tag{12}$$

where Φ^{-1} is the inverse function of the standard normal cdf.

Evaluating MES under the same assumptions gives:

$$\begin{aligned} MES_{i,t} &= E\left(-R_{i,t} \,\middle|\, R_{m,t} < c\right) = -E\left(\sigma_{i,t}\rho_{i,m,t}\varepsilon_{m,t} \,\middle|\, \varepsilon_{m,t} < c/\sigma_{m,t}\right) + 0 \\ &= \sigma_{i,t}\rho_{i,m,t}E\left(\varepsilon_{m,t} \,\middle|\, \varepsilon_{m,t} < c/\sigma_{m,t}\right) \end{aligned} \tag{13}$$

This expression depends upon firm *i* through the product of its correlation with the market and its volatility whereas *CoVaR* depends only on the correlation. Two firms with the same correlation with the market but different volatilities will be treated the same by *CoVaR* even if one has volatility nearly zero and is essentially riskless. Adrian and Brunnermeier introduce a second measure called *Exposure CoVaR,* which reverses the conditioning and gets the same result as *MES*. *CoVaR* measures are also not explicitly sensitive to size or leverage, while other work such as ours is aimed at capturing these features.

This discussion raises the question of causality. Are firms weak because of the crisis or does the crisis happen because the firms are weak? We would argue that both are true. There cannot be a financial crisis without weak firms. These are jointly endogenous variables with no implication of causality. The research of Billio, Getmansky, Lo and Pelizzon (2011) presents five different systemic risk measures. The last two are Granger causality tests and therefore address this question of causality. Among these tests, one is linear and the other non-linear. The non-linear version includes volatility shocks from one firm or sector to another. The linear test examines whether returns on one firm can predict returns on another firm a month or more in the future. This used to be considered a market efficiency test but here is taken as a sign of a network linkage. The linkages are estimated with bivariate models that partially correct for heteroskedasticity and market wide shocks. However it is well known that Granger causality tests cannot be correctly interpreted unless *all* the shocks are considered at the same time. It is not possible to know whether one firm Granger causes another or whether some third firm causes both. This represents a fundamental difficulty in the interpretation of these results and argues in favor of tests for weakness of individual firms as a function of market weakness such as *Exposure CoVaR* or *MES*.

IV. U.S. SYSTEMIC RISK MEASURES

At the end of 2011 the 10 most systemically risky financial firms in the US are given in Table 1, which shows the *SRISK* for these firms as well as the *LRMES*, Beta, Leverage and MV.

Judging from *SRISK*, the three top firms have the bulk of the contributions to systemic risk. For Bank of America and Citigroup, this is due to high leverage, and for JP Morgan, it is due to its enormous size (MV).

Table 2 shows the same information two weeks before the Lehman bankruptcy filing. As can be seen, this is a list of the institutions that were either rescued or restructured. All but one of the top 10 firms was on the verge of failure within weeks. The interesting observation is that Lehman was number 11. Perhaps it was believed that this institution was not sufficiently systemic to require rescue or perhaps there was a limit to the resources and Lehman was the next on the list. Nevertheless, the list is a close approximation to the policy decisions that were made at that time.

V. EUROPEAN SYSTEMIC RISK MEASURES

The same set of results is now available for 1200 global financial institutions. The method is the same although the econometrics must be adjusted to incorporate non-synchronous trading in multiple markets. The methodology is based on insights from Scholes and Williams (1977) and more recently by Burns, Engle and Mezrich (1998). The econometric implementation is based on the Dynamic Conditional Beta model recently proposed in Engle (2011). The top European institutions today are shown in Table 3. These institutions represent all the large nations of Europe and tell an important message about the seriousness of the challenge to the European financial system. This list can be compared with the set of 17 European Banks considered to be *G*lobal *SIFIs* by the BIS/FSB/G-20 in their statement released Nov 4, 2011. The lists are identical except that NYU list includes Banco Intessa and BIS includes

Dexia (which has dropped down to number 20 for NYU). It took the BIS two years and many meetings to develop this list. The NYU list, ranked by *SRISK%,* has already been updated many times since early November. It remains to be seen how the BIS will rank these financial institutions or set capital charges.

References:

Acharya, V. V., Pedersen, L. H., Philippon, T, and Richardson, M. P., 2010, "Measuring Systemic Risk", in *Regulating Wall Street: The Dodd-Frank Act and the New Architecture of Global Finance,* Acharya, V. V., Cooley, T., Richardson, M, and Walter, I. (Eds), John Wiley & Sons.

Acharya, V. V., Pedersen, L. H., Philippon, T, and Richardson, M. P., 2010, "Taxing Systemic Risk", in *Regulating Wall Street: The Dodd-Frank Act and the New Architecture of Global Finance,* Acharya, V. V., Cooley, T., Richardson, M, and Walter, I. (Eds), John Wiley & Sons.

