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How to Calculate Systemic Risk Surcharges

Viral V. Acharya, Lasse H. Pedersen, Thomas Philippon, and Matthew Richardson

5.1 Introduction

Current and past financial crises show that systemic risk emerges when aggregate capitalization of the financial sector is low. The intuition is straightforward. When a financial firm's capital is low, it is difficult for that firm to perform its intended financial services, and when capital is low in the aggregate, it is not possible for other financial firms to step into the breach. This breakdown in financial intermediation is the reason there are severe consequences for the broader economy in crises. Systemic risk therefore can be broadly thought of as the failure of a significant part of the financial sector leading to a reduction in credit availability that has the potential to adversely affect the real economy.

Existing financial regulation such as the Basel capital requirements seeks to limit each institution's risk. However, unless the external costs of systemic

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risk are internalized by each financial institution, the institution will have the incentive to take risks that are supposedly borne by others in the economy. That is, each individual firm may take actions to prevent its own collapse but not necessarily the collapse of the entire system. It is in this sense that a financial institution's risk can be viewed as a negative externality on the system.[1] An illustration from the current crisis is that financial institutions took bets on securities and portfolios of loans (such as AAA-rated subprime mortgage-backed tranches), which faced almost no idiosyncratic risk, but large amounts of systematic risk.

As a result, a growing part of the literature argues that financial regulation should be focused on limiting systemic risk, that is, the risk of a crisis in the financial sector and its spillover to the economy at large. Indeed, there is a plethora of recent papers that provides measures of systemic risk in this context.[2] Several papers in particular—Acharya, Pedersen, et al. (2010a, 2010b) (hereafter APPR), Korinek (2010), Morris and Shin (2008), and Perotti and Suarez (2011)—provide theoretical arguments and explore the optimality properties of a "Pigovian tax" as a potential regulatory solution to the problem of systemic risk.

In these frameworks, each financial institution must face a "surcharge" that is based on the extent to which it is likely to contribute to systemic risk (defined, for example, by APPR as the realization of states of the world in which the financial sector as a whole becomes undercapitalized). The idea of systemic risk surcharges is that they provide incentives for the financial firm to limit its contributions to systemic risk; that is, to lower its surcharge by reducing size, leverage, risk, and correlation with the rest of the financial sector and the economy.

This chapter analyzes various schemes to estimate such a surcharge: (a) *regulatory stress tests of financial institutions* that measure their capital losses in adverse scenarios; (b) *statistical-based measures of capital losses* of financial firms extrapolated to crisis periods; (c) pricing of *contingent capital insurance for systemic risk,* that is, government-run insurance for each firm against itself becoming undercapitalized when the financial sector as a whole becomes undercapitalized; and (d) *market-based discovery of the price of such risk insurance* that financial institutions must purchase partly from the private sector and mostly from the government or the central bank.

While the chapter provides a discussion of each scheme, we perform a detailed analysis of scheme (c). In particular, we provide an explicit calcu-

1. An analogy can be made to an industrial company that produces emissions that lower its own costs but pollute the environment.

2. See, for example, Acharya, Cooley, et al. (2010b); Acharya, Pedersen, et al. (2010a); Adrian and Brunnermeier (2009); Billio et al. (2010); De Jonghe (2009); Gray, Merton, and Bodie (2008); Gray and Jobst (2009); Segoviano and Goodhart (2009); Hartmann, Straetmans, and De Vries (2005); Huang, Zhou, and Zhu (2009); Lehar (2005); Perotti and Suarez (2011); and Tarashev, Borio, and Tsatsaronis (2009), among others.

lation formula for contingent capital insurance and illustrate how the systemic risk surcharge varies with the size of the institution, its leverage, risk (equity volatility), and importantly, its correlation with rest of the economy or with the systemically important part of the financial sector. In applying the method to the period prior to the start of the financial crisis in July 2007, the measure of systemic risk sorts well on the firms that ended up running aground in the crisis (e.g., only eighteen firms show up in the top fifteen systemic firms in all four years from 2004 to 2007). These firms are a who's who of the current crisis, including American International Group (AIG), Bank of America, Bear Stearns, Citigroup, Countrywide, Fannie Mae, Freddie Mac, Goldman Sachs, Hartford Financial, JP Morgan, Lehman Brothers, Lincoln National, Merrill Lynch, Metlife, Morgan Stanley, Prudential Financial, Wachovia, and Washington Mutual. Moreover, the measure is not just size-based. Many of these firms also show up at the top of the list when we reapply the method, while adjusting for their market capitalization.

The chapter is organized as follows. Section 5.2 reviews the recent literature on systemic risk measurement and regulation, focusing in particular on the APPR paper. In the context of the description in section 5.2, section 5.3 describes various approaches to estimating systemic risk surcharges. Section 5.4 presents a detailed analysis of one of the schemes to charge financial firms for their systemic risk contributions, which is based on the price of their contingent capital insurance. We provide an exact formula for the price of each firm's contingent capital insurance and calibrate it using data prior to the start of the financial crisis beginning in the summer of 2007. Section 5.5 concludes.

5.2 Surcharges on Systemic Risk

As described earlier, systemic risk is broadly considered to be the joint failure of financial institutions or markets, which leads to the impairing of the financial intermediation process. In the recent crisis, full-blown systemic risk emerged only when the Government-Sponsored Enterprises (GSEs), Lehman Brothers, AIG, Merrill Lynch, Washington Mutual, Wachovia, and Citigroup, among others, effectively failed in the early fall of 2008. Consider the impact of the financial crisis of 2007 to 2009 on the economy. In the late fall and winter of 2008 and 2009, the worldwide economy and financial markets collapsed. On a dollar-adjusted basis, stock markets fell 42 percent in the United States, dropped 46 percent in the United Kingdom, 49 percent in Europe at large, 35 percent in Japan, and around 50 percent in the larger Latin American countries. Likewise, global GDP fell by 0.8 percent (the first contraction in decades), with a sharp decline in advanced economies of 3.2 percent. Furthermore, international trade fell almost 12 percent. When economists describe the impact of systemic risk, this is generally what they mean.

While the mechanism by which many financial firms fail simultaneously—aggregate shock, a "bank" run, counterparty risk, fire sales—may differ, the end result is invariably a capital shortfall of the aggregate financial sector. Individual firms do not have the incentive to take into account their contribution to this aggregate capital shortfall. By its very nature, therefore, systemic risk is a negative externality imposed by each financial firm on the system. A number of researchers and policymakers have argued that a major failure of the current crisis was that existing financial sector regulation seeks to limit each institution's risk seen in isolation and are not sufficiently focused on systemic risk. As a result, while individual firm's risks are properly dealt with in normal times, the system itself remains, or is in fact encouraged to be, fragile and vulnerable to large macroeconomic shocks.

As mentioned in the introduction, there is a growing literature in economics and finance that analyzes the problem of systemic risk of financial firms. APPR suggest a methodology to get around this market and regulatory failure and induce financial institutions to internalize the negative externality of systemic risk. Firms are often regulated to limit their pollution or charged based on the externality they cause (see, e.g., the classic regulation theory of Stigler [1971] and Peltzman [1976]). Similarly, APPR derive a Pigovian tax on financial firms' contribution to systemic risk.[3]

Specifically, in (a) a model of a banking system in which each bank has limited liability and maximizes shareholder value, (b) the regulator provides some form of a safety net (i.e., guarantees for some creditors such as deposit or too-big-to-fail insurance), and (c) the economy faces systemic risk (i.e., system-wide costs) in a financial crisis when the banking sector's equity capitalization falls below some fraction of its total assets and that these costs are proportional to the magnitude of this shortfall, the welfare costs imposed by each financial firm can be shown to equal the sum of two components:

$$\begin{aligned}\text{Costs to society of the financial firm} &= \text{Expected losses of the firm's} \\ &\quad \text{guaranteed debt upon default} \\ &\quad + \text{Expected systemic costs in a crisis per dollar of capital shortfall} \\ &\quad \times \text{Expected capital shortfall of the firm if there is a crisis.}\end{aligned}$$

1. *The expected losses upon default of the liabilities that are guaranteed by the government:* That is, the government guarantees in the system need to be priced, or, in other words, financial firms must pay for the guarantees they receive. Because the price of these guarantees will vary across firms due to the firm's risk characteristics, the firm will choose an optimal level of leverage and risk-taking activities at a more prudent level. Currently, the Federal Deposit Insurance Corporation (FDIC) in the United States chooses the

3. See, for example, Baumol (1972) and, in the context of the financial crisis, Korinek (2010) and Perotti and Suarez (2011).

level of FDIC premiums on a risk-adjusted basis. However, in reality, premiums are only charged when the fund is poorly capitalized so the current FDIC scheme will in general not achieve this optimal policy.

2. *The firm's contribution to expected losses in the crisis (i.e., the contribution of each firm to aggregate losses above a certain threshold) multiplied by the expected systemic costs when the financial sector becomes undercapitalized:* The systemic risk also needs to be priced, that is, financial institutions need to internalize the costs of the negative externality imposed on the system. There are two terms to this component of the surcharge. The first term—expected systemic costs—involves estimating the probability of a systemic crisis and the external costs of such a crisis, and represents the level of the surcharge. This can be considered the *time-series* component of the surcharge. There is substantial evidence on what leads to financial crises and the costs to economies of such crises beyond the impact of a normal economic downturn.[4] The second term—the firm's contribution of each institution to the financial sector collapse—measures which institutions pay more surcharge. This can be considered the *cross-sectional* component of the surcharge. The key ingredient is the expected capital shortfall of the firm in a crisis, denoted $E(\text{Capital Shortfall}_{\text{Firm i}} \mid \text{Crisis})$.

The main goal of systemic risk surcharges are to incentivize firms to limit systemic risk taking or to be well capitalized against systemic risk in order to reduce the cost of these surcharges. In the next section, we describe several approaches to calculating systemic risk surcharges.

5.3 Estimating Capital Shortfalls in a Crisis

Within the APPR framework given earlier, calculating the relative contribution of systemic risk surcharges is equivalent to estimating the expected capital shortfall of a financial firm in a financial crisis. The firm's relative contribution is simply its expected shortfall over the expected aggregate shortfall. Interestingly, if a firm had an expected capital surplus in a crisis, then it would actually reduce the systemic costs of the financial sector

4. There is a growing evidence of large bailout costs and real economy welfare losses associated with banking crises. For example, Hoggarth, Reis, and Saporta (2002) estimate output losses somewhere between 10 to 15 percent of GDP; Caprio and Klingebiel (1996) argue that the bailout of the thrift industry in the US in the late 1980s cost $180 billion (3.2 percent of GDP). They also document that the estimated cost of episodes of systemic banking crises were 16.8 percent for Spain, 6.4 percent for Sweden, and 8 percent for Finland. Honohan and Klingebiel (2000) find that countries spent 12.8 percent of their GDP to clean up their banking systems. Claessens, Djankov, and Klingebiel (1999), however, set the cost at 15 to 50 percent of GDP. These papers outline the costs of financial crises. Of equal importance is the probability of such crises occurring. In an extensive analysis across many countries and time periods, Reinhart and Rogoff (2008a, 2008b) look at the factors that lead to banking crises, thus providing some hope of probabilistic assessments of such crises. Borio and Drehmann (2009) study leading indicators for banking systems affected by the current crisis.

and should be "subsidized." The intuition is that firms that have plenty of capital, less risky asset holdings, or safe funding can still provide financial intermediation services when the aggregate financial sector is weak. In this section, we describe various ways to estimate and consider related measures of $E(\text{Capital Shortfall}_{\text{Firm i}} \mid \text{Crisis})$.