Acharya, V. V., Pedersen, L., Philippon, T., and Richardson, M., 2010, "Measuring Systemic Risk", Technical report, Department of Finance, NYU Stern School of Business.

Adrian, T. and Brunnermeier, M. K. (2009), "CoVaR", *Technical report*, FRB of New York. Staff Report No. 348.

Bernanke, B., 1983, "Non-Monetary Effects of the Financial Crisis in the Propagation of the Great Depression", *NBER Working paper No. 1054*.

Billio, M., Getmansky, M., Lo, A. W., and Pellizzon, L., 2010, "Econometric Measures of Systemic Risk in The Finance and Insurance Sectors", *Technical report*.

Brownlees, C. and Engle, R., 2011, "Volatility, Correlation and Tails for Systemic Risk Measurement", *Working Paper*, New York University.

Burns, P., Engle, R., and Mezrich, J., 1998, "Correlations and Volatilities of Asynchronous Data", *The Journal Of Derivatives*, Vol. 5(4), pp. 7-18.

Engle, R., 2011, "Dynamic Conditional Beta", Volatility Institute manuscript, NYU

Gibson, M., 1997, "More Evidence on the Link between Bank Health and Investment in Japan", *Journal of the Japanese and International Economies*", Vol. 11(3), pp. 296-310.

Holmstrom, B. and Tirole, J., 1997, "Financial Intermediation, Loanable Funds, and the Real Sector", *The Quarterly Journal of Economics*, Vol. 112 (3), pp. 663-691.

Scholes, M. and Williams, J., 1977, “Estimating Betas From Nonsynchronous Data”, *Journal Of Financial Economics*, Vol 5. (3), pp. 309-327.

Slovin, M., Sushka, M.. and Polonchek, J., 1993, “The Value of Bank Durability: Borrowers as Bank Stakeholders”, *the Journal of Finance*, Vol. 48(1), pp. 247-226.

Thakor, A. V., 1996, “The Design of Financial Systems: An Overview”, *Journal of Banking and Finance,* Vol. 20(5), pp. 917-948.

APPENDIX

Table 1.

NYU Stern US Systemic Risk Rankings 12/27/2012 from V-LAB

NAME	SRISK	LRMES	BETA	LVG	MV
Bank Of America	144,115	71	2.28	36.3	56355.4
JP Morgan Chase	138,956	74.53	2.02	17.68	126342.1
Citigroup	125,393	78.61	2.51	23.84	76922.7
Goldman Sachs	54,567	61.86	1.92	20.71	44519.8
Morgan Stanley	52,725	80.38	2.66	25.86	29161.6
MetLife	48,896	70.16	1.83	22.97	32977
Wells Fargo	39,465	59.77	1.54	9.02	145338.3
Prudential Financial	39,131	68.93	1.65	25.25	23656.6
A.I.G.	22,394	66.82	2.1	11.17	44062
Hartford Financial	20,405	66.68	2.2	40.05	7243.3

Table 2.

NYU Stern US Systemic Risk Rankings 8/29/2008

NAME	SRISK	LRMES	BETA	LVG	MV
Citigroup	136,739	78.58	2.62	19.99	103407.9
JP Morgan Chase	110,950	83.2	2.42	13.42	132291.7
Bank Of America	97,315	79.32	2.9	11.94	142001.9
Morgan Stanley	70,507	77.84	2.09	23.01	45281
Freddie Mac	68,807	82.5	5.02	297.76	2918
Merrill Lynch	68,523	85	3.43	22.45	43417
Fannie Mae	67,068	92.71	5.51	115.68	7363.9
A.I.G.	66,345	80.25	3.47	17.62	57783
Goldman Sachs	57,738	58.14	1.7	16.99	64572.2
Wachovia Bank	54,173	85.52	3.06	22.4	34304.2
Lehman Brothers	47,552	85.4	5	55.88	11172.9

Table 3.

NYU Stern European Systemic Risk Rankings 12/30/2011

NAME	SRISK%
Deutsche Bank AG	9.93%
BNP Paribas	8.74%
Barclays PLC	7.58%
Credit Agricole SA	7.57%
Royal Bank of Scotland Group	7.13%
HSBC Holdings PLC	5.95%
ING Groep NV	5.48%
Societe Generale	5.40%
Lloyds Banking Group PLC	4.88%
UBS AG-REG	4.43%
Banco Santander SA	4.38%
UniCredit SpA	4.09%
Credit Suisse Group AG	3.42%
Commerzbank AG	3.21%
AXA SA	2.97%
Nordea Bank AB	2.55%
Intesa Sanpaolo SpA	2.49%
Allianz SE	2.13%
Natixis	2.09%
Banco Bilbao Vizcaya Argentari	1.92%
Dexia SA	1.89%
Danske Bank A/S	1.77%