This measure is closely related to the standard risk measures used inside financial firms, namely value at risk (VaR) and expected shortfall (ES). These seek to measure the potential loss incurred by the firm as a whole in an extreme event. Specifically, VaR is the most that the bank loses with a confidence level of $1 - \alpha$, where α is typically taken to be 1 percent or 5 percent. For instance, with $\alpha = 5\%$, VaR is the most that the bank loses with 95 percent confidence. Hence, VaR $= -q_\alpha$, where q_α is the α quantile of the bank's return R:

$$q_a = \sup\{z \mid \Pr[\mathrm{R} < z] \leq \alpha\}.$$

The ES is the expected loss conditional on something bad happening. That is, the loss conditional on the return being less than the α quantile:

$$ES_\alpha = -E[R \mid R \leq q_\alpha].$$

Said differently, ES is the average returns on days when the portfolio exceeds its VaR limit. The ES is often preferred because VaR can be gamed in the sense that asymmetric, yet very risky, bets may *not* produce a large VaR. For risk management, transfer pricing, and strategic capital allocation, banks need to know how their possible firm-wide losses can be broken down into its components or contributions from individual groups or trading desks. To see how, let us decompose the bank's return R into the sum of each group's return r_i, that is, $R = \Sigma_i y_i r_i$, where y_i is the weight of group i in the total portfolio. From the definition of ES, we see that

$$ES_\alpha = -\sum_i y_i E[r_i \mid R \leq q_\alpha].$$

From this expression we see the sensitivity of overall risk to exposure y_i to each group i:

$$\frac{\partial ES_\alpha}{\partial y_i} = -E[r_i \mid R \leq q_\alpha] \equiv MES_\alpha^i,$$

where MES_α^i is group i's *marginal expected shortfall* (MES). The marginal expected shortfall measures how group i's risk taking adds to the bank's overall risk. In other words, MES can be measured by estimating group i's losses when the firm as a whole is doing poorly.

These standard risk-management practices are then completely analogous to thinking about the overall risk of the financial system. For this, we can consider the expected shortfall of the overall banking *system* by letting R be the return of the aggregate banking sector. Then each bank's contribution to this risk can be measured by its MES. Hence, a financial system is constituted by a number of banks, just like a bank is constituted by a number of groups, and it is helpful to consider each component's risk contribution to the whole. As shown in section 5.3.2, MES is an important component of measuring expected capital shortfall.

5.3.1 Government Stress Tests

One of the advantages of the aforementioned approach is that the regulator has a quantifiable measure of the relative importance of a firm's contribution to overall systemic risk and thus the percentage of total systemic surcharges it must pay. The surcharge component captures in one fell swoop many of the characteristics, that are considered important for systemic risk such as size, leverage, concentration, and interconnectedness, all of which serve to increase the expected capital shortfall in a crisis. But the surcharge measure also provides an important addition, most notably the comovement of the financial firm's assets with the aggregate financial sector in a crisis. The other major advantage of this surcharge component is that it makes it possible to understand systemic risk not just in terms of an individual financial firm but in the broader context of financial subsectors. For example, since expected capital shortfall is additive, it is just one step to compare the systemic risk surcharges of, say, the regional banking sector versus a large complex bank.

Most important, however, is the fact that US regulators can implement the aforementioned approach using current tools at their disposal. In particular, stress tests are a common tool used by regulators and are now mandatory under various sets of regulation including both the Dodd-Frank Act of 2010 and the proposed Basel III accords. Stress tests measure whether financial firms will have enough capital to cover their liabilities under severe economic conditions, in other words, an estimate of $E(\text{Capital Shortfall}_{\text{Firm i}} \mid \text{Crisis})$.

For example, the Supervisory Capital Assessment Program (SCAP) that was initiated in the US in February 2009 and concluded in May 2009 was originated amidst the credit crisis, which had cast into doubt the future solvency of many large and complex financial firms. The idea was to conduct a stress test in order to assess the financial ability of the largest US Bank Holding Companies (BHCs) to withstand losses in an even more adverse economic environment. The SCAP focused on the nineteen largest financial companies, which combined held two-thirds of assets and more than half of loans in the US banking system, and whose failure was deemed to pose a systemic risk. The goal of the SCAP was to measure the ability of these financial firms to absorb losses in the case of a severe macroeconomic shock. In particular, the scenarios were two-years-ahead what-if exercises and considered losses across a range of products and activities (such as loans, investments, mortgages, and credit card balances), as well as potential trading losses and counterparty credit losses. Specifically, the stress test measured the ability of a firm to absorb losses in terms of its Tier 1 capital, with emphasis on Tier 1 Common Capital "reflecting the fact that common equity is the first element of the capital structure to absorb losses." Firms whose capital buffers were estimated small relative to estimated losses under the adverse scenario would be required to increase their capital ratios. The size of the SCAP buffer was determined in accordance with the estimated losses under the worst scenario and the ability of a firm to have a Tier 1 risk-based ratio in excess of 6 percent at year-end 2010 and its ability to have a Tier 1 Common Capital risk-based ratio in excess of 4 percent at year-end 2010.

The idea of conducting joint stress tests across the largest firms was that regulators could cross-check each firm's estimate of its own losses across these products and therefore get a more precise and unbiased estimate of what the losses should be. Table 5.1 summarizes the results for each bank. The main finding was that ten of the nineteen original banks needed to raise

Table 5.1 **Banks included in the stress test, descriptive statistics**

Bank name	SCAP	Tang. comm.	SCAP/tang. comm. (%)	SCAP/total SCAP (%)	MES (%)	SRISK (%)
GMAC	11.5	11.1	103.60	14.88	n/a	n/a
Bank of America Corp.	33.9	75	45.50	45.44	15.05	22.96
Wells Fargo & Co.	13.7	34	40.41	18.36	10.57	10.50
Regions Financial Corp.	2.5	7.6	32.89	3.35	14.8	1.37
Keycorp	1.8	6	30.00	2.41	15.44	0.96
Citigroup Inc.	5.5	23	24.02	7.37	14.98	18.69
Suntrust Banks Inc.	2.2	9.4	23.40	2.95	12.91	1.66
Fifth Third Bancorp	1.1	4.9	22.45	1.47	14.39	1.18
Morgan Stanley	1.8	18	10.11	2.41	15.17	6.26
PNC Financial Services Grp	0.6	12	5.13	0.08	10.55	2.30
American Express Co.	0	10.1	0.00	0.00	9.75	0.36
BB&T Corp.	0	13.4	0.00	0.00	9.57	0.92
Bank New York	0	15.4	0.00	0.00	11.09	0.63
Capital One Financial	0	16.8	0.00	0.00	10.52	1.47
Goldman Sachs	0	55.9	0.00	0.00	9.97	7.21
JPMorgan Chase & Co.	0	136.2	0.00	0.00	10.45	16.81
MetLife Inc.	0	30.1	0.00	0.00	10.28	4.37
State Street	0	14.1	0.00	0.00	14.79	1.28
US Bancorp	0	24.4	0.00	0.00	8.54	1.07

Notes: This table contains the values of SCAP shortfall (in $ billion), tangible common equity (in $ billion), SCAP shortfall/tangible common equity, SCAP/Total SCAP, MES, and SRISK for the nineteen banks that underwent stress testing. The banks are sorted according to the SCAP/Tangible Common Equity ratio. SCAP shortfall is calculated as max [0, 0.08 D – 0.92 MES (1 – 6.13 * MES)], where D is the book value of debt and MES is the marginal expected shortfall of a stock given that the market return is below its fifth percentile. SRISK is shortfall divided by the sum of shortfall values for all nineteen firms. MES is measured for each individual company's stock using the period April 2008 till March 2009 and the S&P 500 as the market portfolio.

additional capital in order to comply with the capital requirements set forth in the SCAP. In all ten cases the additional buffer that had to be raised was due to inadequate Tier 1 Common Capital. In total, around \$75 billion had to be raised, though there were significant variations across the firms ranging from \$0.6 to \$33.9 billion. The number is much smaller than the estimated two-year losses, which were at \$600 billion or 9.1 percent on total loans. The total amount of reserves already in place was estimated to be able to absorb much of the estimated losses. Only using data up to the end of 2008, the required additional buffer that had to be raised was estimated at \$185 billion. However, together with the adjustments after the first quarter of 2009, the amount was reduced to \$75 billion.

It should be clear, however, that in the SCAP the regulators in effect were estimating expected capital shortfalls, albeit under a given scenario and over a limited two-year time period. More generally, the methodology would need to be extended to estimate systemic risk, that is, $E(\text{Capital Shortfall}_{\text{Firm i}} \mid \text{Crisis})$. Specifically, the first (and most important) step would be to create a range of economic scenarios or an average scenario that *necessarily* leads to an aggregate capital shortfall. This would be a substantial departure from the SCAP and recent stress tests performed in the United States and in Europe. The question here is a different one than asking whether an adverse economic scenario imperils the system, but instead asks, if the system is at risk, which firm contributes to this risk?

In addition, the set of financial firms investigated by these stress tests would have to be greatly expanded beyond the current set of large BHCs. This expansion would in theory include insurance companies, hedge funds, possibly additional asset management companies, and other financial companies. This is not only necessary because some of these companies may be important contributors to the aggregate capital shortfall of the financial sector, but also because their interconnections with other firms may provide valuable information about estimated counterparty losses.[5] Finally, an important element of a financial crisis is illiquidity, that is, the difficulty in

5. In order to have any hope of assessing interconnectedness of a financial institution and its pivotal role in a network, detailed exposures to other institutions through derivative contracts and interbank liabilities is a must. This could be achieved with legislation that compels reporting, such that all connections are registered in a repository immediately after they are formed or when they are extinguished, along with information on the extent and form of the collateralization and the risk of collateral calls when credit quality deteriorates. These reports could be aggregated by risk and maturity types to obtain an overall map of network connections. What is important from the standpoint of systemic risk assessment is that such reports, and the underlying data, be rich enough to help estimate *potential exposures* to counterparties under infrequent but socially costly market- or economy-wide stress scenarios. For instance, it seems relevant to know for each systemically important institution (a) what are the most dominant risk factors in terms of losses and liquidity risk (e.g., collateral calls) likely to realize in stress scenarios; and (b) who its most important counterparties are in terms of potential exposures in stress scenarios. A transparency standard that encompasses such requirements would provide ready access to information for purposes of macro-prudential regulation.

converting assets into cash. Basel III has laid out a framework for banks to go through stress test scenarios during a liquidity crisis. It seems natural that liquidity shocks would be part of the "doomsday" scenario of systemic risk. The application of such a scenario would be that firms subject to capital withdrawals, whether through wholesale funding of banks, investors in asset management funds, or even (less sticky) policyholders at insurance companies, would have to take a substantial haircut on the portion of its assets that must be sold and are illiquid in light of these withdrawals. Regulators would need to assess both the level of a financial firm's systemically risky funding and the liquidity of its asset holdings. Cross-checking against likewise institutions would be particularly useful in this regard.

5.3.2 Statistical Models of Expected Capital Shortfall

A major problem with stress tests is that from a practical point of view the analysis is only periodic in nature and is limited by the applicability of the stress scenarios. Financial firms' risks can change very quickly. This problem suggests that the stress tests need to be augmented with more up-to-date information. It is possible to address this question by conducting a completely analogous estimate of systemic risk, that is, $E(\text{Capital Shortfall}_{\text{Firm i}} \mid \text{Crisis})$, using state-of-the-art statistical methodologies based on publicly available data.

Table 5.1 summarizes the stress tests of large BHCs conducted by the US government in May 2009. The table also provides statistical estimates of expected equity return losses in a crisis (denoted as MES) and the percentage capital shortfall in the sector (denoted as SRISK) developed by APPR (2010a), Brownlees and Engle (2010), and the NYU Stern Systemic Risk Rankings described in Acharya, Brownlees et al. (2010).[6] These estimates are based on historical data on equity and leverage, and statistical models of joint tail risk. Table 5.1 implies that these estimates, while not perfectly aligned with the stress tests, load up quite well on the firms that required additional capital. For example, ignoring General Motors Acceptance Corporation (GMAC), for which there is not publicly available stock return data, the eight remaining firms in need of capital based on the SCAP belonged to the top ten MES firms. Moreover, the financial firms that represented the higher percentage of SCAP shortfalls such as Bank of America, Wells Fargo, Citigroup, etc., also had the highest levels of the corresponding statistical measure SRISK. That said, there are Type-I errors with the SRISK measure. Alternatively, one could argue that the stress test was not harsh enough, as it did not generate an aggregate capital shortfall.

In order to better understand the statistical measures, note that a financial

6. For more information on the NYU Stern Systemic Risk rankings, see http://vlab.stern.nyu.edu/welcome/risk.

firm has an expected capital shortfall in a financial crisis if its equity value (denote E_i) is expected to fall below a fraction K_i of its assets (denote A_i); that is, its equity value plus its obligations (denote D_{i0}):

$$E(\text{Capital Shortfall}_{\text{Firm i}} \mid \text{Crisis}) = E[E_i \mid crisis] - K_i E[A_i \mid crisis].$$

Rearranging into return space, we get the following definition:

$$\frac{E(\text{Capital Shortfall}_{\text{Firm i}} \mid \text{Crisis})}{E_{i0}} = (1 - K_i)(1 - MES_i) - K_i L_{i0},$$

where the leverage ratio

$$L_{i0} \equiv \frac{A_{i0}}{E_{i0}} = \frac{D_{i0} + E_{i0}}{E_{i0}}.$$

Estimating the expected capital shortfall in a crisis as a fraction of current equity is paramount to estimation of $MES_{i,t} = E_{t-1}(R_{i,t} \mid crisis)$. Of course, there are a variety of statistical methods at one's disposal for estimating this quantity. For example, APPR (2010a) estimate the crisis as the market's worst 5 percent days and derive a nonparametric measure of MES; Brownlees and Engle (2010) condition on daily market moves less than 2 percent, derive a full-blown statistical model based on asymmetric versions of generalized autoregressive conditional heteroskedasticity (GARCH), dynamic conditional correlation (DCC), and nonparametric tail estimators, and extrapolate this to a crisis (i.e., to MES); and a number of other researchers develop statistical approaches that could easily be adjusted to measure MES, such as De Jonghe (2010), Hartmann, Straetmans, and de Vries (2005), and Huang, Zhou, and Zhu (2009), among others.

Table 5.2 ranks the ten financial firms contributing the greatest fraction to expected aggregate capital shortfall of the 100 largest financial institutions for three dates ranging from July 1, 2007, through March 31, 2009. Estimates of MES are also provided. The methodology used is that of Brownlees and Engle (2010) and the numbers and details are available at www.systemicrisk ranking.stern.nyu.edu. The dates are chosen to coincide with the start of the financial crisis (July 1, 2007), just prior to the collapse of Bear Stearns (March 1, 2008), and the Friday before Lehman Brothers' filing for bankruptcy (September 12, 2008).

The important thing to take from table 5.2 is that the methodology picks out the firms that created most of the systemic risk in the financial system and would be required to pay the greater fraction of systemic risk surcharges. Of the major firms that effectively failed during the crisis, that is, either failed, were forced into a merger, or were massively bailed out—Bear Stearns, Fannie Mae, Freddie Mac, Lehman Brothers, AIG, Merrill Lynch, Wachovia, Bank of America, and Citigroup—all of these firms show up early as having large expected capital shortfalls during the period in ques-

Table 5.2 **Systemic risk rankings during the financial crisis of 2007 to 2009**

	July 1, 2007 Risk% (Rank)			March 1, 2008 Risk% (Rank)			September 12, 2008 Risk% (Rank)		
	SRISK		MES	SRISK		MES	SRISK		MES
Citigroup	14.3	1	3.27	12.9	1	4.00	11.6	1	6.17
Merrill Lynch	13.5	2	4.28	7.8	3	5.36	5.7	5	6.86
Morgan Stanley	11.8	3	3.25	6.7	6	3.98	5.2	7	4.87
JP Morgan Chase	9.8	4	3.44	8.5	2	4.30	8.6	4	5.2
Goldman Sachs	8.8	5	3.6	5.3	9	3.14	4.2	9	3.58
Freddie Mac	8.6	6	2.35	5.9	7	4.60	—	—	—
Lehman Brothers	7.2	7	3.91	5.0	9	4.88	4.6	8	15.07
Fannie Mae	6.7	8	2.47	7.1	4	5.88	—	—	—
Bear Stearns	5.9	9	4.4	2.9	12	4.16	—	—	—
MetLife	3.6	10	2.57	2.2	15	2.93	1.9	12	3.20
Bank of America	0	44	2.06	6.7	5	3.60	9.6	2	6.33
AIG	0	45	1.51	5.5	8	4.63	9.6	3	10.86
Wells Fargo	0	48	2.38	1.9	16	4.14	3.0	10	5.40
Wachovia	0	51	2.2	4.6	11	4.64	5.7	6	9.61

Source: www.systemicriskranking.stern.nyu.edu.

Notes: This table ranks the ten most systemically risky financial firms among the one hundred largest financial institutions for three dates ranging from July 1, 2007, through September 12, 2008. The marginal expected shortfall (MES) measures how much the stock of a particular financial company will decline in a day, if the whole market declines by at least 2 percent. When equity values fall below prudential levels of 8 percent of assets, the Systemic Risk Contribution, SRISK percent, measures the percentage of all capital shortfall that would be experienced by this firm in the event of a crisis. Note that the SRISK percent calculations here incorporate existing capital shortfalls from failed institutions.

tion. For example, all but Bank of America, AIG, and Wachovia are in the top ten on July 1, 2007. And by March 2008, both Bank of America and AIG have joined the top ten, with Wachovia ranked eleventh.

In addition, most of expected aggregate capital shortfall is captured by just a few firms. For example, in July 2007, just five firms captured 58.2 percent of the systemic risk in the financial sector. By March 1, 2008, however, as the crisis was impacting many more firms, the systemic risk was more evenly spread, with 43 percent covered by five firms. As the crisis was just about to go pandemic with massive failures of a few institutions, the concentration crept back up, reaching 51.1 percent in September 2008 (where we note that the SRISK percent have been scaled up to account for the capital shortfalls of failed institutions). These results suggest, therefore, that had systemic risk surcharges been in place prior to the crisis, a relatively small fraction of firms would have been responsible for those surcharges. As the theory goes, these surcharges would have then discouraged behavior of these firms that led to systemic risk.

To the extent systemic risk remains, these levies would have then gone toward a general "systemic crisis fund" to be used to help pay for the remaining systemic costs, either injecting capital into solvent financial institutions affected by the failed firms or even supporting parts of the real economy hurt by the lack of adequate financial intermediation. Going back to section 5.2, only those losses due to the default of the liabilities that are guaranteed by the government would be covered by a separate FDIC-like fund. The purpose of the systemic crisis fund is not to bail out failed institutions but to provide support to financial institutions, markets, and the real economy that are collateral damage caused by the failed institution.

5.3.3 Contingent Claim Pricing Models of Expected Capital Shortfall

An alternative methodology to estimating expected capital shortfalls would be to set an economic price for such shortfalls, that is, *contingent capital insurance.*[7] These insurance charges would allow the regulator to determine the proportionate share of expected losses contributed by each firm in a crisis (i.e., the relative systemic risk of each firm in the sector). This would be used to determine who pays their share of the overall systemic surcharge. The regulator would then take this proportionate share of each firm and multiply it by the expected systemic costs of a crisis to determine the level of the surcharge.

Putting aside for the moment who receives the insurance payments, suppose we require (relying on results and insights from APPR) that each financial firm take out government insurance against itself becoming undercapitalized when the financial sector as a whole becomes undercapitalized. This would be similar in spirit to how deposit insurance schemes are run. The pricing of such an insurance contract fits into the literature on pricing multivariate contingent claims (see, e.g., Margrabe 1978, Stulz 1982, Stapleton and Subrahmanyam 1984, Kishimoto 1989, Rosenberg 2000, and Camara 2005). This literature develops contingent-claim valuation methodologies for cases in which the valuation of claims depends on payoffs that are based on the realizations of multiple stochastic variables. Here, the insurance contract only pays off if the financial institutions' results are extremely poor when the aggregate sector is in distress.[8]

To make the argument more formal, let X_{it} and M_t be the value of the financial institution i's and the aggregate market's (e.g., financial sector or

7. A related method would be to require financial institutions to hold in their capital structure a new kind of "hybrid" claim that has a *forced* debt-for-equity conversion whenever a prespecified threshold of distress (individual and systemic) is met. These hybrid securities have been called contingent capital bonds. Examples in the literature of such approaches are: Wall (1989) propose subordinated debentures with an embedded put option; Doherty and Harrington (1997) and Flannery (2005) propose reverse convertible debentures; and Kashyap, Rajan, and Stein (2008) propose an automatic recapitalization when the overall banking sector is in bad shape, *regardless of the health of a given bank at that point.*

8. For related contingent claim analyses that focus on the balance sheets of financial institutions, see also Lehar (2005), Gray and Jobst (2009), and Gray, Merton, and Bodie (2008).

public equity market) particular measure of performance (e.g., equity value, equity value/debt value, writedowns, etc.), respectively. It is well-known that the value of any contingent claim that depends on X_{iT} and M_T can be written as

$$V_t = E_t[F(X_{iT}, M_T)SD_T] \tag{1}$$

where $F(\cdot)$ is the payoff function depending on realizations of X_{iT} and M_T at maturity of the claim, and SD_T is the stochastic discount factor or the pricing kernel.

Beyond assumptions about the stochastic process followed by the variables, the problem with equation (1) is that it requires estimates of preference parameters, such as the level of risk-aversion and the rate of time discount. Alternatively, assuming continuous trading, one can try and set up a self-financing strategy that is instantaneously riskless. Then, as in Black and Scholes (1973), one can solve the resulting partial differential equation with the preference parameters being embedded in the current value of the assets. Valuation techniques such as Cox and Ross (1976) can then be applied.

Appealing to Brennan (1979) and Rubinstein (1976), Stapleton and Subrahmanyam (1984) show that risk-neutral valuation can be applied in a multivariate setting even when the payoffs are functions of cash flows and not traded assets, as may be the case for our setting. In particular, under the assumption that aggregate wealth and the stochastic processes are multivariate lognormal and the representative agent has constant relative risk aversion preferences, one can apply risk neutral valuation methods to the pricing of equation (1).[9]

As described earlier, assume that the financial institution is required to take out insurance on systemic losses tied to the market value of equity of the firm and the overall sector. Formally, a systemic loss is defined by:

1. The market value of the equity of the aggregate financial sector, S_{MT}, falling below K_{S_M}.
2. The required payment at maturity of the claim is the difference between some prespecified market value of the equity of the financial institution, K_{S_i}, and its actual market value, S_{iT}.

The payoff at maturity T can be represented mathematically as

$$F(S_{MT}, S_{iT}) = \frac{\max(K_{S_M} - S_{MT}, 0)}{K_{S_M} - S_{MT}} \times \max(K_{S_i} - S_{iT}, 0). \tag{2}$$

9. Obviously, in practice, one of the advantages of this methodology is that it allows for more complex joint distributions that are not multivariate normal such as ones that involve either time varying distributions (e.g., Bollerslev and Engle 1986, 1988, Engle 2002) or tails of return distributions described by extreme value theory (e.g., Barro 2006, Gabaix 2009, and Kelly 2009). The pricing framework would need to be extended for such applications (e.g., Engle and Rosenberg 2002).

Applying the results in Stapleton and Subrahmanyam (1984), equation (1) can be rewritten as

$$(3)\qquad V_t = \frac{1}{r^{T-t}} \int_0^{\infty}\int_0^{\infty} \frac{\max(K_{S_M} - S_{MT}, 0)}{K_{S_M} - S_{MT}} \times \max(K_{S_i} - S_{iT}, 0)\phi'(S_{MT}, S_{iT})dS_{MT}dS_{iT}$$

$$= \frac{1}{r^{T-t}} \int_0^{K_{S_M}}\int_0^{K_{S_i}} (K_{S_i} - S_{iT})\phi'(S_{MT}, S_{iT})dS_{MT}dS_{iT},$$

$$\phi'(S_{MT}, S_{iT}) = \frac{1}{2\pi(T-t)\sigma_{S_M}\sigma_{S_i}(1-\rho_{Mi})S_{MT}S_{iT}} e^{-1/[2(1-\rho_{Mi}^2)]\varpi_T}$$

$$\varpi_T = \left[\frac{\{\ln S_{MT} - (T-t)\ln r - \ln S_{Mt} + [(T-t)\sigma_{S_M}^2/2]\}}{\sigma_{S_M}\sqrt{T-t}}\right]^2 + \left[\frac{\{\ln S_{iT} - (T-t)\ln r - \ln S_{it} + [(T-t)\sigma_{S_i}^2/2]\}}{\sigma_{S_i}\sqrt{T-t}}\right]^2$$

where

$$- 2\rho_{Mi}\left[\frac{\{\ln S_{MT} - (T-t)\ln r - \ln S_{Mt} + [(T-t)\sigma_{S_M}^2/2]\}}{\sigma_{S_M}\sqrt{T-t}}\right] \times \left[\frac{\{\ln S_{iT} - (T-t)\ln r - \ln S_{it} + [(T-t)\sigma_{S_i}^2/2]\}}{\sigma_{S_i}\sqrt{T-t}}\right],$$

and σ_{S_M}, σ_{S_i}, and ρ_{S_M} are the volatility of the financial sector return, the volatility of the return of the financial institution *i*, and the correlation between them, respectively. And *r* is the risk-free rate.

Equation (3) provides one way regulators could set the price for contingent capital insurance. As an illustration, section 5.4 presents a detailed analysis of equation (3) in the context of the financial crisis of 2007 to 2009. As described in section 5.3.2, the insurance charges would be placed in a general systemic crisis fund to be used to help cover systemic costs and not to bail out the failed institution per se. In other words, there is no question of moral hazard here.

5.3.4 Market-Based Estimates of Expected Capital Shortfall

One of the issues with estimating expected capital shortfalls in a crisis is that the statistical approach of section 5.3.2 and the contingent claim methodology of 5.3.3 rely on projecting out tail estimates of capital shortfall of a firm to an even more extreme event; that is, when the aggregate sector suffers a shortfall. The assumption is that the cross-sectional pattern amongst financial firms is maintained as events get further in the tail of the distribution. This is not necessarily the case. For example, interconnectedness might rear its problems only under the most extreme circumstances. If some firms are more interconnected than others, then the estimation and pricing methodology will not capture this feature.

Moreover, measurement errors are likely, especially if some financial firms have fatter tail distributions, or face different individual term structure volatilities than other firms. A natural way to rectify this problem would be to allow market participants to estimate and trade on these insurance costs. In a competitive market, it is likely that the measurement errors would be reduced.

A market-based approach that uses market prices, assuming market efficiency will reflect all available information, may be able to uncover the tail distributions and give a more robust estimate of the cross-sectional contribution of each firm to aggregate expected capital shortfall. The core idea of a market-based plan to charge for systemic risk is that each financial firm would be required to buy private insurance against its own losses in a systemic risk scenario in which the whole financial sector is doing poorly. In the event of a payoff on the insurance, the payment would not go to the firm itself, but to the regulator in charge of managing systemic risk and stabilizing the financial sector. This contingent capital insurance cost, however, is not necessarily equal to the systemic risk surcharge. It would be used to determine the proportionate share of each financial firm's contribution to the total systemic risk surcharge. The level of the systemic risk surcharge would be determined by the expected systemic costs of a financial crisis times the proportionate share of each firm.[10] The important point is that each firm's share would be determined by the private market for insurance.

This scheme would in theory not only provide incentives for the firm to limit its contributions to systemic risk, but also provide a market-based estimate of the risk (the cost of insurance), and avoid moral hazard (because the firm does not get the insurance payoff). The problem with private insurance markets, however, is that they are not set up to insure against systemic risks. By their very nature, systemic risks cannot be diversified away. The underlying capital required to cover these losses, therefore, is quite large even though the possibility of such an event is very small. Examples of this problem can be found in the recent financial crisis with the major monoline insurers, such as Ambac Financial Group and Municipal Bond Insurance Association (MBIA), and, of course, the division of AIG named AIG Financial Products. These monolines guarantee repayment when an issuer

10. The expected systemic costs may be higher or lower than the contingent capital insurance costs. The insurance costs assume a dollar systemic cost for every dollar of loss of the firm in a systemic risk scenario.

defaults. Going into the crisis, their businesses focused more and more on structured products, such as asset-backed securities, collateralized debt obligations, and collateralized loan obligations, which already represent well-diversified portfolios. Moreover, the majority of insurance was placed on the so-called AAA super senior portions. Almost by construction, the AAA tranches' only risk is systemic in nature.[11] Undercapitalized relative to the systemic event, almost all the monolines and AIG Financial Products were effectively insolvent.

Since the role of the private sector in providing such insurance is primarily for price discovery and the amount of private capital available to provide such systemic insurance is likely to be limited, it seems natural that most of the insurance would be purchased from the government. APPR (2009, 2010b) describe how private-public contingent capital insurance might work in practice. Each regulated firm would be required to buy insurance against future losses, but only losses during a future general crisis. For example, each financial institution would have a "target capital" of, say, 8 percent of current assets in the event of a crisis.[12] For every dollar that the institution's capital falls below the target capital in the crisis, the insurance company would have to pay N cents to the regulator (e.g., a systemic risk fund).[13] This way, the insurance provider would have every incentive to correctly estimate the systemic risk of a firm in a competitive market and charge the firm accordingly. The financial firms would need to keep acquiring insurance, and thus pay surcharges, on a continual basis to ensure continual monitoring and price discovery, and to prevent sudden high insurance premiums from causing funding problems because the purchases of premiums are spread out. For example, each month, each firm would need to buy a fractional amount of insurance to cover the next five years. Hence, the coverage of the next month would be provided by the insurance purchased over the last five years.

Note that the surcharge proceeds are *not* meant to bail out failed institutions, but to support the affected real sector and solvent institutions. In other words, to the extent systemic risk still remains once the surcharge has been imposed, the proceeds of the surcharge are to cover systemic risk costs. Future expected bailouts (i.e., government guarantees) need to be priced

11. Coval, Jurek, and Stafford (2009) call these securities economic catastrophe bonds and show that the securities' underlying economics is akin to out-of-the-money put options on the aggregate market.

12. A crisis would be ex ante defined by the regulator as a time when the aggregate losses in the financial industry (or the economy at large) exceed a specified amount.

13. N cents represent the proportional share of the private market's participation in the insurance component of the public-private plan. If the proposal were simply contingent capital insurance in which the firm got recapitalized if the firm were doing poorly in a crisis, then the government's share of the payout to the firm would be $100 - N$ cents on the dollar, and the government would receive $(100 - N/100)$ percent of the insurance premiums. To avoid double taxation, the fees paid to the insurance company would be subtracted from the firm's total systemic surcharge bill paid to the regulator.

separately. As described in section 5.2, this portion equals the expected loss on its guaranteed liabilities, akin to the FDIC premium, but they need to be charged irrespective of the size of the resolution fund.

As described before, the major disadvantage of private insurance is that, even for extremely well-capitalized institutions, the insurance sector has struggled for a number of years to provide open-ended (albeit diversifiable) catastrophe insurance. An extensive literature has studied this topic. While the models differ, the primary reason boils down to the inability of insurers to be capitalized well enough to cover large losses. See, for example, the evidence and discussion in Jaffee and Russell (1997), Froot (2001, 2007), and Ibragimov, Jaffee, and Walden (2008). The solution in the catastrophe insurance markets has generally been greater and greater backing by the Federal and state governments (e.g., Federal primary coverage against floods in 1968, insurance against hurricanes after 1992 by Florida, and earthquake coverage by California after 1994). The idea behind these approaches is that private insurers help price the insurance while the government provides significant capital underlying the insurance.

The question arises whether such public-private insurance markets can exist for systemic risk. While some reinsurance schemes have been looked at by the FDIC, most recently in 1993, with the conclusion that the market is not viable, there do exists such markets today. Financial markets in general have become much more sophisticated in how they develop niche markets. A case in point is that coinsurance programs are not without precedent; indeed, motivated by the events of September 11, 2001, the Terrorism Risk Insurance Act (TRIA) was first passed in November 2002, and offers federal reinsurance for qualifying losses from a terrorist attack. It remains an open question whether this can be extended to financial crises.

5.4 Contingent Capital Insurance and the Financial Crisis of 2007 to 2009

Section 5.3.3 described a methodology for uncovering the price of expected capital shortfalls of financial firms in a crisis. In this section, we explore this idea in greater detail. First, for a given set of parameter values describing the multivariate process for the financial firm's stock price and the final sector's stock price, we can estimate the value of the insurance contract using Monte Carlo simulation. We provide some examples and comparative statics to describe some of the underlying economic intuition for the price of this insurance contract. Second, we apply this analysis to the financial crisis of 2007 to 2009.

5.4.1 Comparative Statics

Figure 5.1 graphs the insurance costs as a percentage of the equity of the financial firm as a function of the correlation between the firm's equity return and the market return, and as a function of the strike rate of the insur-

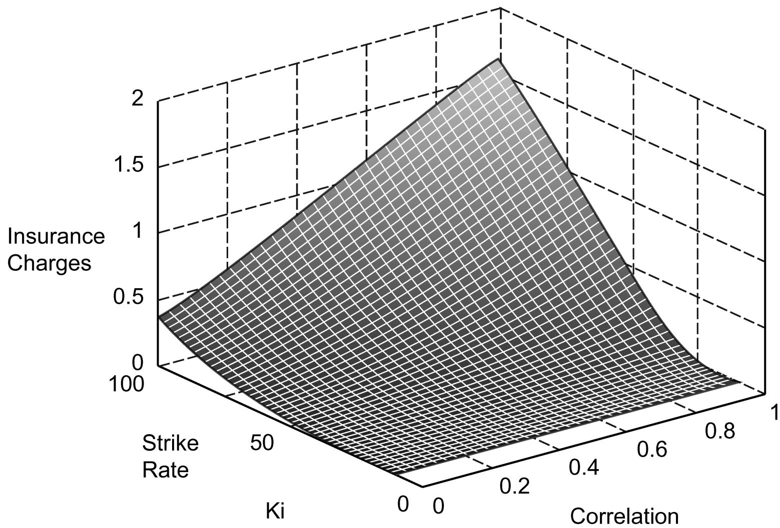

Fig. 5.1 The graph depicts simulated insurance charges as a percent of equity as a function of the correlation between the firm's equity return and the market return, and as a function of the strike rate of the insurance contract

Notes: Specifically, the payoff is triggered when the market drops 40 percent and the firm's ratio of market value of equity to (total liabilities + market equity value) falls below the strike rate, ranging from 1 percent to 10 percent (i.e., Ki = 10 to 100). We assume the following parameters based on recent history: market volatility of 16 percent, firm equity volatility of 27 percent, risk-free rate of 4 percent, and a current firm's ratio of market value of equity to (total liabilities + market equity value) equal to 10 percent. The contract has a four-year maturity.

ance contract. Specifically, the payoff is triggered when the market drops 40 percent and the firm's ratio of market value of equity to (total liabilities + market equity value) falls below some strike rate, ranging from 1 to 10 percent. For example, 1 percent would be a very weak capital requirement while 10 percent would be strict. We assume the following parameters based on recent history: market volatility of 16 percent, firm equity volatility of 27 percent, risk-free rate of 4 percent, and a current firm's ratio of market value of equity to (total liabilities + market equity value) equal to 10 percent. The contract has a four-year maturity.

Figure 5.1 shows that the insurance costs are nonlinearly increasing the stronger the capital requirement and the higher the correlation between the firm's equity return and the market's return. Most important, these factors interact nonlinearly, so the greatest impact by far is when the trigger takes place closer to 10 percent *and* the correlation is very high. To better understand the magnitude of the insurance cost, consider a firm with $100 billion market value of equity, $1 trillion of assets, highly correlated with the market, and facing a trigger close to 10 percent. Even for these extreme

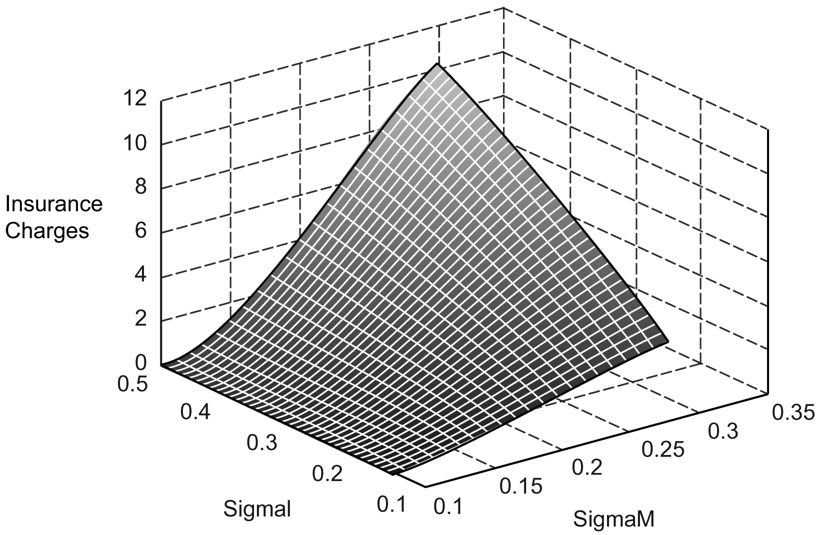

Fig. 5.2 The graph depicts simulated insurance charges as a percent of equity as a function of the volatility of the firm's equity return and the volatility of the market return for a given strike rate of the insurance contract

Notes: Specifically, the payoff is triggered when the market drops 40 percent and the firm's ratio of market value of equity to (total liabilities + market equity value) falls below the strike rate of 10 percent. We assume the following parameters based on recent history: correlation between the firm equity return and the market return of 55 percent, risk-free rate of 4 percent, and a current firm's ratio of market value of equity to (total liabilities + market equity value) equal to 10 percent. The contract has a four-year maturity.

values, the four-year cost is only around $1 billion, which illustrates the fact that the likelihood of both the firm and the market collapsing is a rare event.

While clearly the insurance trigger and the correlation are key factors, what else drives the magnitude of the insurance cost? Figure 5.2 depicts insurance charges as a percent of equity value as a function of the volatility of the firm's equity return and the volatility of the market return for three given strike rates of the insurance contract, namely 10 percent, 7.5 percent, and 5 percent. As before, the payoff is triggered when the market drops 40 percent and the firm's ratio of market value of equity to (total liabilities + market equity value) falls below the strike rate of 10 percent. We also assume the following parameters based on recent history: correlation between the firm equity return and the market return of 55 percent, risk-free rate of 4 percent, and a current firm's ratio of market value of equity to (total liabilities + market equity value) equal to 10 percent. The contract again has a four-year maturity.

Figure 5.2 shows the importance of the interaction between firm volatility, market volatility, and the triggers. A few observations are in order. First, across the different strike rates, the three-dimensional shape is quite

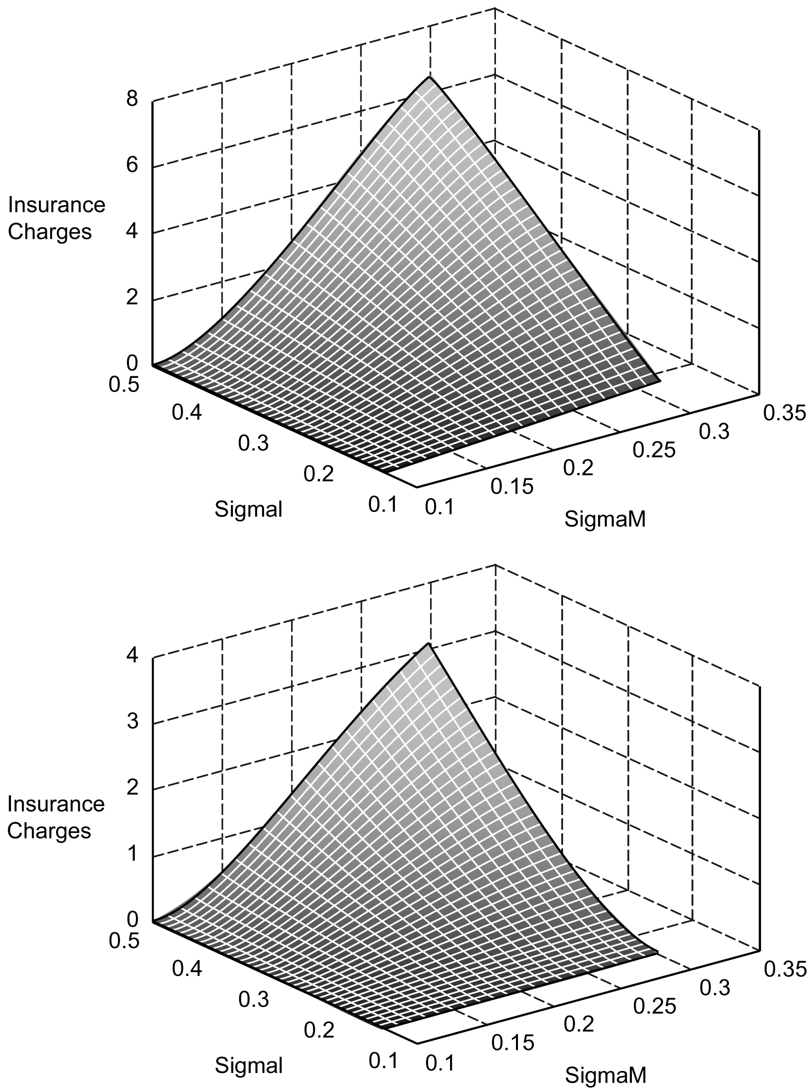

Fig. 5.2 (cont.)

similar. The pattern shows a highly nonlinear relationship that requires both the firm and market volatilities to be high. This should not be surprising given that the payoff occurs only in states where both the firm and market are undercapitalized. Second, in comparison to figure 5.1, the key factor in determining the insurance cost is the level of volatility. For example, for firm and market volatilities of 50 percent and 25 percent, respectively, the insurance costs run as high as 6 percent, 4 percent, and 2 percent of equity value for the strike rates of 10 percent, 7.5 percent, and 5 percent. This is important for understanding the properties of contingent capital insurance. Since volatility tends to be procyclical (high in bad times and low in booms), the cost of contingent capital insurance in general will be procyclical as well. Therefore, to reduce procyclicality of insurance charges, the regulator would have to make the strike rates countercyclical (higher strikes in good times), setting the overall insurance cost such as to avoid an overleveraged financial sector and an overheated economy. This design issue is similar to the trade-off the Federal Open Market Committee (FOMC) must evaluate when setting interest rates.

In the next subsection, we apply the insurance model of section 5.3.3 to available data preceding the financial crisis of 2007 to 2009. In particular, we comment on both the insurance charges and systemic risk contributions that would have emerged if the plan had been put in place during the 2004 to 2007 period.

5.4.2 The Financial Crisis of 2007 to 2009

This section empirically analyzes systemic risk surcharges based on contingent capital insurance for US financial institutions around the recent financial crisis. Here, the institutions have been selected according to (a) their role in the US financial sector, and (b) their market cap as of end of June 2007 being in excess of $5 billion. The companies can be categorized into the following four groups: *Depository Institutions* (e.g., JPMorgan, Citigroup, Washington Mutual, etc.); *Security and Commodity Brokers* (e.g., Goldman Sachs, Morgan Stanley, etc.); *Insurance Carriers* (e.g., AIG, Berkshire Hathaway, etc.) and *Insurance Agents, Brokers and Service* (e.g., Metlife, Hartford Financial, etc.); and a group called *Others* consists of nondepository institutions, real estate firms, and so forth. The total number of firms that meet all these criteria is 102.

Table 5.3 contains descriptive year-by-year statistics of the implied insurance charge for these 102 firms across the four groups—that is, Depository Institutions, Security and Commodity Brokers, Insurance, and Others—over the period 2004 to 2007. As with the simulations provided in section 5.4.1, the insurance payoff is triggered when the aggregate stock market falls 40 percent, and the payoff is based on the fall in the firm's equity value when the ratio of equity value over total assets drops below 10 percent. The amounts are in millions and represent the cost over a four-year period. The main parameter inputs—volatilities and correlations—are estimated over the prior year, and the current ratio of equity value over total assets is computed accordingly from the Center for Research in Security Prices (CRSP) and COMPUSTAT.

Several observations are in order. First, there is a clear ordering of the insurance cost across the type of institution. In particular, brokers/dealers face the highest costs every year; insurance companies face the lowest. Sec-

Table 5.3 **Descriptive statistics of the dollar insurance charge across groups**

	2004	2005	2006	2007
All				
Mean	42.80	8.22	3.41	3.22
Median	1.77	0.33	0.07	0.02
Std. dev.	102.00	19.20	9.11	8.35
Max	540.00	90.30	48.90	39.10
Min	0.00	0.00	0.00	0.00
Depository				
Mean	36.06	6.00	2.53	3.19
Median	4.99	0.86	0.43	0.34
Std. dev.	88.20	13.80	6.32	8.57
Max	425.78	65.70	32.34	38.06
Min	0.06	0.00	0.00	0.00
Nondepository				
Mean	29.68	8.56	1.76	2.06
Median	0.00	0.00	0.00	0.00
Std. dev.	124.00	25.70	8.02	6.65
Max	540.00	90.30	41.00	25.50
Min	0.00	0.00	0.00	0.00
Insurance				
Mean	24.51	4.20	1.71	1.13
Median	0.77	0.05	0.02	0.00
Std. dev.	51.40	8.90	4.14	2.69
Max	226.24	33.32	17.39	11.43
Min	0.00	0.00	0.00	0.00
Broker-Dealer				
Mean	162.00	30.00	17.70	14.00
Median	184.00	30.50	16.30	8.81
Std. dev.	165.77	32.11	18.74	15.76
Max	461.00	87.80	48.90	39.10
Min	0.00	0.00	0.00	0.00

Notes: This table contains descriptive statistics of the dollar insurance charge across the groups by year: Depository Institutions, Security and Commodity Brokers, Insurance, and Others. The insurance payoff is triggered when the aggregate stock market falls 40 percent with the payoff based on the fall in the firm's equity value below a 10 percent equity value over total assets. The amounts are in millions and represent the cost over a four-year period.

ond, for most years, and most of the institution types, there is significant skewness in the cross-section of insurance charges, that is, the mean is multiple times the median. While this finding is mostly due to skewness in the distribution of asset size across firms, the results of section 5.4.1 showed that high costs are due to simultaneous extreme parameters and the moneyness of the option, properties likely to affect just a few firms. Third, there is considerable variation through time in the insurance fees, with a general decline in the level of these fees from 2004 to 2007. The reason for this variation is the general decline of volatilities over this same period.

The latter finding points to the need to state a few caveats. Table 5.3 provides results on insurance fees based on short-term volatility estimates of the financial firms and the market. Acharya, Cooley et al. (2010a) present evidence showing that during the latter years of the relevant period the term structure of volatility was sharply upward sloping. While higher expected volatility in the future may not affect the cross-sectional rankings or proportional share estimates of who pays the systemic risk surcharge, it clearly impacts the contingent capital insurance costs. The latter year calculations provided in table 5.3 therefore are underestimated. Similarly, the contingent capital insurance pricing model of section 5.3.3 makes a number of assumptions about equity return distributions, most notably multivariate normality. To the extent conditional normality produces unconditional fat tails, this assumption may not be as unpalatable as it first seems. Nevertheless, there is evidence that return distributions have some conditional fat tailness, which would also increase the level of the insurance fees.

To better understand what determines the fees during this period, table 5.4 provides results of cross-sectional regressions of the insurance charges for each firm, both in dollar amounts (panel A) and as a percentage of equity value (panel B) against parameters of interest, including leverage (i.e., the moneyness of the trigger), correlation with the market, the firm's volatility, and the institutional form. Generally, across each year, the adjusted *R*-squared's roughly double from the mid-twenties to around 50 percent when the institutional form is included in the regression. The broker/dealer dummy is especially significant. This is interesting to the extent that much of the systemic risk emerging in the crisis derived from this sector. Table 5.4 shows that, as early as 2004, the contingent capital insurance costs of the broker/dealer sector would have been a red flag.

Table 5.4 brings several other interesting empirical facts to light. First, in every year, leverage is a key factor explaining the insurance costs across firms. This result should not be surprising given that the contingent capital trigger is based on leverage. But if one believes the trigger *does* capture systemic risk, it suggests that higher capital requirements will have a first-order effect in containing systemic risk. Second, the correlation between the firm's return and the market return is a key variable, possibly more important than the firm's volatility itself. The reason is that without sufficient correlation the probability that both the firm and market will run aground is remote, pushing down the cost of insurance. Finally, table 5.3 showed that there was significant variation in the mean insurance costs from 2004 to 2007. Table 5.4 runs a cross-sectional stacked regression over the 2004 to 2007 period but also includes market volatility as an additional factor. While the adjusted *R*-squared does drop from the mid-twenties in the year-by-year regressions to 16 percent (in panel A) and to 19 percent (in panel B) for the stacked regressions, the drop is fairly small. This is because the market volatility factor explains almost all the time-series variation.

This result highlights an important point about contingent capital insur-

Table 5.4 **Cross-sectional regression analysis of insurance charges on firm characteristics**

A. *Dependent variable is $ insurance charge of each firm*

	2004		2005		2006		2007		2004–2007	
Intercept	–31.5		–11.4		–8.1		–12.4		–259.2	
	(–0.60)		(–1.08)		(–1.85)		(–2.86)		(–3.64)	
Equity/assets	–148.4	–178.9	–33.5	–40.3	–14.0	–15.8	–10.1	–11.9	–46.2	–54.3
	(–3.92)	(–2.98)	(–3.92)	(–3.61)	(–3.75)	(–3.02)	(–4.65)	(–1.55)	(–5.06)	(–3.80)
Correlation w/ mkt.	169.6	87.1	32.2	19.3	22.3	9.9	25.2	13.9	68.4	35.6
	(2.39)	(1.11)	(2.21)	(1.88)	(2.74)	(1.73)	(3.59)	(2.03)	(2.95)	(1.37)
Firm equity vol.	120.3	–88.2	60.7	14.0	22.0	9.0	28.8	6.1	80.7	16.1
	(0.98)	(–0.71)	(1.90)	(0.56)	(2.45)	(1.41)	(3.10)	(0.64)	(3.08)	(0.55)
Dummy: Broker/dealer		169.7		24.6		13.0		7.3		–201.6
		(1.85)		(2.26)		(1.84)		(0.93)		(–3.18)
Dummy: Depository		33.0		–1.0		–1.9		–3.6		–246.1
		(0.53)		(–0.14)		(–0.56)		(–0.82)		(–3.71)
Dummy: Nondepository		91.3		15.5		3.3		0.1		–226.7
		(0.92)		(1.25)		(0.55)		(0.01)		(–3.55)
Dummy: Insurance		56.6		4.9		0.6		–2.4		–238.4
		(0.88)		(0.63)		(0.16)		(–0.49)		(–3.61)
Market volatility									2147.4	2228.6
									(3.52)	(3.64)
Adj. R^2	19.0%	41.5%	19.9%	45.0%	25.1%	47.9%	29.6%	46.4%	16.2%	25.7%

(*continued*)

Table 5.4 (continued)

	2004		2005		2006		2007		2004–2007	
	B. *Dependent variable is insurance charge of each firm as a % of market value of equity*									
Intercept	0.00023		–0.00081		–0.00014		–0.00021		–0.01038	
	(0.09)		(–0.33)		(–1.62)		(–2.45)		(–4.49)	
Equity/assets	–0.00684	–0.00783	–0.00102	–00118	–0.00039	–0.00044	–0.00026	–0.00031	–0.00197	–0.00220
	(–4.26)	(–4.54)	(–4.87)	(–5.16)	(–4.86)	(–4.34)	(–5.00)	(–4.43)	(–5.20)	(–5.08)
Correlation w/ mkt.	0.00301	0.00138	0.00051	0.00018	0.00042	0.00019	0.00039	0.00017	0.00121	0.00498
	(1.00)	(0.50)	(1.66)	(0.46)	(2.76)	(1.67)	(3.44)	(1.83)	(1.28)	(0.53)
Firm equity vol.	0.00860	0.00108	0.00175	0.00066	0.00067	0.00013	0.00078	0.00027	0.00363	0.00156
	(2.05)	(0.27)	(2.59)	(0.37)	(3.31)	(2.90)	(3.29)	(1.42)	(3.99)	(1.83)
Dummy: Broker/dealer		0.00700		0.00048		0.00030		0.00021		–0.00855
		(1.90)		(2.16)		(2.24)		(1.63)		(–4.74)
Dummy: Depository		0.00117		0.00031		–0.00005		–0.00004		–0.01029
		(0.49)		(0.56)		(–0.60)		(–0.54)		(–4.85)
Dummy: Nondepository		0.00337		0.00036		0.00010		0.00007		–0.00961
		(1.20)		(1.73)		(0.87)		(0.60)		(–4.83)
Dummy: Insurance		0.00337		0.00044		0.00005		0.00002		–0.0961
		(1.30)		(1.53)		(0.68)		(0.24)		(–4.82)
Market volatility									0.09261	0.09480
									(4.32)	(4.47)
Adj. R^2	22.1%	52.1%	25.7%	59.6%	33.3%	61.5%	36.4%	59.7%	19.3%	30%

Notes: This table provides results of cross-sectional regressions of the insurance charges for each firm, both in dollar amounts (panel A) and in a percentage of equity value (Panel B), against parameters of interest, including leverage (i.e., the moneyness of the trigger), correlation with the market, the firm's volatility, and the institutional form; t-statistics in parentheses.

ance. Just prior to the crisis starting in June 2007, market volatility was close to an all-time low. Putting aside the previously mentioned issues of short- versus long-term volatility and conditional fat tails, this low volatility necessarily implies low insurance charges. Consistent with table 5.3's summary, table 5.5 presents the dollar and percent insurance charges firm by

Table 5.5 **US financial firms' ranking by insurance charges**

Ranking (based on %)	Company	Percent of equity	$ charge	Ranking (based on $)	Contribution to costs (%)
1	Bear Stearns Companies Inc.	0.000978	16.292	9	4.96
2	Federal Home Loan Mortgage Corp.	0.000636	25.521	6	7.77
3	Lehman Brothers Holdings Inc.	0.000524	20.719	8	6.31
4	Merrill Lynch & Co. Inc.	0.000478	34.649	3	10.55
5	Morgan Stanley Dean Witter & Co.	0.000443	39.129	1	11.92
6	Federal National Mortgage Assn.	0.000387	24.616	7	7.50
7	Goldman Sachs Group Inc.	0.000311	27.558	5	8.39
8	Countrywide Financial Corp.	0.000263	5.6808	14	1.73
9	MetLife Inc.	0.000239	11.426	10	3.48
10	Hartford Financial Svcs Group I	0.000235	7.3309	13	2.23
11	Principal Financial Group Inc.	0.000182	2.8404	18	0.87
12	Lincoln National Corp. IN	0.000178	3.421	17	1.04
13	Prudential Financial Inc.	0.000175	7.8739	12	2.40
14	JPMorgan Chase & Co.	0.000167	27.645	4	8.42
15	Citigroup Inc.	0.00015	38.058	2	11.59
16	Ameriprise Financial Inc.	0.000147	2.1912	19	0.67
17	E Trade Financial Corp.	0.000141	1.326	21	0.40
18	CIT Group Inc. New	0.000137	1.4368	20	0.44
19	Washington Mutual Inc.	0.000116	4.351	16	1.33
20	Commerce Bancorp Inc. NJ	8.7E-05	0.61563	28	0.19
21	Sovereign Bancorp Inc.	8.34E-05	0.84257	26	0.26
22	Genworth Financial Inc.	6.59E-05	0.98527	24	0.30
23	National City Corp.	6.07E-05	1.1636	22	0.35
24	Wachovia Corp. 2nd New	5.66E-05	5.549	15	1.69
25	Keycorp New	5.22E-05	0.70366	27	0.21
26	SLM Corp.	4.83E-05	1.1444	23	0.35
27	Unum Group	4.58E-05	0.41017	32	0.12
28	UnionBanCal Corp.	4.45E-05	0.36689	34	0.11
29	State Street Corp.	4.28E-05	0.98425	25	0.30
30	Bank of America Corp.	4.21E-05	9.1278	11	2.78
31	Huntington Bancshares Inc.	3.82E-05	0.20437	39	0.06
32	Comerica Inc.	3.63E-05	0.33666	35	0.10
33	MBIA Inc.	2.42E-05	0.19672	40	0.06
34	Regions Financial Corp. New	1.81E-05	0.42231	31	0.13
35	Capital One Financial Corp.	1.8E-05	0.58626	29	0.18

(*continued*)

Table 5.5 (continued)

Ranking (based on %)	Company	Percent of equity	$ charge	Ranking (based on $)	Contribution to costs (%)
36	Bank New York Inc.	1.64E-05	0.5158	30	0.16
37	Zions Bancorp	1.52E-05	0.12619	43	0.04
38	Suntrust Banks Inc.	1.28E-05	0.39277	33	0.12
39	BB&T Corp.	1.15E-05	0.25406	38	0.08
40	Northern Trust Corp.	9.69E-06	0.13695	42	0.04
41	M&T Bank Corp.	9.16E-06	0.10596	44	0.03
42	Hudson City Bancorp Inc.	6.82E-06	0.044336	48	0.01
43	Fifth Third Bancorp	6.43E-06	0.13698	41	0.04
44	Marshall & Ilsley Corp.	4.12E-06	0.050894	46	0.02
45	New York Community Bancorp Inc.	4.07E-06	0.021705	50	0.01
46	PNC Financial Services Grp IN	3.79E-06	0.093488	45	0.03
47	TD Ameritrade Holding Corp.	2.46E-06	0.029364	49	0.01
48	Wells Fargo & Co. New	2.42E-06	0.28287	36	0.09
49	Schwab Charles Corp. New	1.83E-06	0.047105	47	0.01
50	American International Group IN	1.55E-06	0.28175	37	0.09
51	CNA Financial Corp.	1.36E-06	0.017655	51	0.01
52	CIGNA Corp.	9.95E-07	0.014958	53	0.00
53	Aetna Inc. New	6.95E-07	0.017586	52	0.01
54	Compass Bancshares Inc.	6.12E-07	0.005615	54	0.00
55	CB Richard Ellis Group Inc.	3.09E-07	0.002583	56	0.00
56	Berkley WR Corp.	2.55E-07	0.001611	57	0.00
57	Assurant Inc.	1.92E-07	0.001372	58	0.00
58	Allstate Corp.	1.22E-07	0.004564	55	0.00
59	Synovus Financial Corp.	3.74E-08	0.000375	61	0.00
60	NYSE Euronext	3.14E-08	0.00061	60	0.00
61	Travelers Companies Inc.	2.56E-08	0.000909	59	0.00
62	Humana Inc.	2.09E-08	0.000214	62	0.00
63	IntercontinentalExchange Inc.	1.30E-09	1.35E-05	68	0.00
64	Loews Corp.	1.25E-09	3.41E-05	63	0.00
65	Aon Corp.	7.56E-10	9.46E-06	69	0.00
66	AFLAC Inc.	5.89E-10	1.48E-05	67	0.00
67	Peoples United Financial Inc.	4.93E-10	2.63E-06	71	0.00
68	Berkshire Hathaway Inc. Del	4.83E-10	2.38E-05	66	0.00
69	US Bancorp Del	4.28E-10	2.45E-05	64	0.00
70	American Express Co.	3.32E-10	2.41E-05	65	0.00
71	MasterCard Inc.	2.67E-10	3.53E-06	70	0.00
72	Union Pacific Corp.	4.90E-11	1.52E-06	72	0.00
73	NYMEX Holdings Inc.	2.69E-11	3.11E-07	73	0.00
74	Chubb Corp.	1.27E-11	2.77E-07	74	0.00
75	AMBAC Financial Group Inc.	5.94E-12	5.28E-08	75	0.00
76	Western Union Co.	2.57E-12	4.14E-08	76	0.00
77	Fidelity National Finl Inc. New	1.94E-12	1.02E-08	78	0.00
78	Legg Mason Inc.	1.92E-12	2.49E-08	77	0.00
79	Janus Cap Group Inc.	1.72E-12	8.88E-09	79	0.00
80	Edwards AG Inc.	1.26E-12	8.07E-09	80	0.00

Table 5.5 (continued)

Ranking (based on %)	Company	Percent of equity	$ charge	Ranking (based on $)	Contribution to costs (%)
81	Safeco Corp.	6.11E-13	4.04E-09	82	0.00
82	Health Net Inc.	3.85E-13	2.28E-09	84	0.00
83	Blackrock Inc.	3.42E-13	6.21E-09	81	0.00
84	American Capital Strategies Ltd.	1.46E-13	1.13E-09	86	0.00
85	Progressive Corp. OH	1.25E-13	2.18E-09	85	0.00
86	UnitedHealth Group Inc.	3.71E-14	2.54E-09	83	0.00
87	Cincinnati Financial Corp.	2.28E-14	1.70E-10	87	0.00
88	Marsh & McLennan Cos. Inc.	7.75E-15	1.33E-10	88	0.00
89	Torchmark Corp.	7.25E-16	4.64E-12	89	0.00
90	Chicago Mercantile Exch. Hldg. IN	5.69E-17	1.06E-12	90	0.00
91	Fidelity National Info. Svcs. Inc.	1.12E-17	1.17E-13	91	0.00
92	Coventry Health Care Inc.	2.57E-20	2.32E-16	93	0.00
93	Wellpoint Inc.	1.42E-20	6.96E-16	92	0.00
94	Berkshire Hathaway Inc. Del	2.79E-22	3.32E-17	94	0.00
95	Loews Corp.	4.34E-23	3.64E-19	95	0.00
96	Leucadia National Corp.	1.18E-23	9.04E-20	96	0.00
97	CBOT Holdings Inc.	1.78E-25	1.94E-21	98	0.00
98	Alltel Corp.	1.36E-25	3.15E-21	97	0.00
99	Franklin Resources Inc.	1.83E-34	6.05E-30	99	0.00
100	T Rowe Price Group Inc.	2.36E-41	3.25E-37	100	0.00
101	SEI Investments Company	3.69E-51	2.10E-47	101	0.00
102	Eaton Vance Corp.	5.56E-59	3.08E-55	102	0.00

Notes: This table contains the list of US financial firms with a market cap in excess of $5 billion as of June 2007. The firms are listed in descending order according to their insurance costs. The insurance payoff is triggered when the market drops 40 percent and the firm's ratio of market value of equity to (total liabilities + market equity value) falls below 10 percent at the end of a four-year period. The payoff equals the difference between the equity value implied by the 10 percent ratio and the final equity value. The volatility of the firm's equity, the volatility of the market, and the correlation between the two, are estimated using daily data over the prior year. The insurance costs calculation assumes a multivariate normal distribution of equity returns. The first three columns represent, respectively, the insurance charge as a percent of equity, the total dollar insurance charge in millions, and the ranking based on the total dollar amount.

firm. For almost all the financial firms, the capital contingent insurance costs seem quite low, especially in light of what happened just a few months later.

Interestingly, table 5.5 shows an important difference between contingent capital insurance and the systemic risk surcharge. Recall that the systemic risk surcharge separates into the product of two components—the expected systemic costs and the proportional share of systemic risk. Table 5.5 provides an estimate of this share across the 102 firms, and therefore is a measure of the latter component of the systemic risk surcharge. Using the capital insurance charge as its basis, just five firms provide over 50 percent of all the risk, and fifteen firms 92 percent of the risk. This is a key finding and perhaps not surprising given the outcome of the crisis that followed, namely that most of the systemic risk is concentrated in just a few places. Note that in order of importance, table 5.5 lists Morgan Stanley, Citigroup, Merrill Lynch, JP Morgan, Goldman Sachs, Freddie Mac, Fannie Mae, Lehman Brothers, Bear Stearns, Metlife, Bank of America, Prudential Financial, Hartford Financial, Countrywide, and Wachovia as the leading systemic firms. At least nine of these firms either failed or required extraordinary capital infusions or guarantees. In fact, probably only JP Morgan (and to a lesser extent, Goldman Sachs) was considered somewhat safe at the height of the crisis in the late fall of 2008 and the winter of 2009.

Table 5.6 shows that this finding is not a fluke by also reporting the rankings of the insurance costs in the earlier periods of 2004, 2005, and 2006. For example, panel B reports the dollar charges in all four periods and shows that the exact same firms (albeit in different order) show up consistently in the top fifteen. In fact, the only additions to the list are Washington Mutual, AIG, and Lincoln National, two of which failed in the crisis. On a preliminary basis, these results suggest that a measure like the one calculated here (i.e., the cost of contingent capital insurance), does a good job of deciphering which firms are systemic and should pay the share of the surcharge. Of some importance, panel A shows that these rankings are not solely size-based as most of these firms also show up on a percentage of equity basis as well, and APPR provide more extensive evidence of this type for predicting the realized performance of financial firms during the stress test (SCAP) exercise, the crisis period of 2007 to 2009, and other crises of the past.

The APPR approach to measuring systemic risk has its limitations. The basic assumption in that paper is that the negative externality gets triggered in a proportional amount to each dollar of aggregate capital that falls below the aggregate capital threshold level. Therefore, irrespective of the type of financial institution or how that institution is funded, its capital loss contribution is treated the same below the threshold. To take just one example, in table 5.5, large insurance companies like Metlife, Prudential Financial, and Hartford Financial show up as systemically quite risky. Their presence is due to their large offerings of guaranteed investment products that exposed them to aggregate risk and a large MES. Is this a fair outcome? While their funding via insurance premiums is stickier than a large bank, which relies on wholesale funding, it is not obvious that these firms do not pose systemic risk. For example, insurance premiums represent almost 10 percent of GDP, insurance policies are subject to limited runs and, most important, as the largest buyer of corporate debt, insurance companies provide an important financial intermediation service. Disruptions in any of these activities would have important consequences. A final comment on the APPR concept of systemic risk is that the basic intuition is all financial firms are part of the entire system in that well-capitalized financial institutions could take over

Table 5.6 **Ranking by insurance charge**

A. *Ranking by percent of market value of equity*			
July 2003–June 2004	July 2004–June 2005	July 2005–June 2006	June 2006–June 2007
1. Bear Stearns Companies Inc.	Bear Stearns Companies Inc.	Bear Stearns Companies Inc.	Bear Stearns Companies Inc.
2. Genworth Financial Inc.	Federal Home Loan Mortgage Corp.	Federal National Mortgage Assn.	Federal Home Loan Mortgage Corp.
3. Lehman Brothers Holdings Inc.	Federal National Mortgage Assn.	Morgan Stanley Dean Witter & Co.	Lehman Brothers Holdings Inc.
4. Prudential Financial Inc.	Morgan Stanley Dean Witter & Co.	Lehman Brothers Holdings Inc.	Merrill Lynch & Co. Inc.
5. Morgan Stanley Dean Witter & Co.	Lincoln National Corp. IN	Goldman Sachs Group Inc.	Morgan Stanley Dean Witter & Co.
6. Lincoln National Corp. IN	Lehman Brothers Holdings Inc.	Merrill Lynch & Co. Inc.	Federal National Mortgage Assn.
7. Federal National Mortgage Assn.	Goldman Sachs Group Inc.	MetLife Inc.	Goldman Sachs Group Inc.
8. Hartford Financial Svcs Group I	Merrill Lynch & Co. Inc.	Hartford Financial Svcs Group I	Countrywide Financial Corp.
9. MetLife Inc.	Hartford Financial Svcs Group I	Prudential Financial Inc.	MetLife Inc.
10. Merrill Lynch & Co. Inc.	Prudential Financial Inc.	Lincoln National Corp. IN	Hartford Financial Svcs Group I
11. Goldman Sachs Group Inc.	Genworth Financial Inc.	Ameriprise Financial Inc.	Principal Financial Group Inc.
12. JPMorgan Chase & Co.	MetLife Inc.	Countrywide Financial Corp.	Lincoln National Corp. IN
13. Principal Financial Group Inc.	Principal Financial Group Inc.	JPMorgan Chase & Co.	Prudential Financial Inc.
14. E Trade Financial Corp.	JPMorgan Chase & Co.	Unum Group	JPMorgan Chase & Co.
15. Unum Group	E Trade Financial Corp.	Sovereign Bancorp Inc.	Citigroup Inc.
16. Travelers Companies Inc.	Unum Group	Principal Financial Group Inc.	Ameriprise Financial Inc.
17. CIGNA Corp.	Washington Mutual Inc.	E Trade Financial Corp.	E Trade Financial Corp.
18. Sovereign Bancorp Inc.	CNA Financial Corp.	Washington Mutual Inc.	CIT Group Inc. New
19. Washington Mutual Inc.	Countrywide Financial Corp.	Commerce Bancorp Inc. NJ	Washington Mutual Inc.
20. Commerce Bancorp Inc. NJ	Commerce Bancorp Inc. NJ	Huntington Bancshares Inc.	Commerce Bancorp Inc. NJ

(*continued*)

Table 5.6 (continued)

July 2003–June 2004	July 2004–June 2005	July 2005–June 2006	June 2006–June 2007
	B. *Ranking by total dollar amount*		
1. Federal National Mortgage Assn.	Federal National Mortgage Assn.	Morgan Stanley Dean Witter & Co.	Morgan Stanley Dean Witter & Co.
2. Morgan Stanley Dean Witter & Co.	Morgan Stanley Dean Witter & Co.	Federal National Mortgage Assn.	Citigroup Inc.
3. JPMorgan Chase & Co.	Federal Home Loan Mortgage Corp.	Goldman Sachs Group Inc.	Merrill Lynch & Co. Inc.
4. Merrill Lynch & Co. Inc.	JPMorgan Chase & Co.	Merrill Lynch & Co. Inc.	JPMorgan Chase & Co.
5. Goldman Sachs Group Inc.	Merrill Lynch & Co. Inc.	JPMorgan Chase & Co.	Goldman Sachs Group Inc.
6. Lehman Brothers Holdings Inc.	Goldman Sachs Group Inc.	Lehman Brothers Holdings Inc.	Federal Home Loan Mortgage Corp.
7. Prudential Financial Inc.	Lehman Brothers Holdings Inc.	MetLife Inc.	Federal National Mortgage Assn.
8. Citigroup Inc.	Prudential Financial Inc.	Bear Stearns Companies Inc.	Lehman Brothers Holdings Inc.
9. Bear Stearns Companies Inc.	MetLife Inc.	Prudential Financial Inc.	Bear Stearns Companies Inc.
10. MetLife Inc.	Citigroup Inc.	Hartford Financial Svcs Group I	MetLife Inc.
11. Hartford Financial Svcs Group I	Bear Stearns Companies Inc.	Citigroup Inc.	Bank of America Corp.
12. Bank of America Corp.	Bank of America Corp.	Bank of America Corp.	Prudential Financial Inc.
13. Wachovia Corp. 2nd New	American International Group IN	Washington Mutual Inc.	Hartford Financial Svcs Group I
14. Washington Mutual Inc.	Hartford Financial Svcs Group I	Countrywide Financial Corp.	Countrywide Financial Corp.
15. Lincoln National Corp. IN	Wachovia Corp. 2nd New	Wachovia Corp. 2nd New	Wachovia Corp. 2nd New
16. Genworth Financial Inc.	Washington Mutual Inc.	Lincoln National Corp. IN	Washington Mutual Inc.
17. Principal Financial Group Inc.	Lincoln National Corp. IN	Ameriprise Financial Inc.	Lincoln National Corp. IN
18. Travelers Companies Inc.	Principal Financial Group Inc.	American International Group IN	Principal Financial Group Inc.
19. CIGNA Corp.	Genworth Financial Inc.	Principal Financial Group Inc.	Ameriprise Financial Inc.
20. Suntrust Banks Inc.	Countrywide Financial Corp.	Sovereign Bancorp Inc.	CIT Group Inc. New

Notes: This table contains the names of the top twenty companies ranked in descending order according to their insurance charge for the specified periods as a percent of their market value of equity. The insurance payoff is triggered when the market drops 40 percent and the firm's ratio of market value of equity to (total liabilities + market equity value) falls below 10 percent at the end of a four-year period.

poorly capitalized institutions. This is, of course, not possible when aggregate capital losses exceed a large enough threshold.

5.5 Concluding Remarks

Based on a recent literature that focuses on systemic risk surcharges, the centerpiece underlying these surcharges is the measurement of a firm's share of expected losses conditional on the occurrence of a systemic crisis. In this chapter, we describe and analyze various ways to estimate these expected capital shortfalls. As an example of one particular way to measure the firm's share of systemic risk, we analyze the pricing of contingent capital insurance from both a theoretical and empirical point of view. Using the current crisis as an illustration, the measure appears to successfully choose the systemic firms, consistent with recent statistical-based measures of systemic risk (e.g., APPR 2010a and Brownlees and Engle 2010, among others).

Appendix

This appendix contains the names of the US financial institutions used in the analysis of the recent crisis. The institutions have been selected according to their inclusion in the US financial sector and their market cap as of end of June 2007, where all firms had a market cap in excess of $5 billion.

The companies can be categorized into the following four groups: *Depository Institutions* (JPMorgan, Citigroup, WAMU, etc.); *Security and Commodity Brokers* (Goldman Sachs, Morgan Stanley, etc.); *Insurance Carriers* (AIG, Berkshire Hathaway, Countrywide, etc.); *Insurance Agents, Brokers, Service* (Metlife, Hartford Financial, etc.); and a group called *Others* consisting of nondepository institutions, real estate, and so forth.

Table 5A1

Depository institutions: 29 companies, 2-digit SIC code = 60	Other: Nondepository institutions, etc.: 27 companies, 2-digit SIC code = 61, 62(except 6211), 65, 67	Insurance: 36 companies, 2-digit SIC code = 63 and 64	Security and commodity brokers: 10 companies, 4-digit SIC code = 6211
1. BB&T Corp.	1. Alltel Corp.	1. AFLAC Inc.	1. Bear Stearns Companies Inc.
2. Bank New York Inc.	2. American Capital Strategies Ltd.	2. Aetna Inc. New	2. E Trade Financial Corp.
3. Bank of America Corp.	3. American Express Co.	3. Allstate Corp.	3. Edwards AG Inc.
4. Citigroup Inc.	4. Ameriprise Financial Inc.	4. AMBAC Financial Group Inc. American	4. Goldman Sachs Group Inc.
5. Comerica Inc.	5. Blackrock Inc.	5. International Group Inc.	5. Lehman Brothers Holdings Inc.
6. Commerce Bankcorp Inc. NJ	6. CBOT Holdings Inc.	6. Aon Corp. Assurant Inc.	6. Merrill Lynch & Co. Inc.
7. Hudson City Bancorp Inc.	7. CB Richard Ellis Group Inc.	7. Berkley WR Corp.	7. Morgan Stanley Dean Witter & Co.
8. Huntington Bancshares Inc.	8. CIT Group Inc. New	8. Berkshire Hathaway Inc. Del	8. NYMEX Holdings Inc.
9. JPMorgan Chase & Co.	9. Capital One Financial Corp.	9. Berkshire Hathaway Inc. Del	9. Schwab Charles Corp. New
10. Keycorp New	10. Chicago Mercantile Exch Hldg Inc.	10. CIGNA Corp.	10. T Rowe Price Group Inc.
11. M&T Bank Corp.	11. Compass Bancshares Inc.	11. CNA Financial Corp.	
12. Marshall & Ilsley Corp.	12. Eaton Vance Corp.	12. Chubb Corp.	
13. National City Corp.	13. Federal Home Loan Mortgage Corp.	13. Cincinnati Financial Corp.	
14. New York Community Bancorp Inc.	14. Federal National Mortgage Assn.	14. Countrywide Financial Corp.	

15. Northern Trust Corp.	15. Fidelity National Info. Svcs Inc.	15. Coventry Health Care Inc.
16. PNC Financial Services Grp Inc.	16. Fifth Third Bancorp	16. Fidelity National Finl Inc. New
17. Peoples United Financial Inc.	17. Franklin Resources Inc.	17. Genworth Financial Inc.
18. Regions Financial Corp. New	18. IntercontinentalExchange Inc.	18. Hartford Financial
19. Sovereign Bancorp Inc.	19. Janus Cap Group Inc.	19. SVCS Group IN
20. State Street Corp.	20. Legg Mason Inc.	20. Health Net Inc.
21. Suntrust Banks Inc.	21. Leucadia National Corp.	21. Humana Inc.
22. Synovus Financial Corp.	22. MasterCard Inc.	22. Lincoln National Corp. IN
23. US Bancorp Del	23. NYSE Euronext	23. Loews Corp.
24. UnionBanCal Corp.	24. SEI Investments Company	24. Loews Corp.
25. Wachovia Corp. 2nd New	25. SLM Corp.	25. MBIA Inc.
26. Washington Mutual Inc.	26. TD Ameritrade Holding Corp.	26. Marsh & McLennan Cos. Inc.
27. Wells Fargo & Co. New	27. Union Pacific Corp.	27. MetLife Inc.
28. Western Union Co.		28. Principal Financial Group Inc.
29. Zions Bancorp		29. Progressive Corp.
		30. Prudential Financial Inc.
		31. Safeco Corp.
		32. Torchmark Corp.
		33. Travelers Companies Inc.
		34. UnitedHealth Group Inc.
		35. Unum Group
		36. Wellpoint Inc.

Notes: The total number of firms in the sample is 102. Note that although Goldman Sachs has a SIC (standard industrial classification) code of 6282, thus initially making it part of the group called *Others,* we have nonetheless chosen to put in the group of *Security and Commodity Brokers.*

References

Acharya, Viral V., Christian Brownless, Farhang Farazmand, Robert Engle, and Matthew Richardson. 2010. "Measuring 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, 87–120. Princeton, NJ: Princeton University Press.

Acharya, Viral V., Thomas Cooley, Matthew Richardson, and Ingo Walter. 2010a. "Manufacturing Tail Risk: A Perspective on the Financial Crisis of 2007–2009." *Foundations and Trends in Finance* 4 (2009): 247–325.

———. 2010b. *Regulating Wall Street: The Dodd-Frank Act and the New Architecture of Global Finance.* Princeton, NJ: Princeton University Press.

Acharya, Viral V., Lasse H. Pedersen, Thomas Philippon, and Matthew Richardson. 2009. "Regulating Systemic Risk." In *Restoring Financial Stability: How to Repair a Failed System,* edited by Viral V. Acharya and Matthew Richardson, 283–304. New York: New York University Stern School of Business, John Wiley and Sons.

———. 2010a. "Measuring Systemic Risk." Working Paper. New York University Stern School of Business.

———. 2010b. "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, 121–42. Princeton, NJ: Princeton University Press.

Adrian, Tobias, and Markus Brunnermeier. 2009. "CoVaR." Working Paper. Federal Reserve Bank of New York.

Barro, R. 2006. "Rare Disasters and Asset Markets in the Twentieth Century." *The Quarterly Journal of Economics* 121:823–66.

Baumol, W. J. 1972. "On Taxation and the Control of Externalities." *American Economic Review* 62 (3): 307–22.

Billio, Monica, Mila Getmansky, Andrew W. Lo, and Loriana Pelizzon. 2010. "Econometric Measures of Systemic Risk in the Finance and Insurance Sectors." NBER Working Paper no. 16223. Cambridge, MA: National Bureau of Economic Research, July.

Black, Fischer, and Myron Scholes. 1973. "The Pricing of Options and Corporate Liabilities." *The Journal of Political Economy* 81 (3): 637–54.

Bollerslev, Tim, and Robert F. Engle. 1986. "Modelling the Persistence of Conditional Variances." *Econometric Reviews* 5 (1): 1–50.

———. 1988. "A Capital Asset Pricing Model with Time-Varying Covariances." *The Journal of Political Economy* 96 (1): 116–31.

Borio, Claudio, and Mathias Drehmann. 2009. "Assessing the Risk of Banking Crises—Revisited." *BIS Quarterly Review* March:29–46.

Brennan, Michael J. 1979. "The Pricing of Contingent Claims in Discrete Time Models." *Journal of Finance* 34:53–68.

Brownlees, Christian, and Robert F. Engle. 2010. "Volatility, Correlation and Tails for Systemic Risk Measurement." Working Paper. NYU Stern School of Business.

Camara, A. 2005. "Option Prices Sustained by Risk-Preferences." *Journal of Business* 78:1683–708.

Caprio, Gerard, and Daniela Klingebiel. 1996. "Bank Insolvencies: Cross Country Experience." World Bank, Policy Research Working Paper no. 1620. Washington, DC: World Bank.

Claessens, Stijn, Simeon Djankov, and Daniela Klingebiel. 1999. "Financial Restructuring in East Asia: Halfway There?" World Bank, Financial Sector Discussion Paper no. 3. Washington, DC: World Bank.

Cox, J., and S. A. Ross. 1976. "The Valuation of Options for Alternative Stochastic Processes." *Journal of Financial Economics* 3:145–66.

Coval, J., J. Jurek, and E. Stafford. 2009. "Economic Catastrophe Bonds." *American Economic Review* 99 (3): 628–66.

De Jonghe, Olivier. 2010. "Back to the Basics in Banking? A Micro-Analysis of Banking System Stability." *Journal of Financial Intermediation* 19 (3): 387–417.

Doherty, Neil A., and Scott Harrington. 1997. "Managing Corporate Risk with Reverse Convertible Debt." Working Paper. The Wharton School.

Engle, Robert F. 2002. "Dynamic Conditional Correlation." *Journal of Business and Economic Statistics* 20 (3): 339–50.

Engle, Robert F., and Joshua Rosenberg. 2002. "Empirical Pricing Kernels." *Journal of Financial Economics* 64 (3): 341–72.

Flannery, Mark J. 2005. "No Pain, No Gain? Effecting Market Discipline via 'Reverse Convertible Debentures.'" In *Capital Adequacy beyond Basel: Banking, Securities, and Insurance,* edited by Hal S. Scott, 171–96. New York: Oxford University Press.

Froot, Kenneth. 2001. "The Market for Catastrophe Risk: A Clinical Examination." *Journal of Financial Economics* 60 (2): 529–71.

———. 2007. "Risk Management, Capital Budgeting, and Capital Structure Policy for Insurers and Reinsurers." *The Journal of Risk and Insurance* 74 (2): 273–99.

Gabaix, Xavier. 2009. "Power Laws in Economics and Finance." *Annual Review of Economics* 1 (1): 255–94.

Gray, Dale F., and Andreas A. Jobst. 2009. "Higher Moments and Multivariate Dependence of Implied Volatilities from Equity Options as Measures of Systemic Risk." In *Global Financial Stability Report,* 128–31. Washington, DC: International Monetary Fund.

Gray, Dale F., Robert C. Merton, and Zvi Bodie. 2008. "New Framework for Measuring and Managing Macrofinancial Risk and Financial Stability." Working Paper no. 09-015. Boston: Harvard Business School, August.

Hartmann, P., S. Straetmans, and C. de Vries. 2005. "Banking System Stability: A Cross-Atlantic Perspective." NBER Working Paper no. 11698. Cambridge, MA: National Bureau of Economic Research, October.

Hoggarth, Glenn, Ricardo Reis, and Victoria Saporta. 2002. "Costs of Banking System Instability: Some Empirical Evidence." *Journal of Banking and Finance* 26 (5): 825–55.

Honohan, Patrick, and Daniela Klingebiel. 2000. "Controlling Fiscal Costs of Bank Crises." World Bank, Working Paper no. 2441. Washington, DC: World Bank.

Huang, Xin, Hao Zhou, and Haibin Zhu. 2009. "A Framework for Assessing the Systemic Risk of Major Financial Institutions." *Journal of Banking & Finance* 33 (11): 2036–49.

Ibragimov, Rustam, Dwight Jaffee, and Johan Walden. 2009. "Nondiversification Traps in Catastrophe Insurance Markets." *Review of Financial Studies* 22 (3): 959–93.

Jaffee, Dwight, and Thomas Russell. 1997. "Catastrophe Insurance, Capital Markets, and Uninsurable Risks." *Journal of Risk and Insurance* 64 (2): 205–30.

Kashyap, Anil, Raghuram Rajan, and Jeremy Stein. 2008. "Rethinking Capital Regulation." Paper presented at the Kansas City Symposium, "Maintaining Stability in a Changing Financial System." Jackson Hole, WY. August 21–23.

Kelly, Bryan. 2009. "Risk Premia and the Conditional Tails of Stock Returns." Working Paper. NYU Stern School of Business.

Kishimoto, N. 1989. "Pricing Contingent Claims under Interest Rate and Asset Price Risk." *Journal of Finance* 45 (3): 571–89.

Korinek, Anton. 2010. "Systemic Risk-Taking: Amplification Effects, Externalities, and Regulatory Responses." Working Paper. University of Maryland.
Lehar, A. 2005. "Measuring Systemic Risk: A Risk Management Approach." *Journal of Banking and Finance* 29:2577–603.
Margrabe, William. 1978. "The Value of an Option to Exchange One Asset for Another." *Journal of Finance* 33:177–86.
Morris, Stephen, and Hyun Song Shin. 2008. "Financial Regulation in a System Context." *Brookings Papers on Economic Activity* Fall:229–74.
Peltzman, Sam. 1976. "Toward a More General Theory of Regulation." *Journal of Law and Economics* 19:211–40.
Perotti, Enrico, and Javier Suarez. 2011. "A Pigovian Approach to Liquidity Regulation." CEPR Discussion Paper no. DP8271. Washington, DC: Center for Economic and Policy Research.
Reinhart, Carmen M., and Kenneth S. Rogoff. 2008a. "Is the 2007 US Sub-Prime Financial Crisis So Different? An International Historical Comparison." *American Economic Review: Papers & Proceedings* 98 (2): 339–44.
———. 2008b. "This Time Is Different: A Panoramic View of Eight Centuries of Financial Crises." NBER Working Paper no. 13882. Cambridge, MA: National Bureau of Economic Research, March.
Rosenberg, Joshua. 2000. "Asset Pricing Puzzles: Evidence from Options Markets." Leonard N. Stern School Finance Department Working Paper Series 99-025. New York University.
Rubinstein, Mark. 1976. "The Valuation of Uncertain Income Streams and the Pricing of Options." *Bell Journal of Economics and Management Science* 7:407–25.
Segoviano, Miguel, and Charles Goodhart. 2009. "Banking Stability Measures." IMF Working Paper 09/04. Washington, DC: International Monetary Fund.
Stapleton, R. C., and M. G. Subrahmanyam. 1984. "The Valuation of Multivariate Contingent Claims in Discrete Time Models." *Journal of Finance* 39:207–28.
Stigler, George. 1971. "The Theory of Economic Regulation." *Bell Journal of Economics and Management Science* 2:3–21.
Stulz, Rene M. 1982. "Options on the Minimum or the Maximum of Two Risky Assets: Analysis and Applications." *Journal of Financial Economics* 10 (2): 161–85.
Tarashev, Nikola, Claudio Borio, and Kostas Tsatsaronis. 2009. "Allocating Systemic Risk to Individual Institutions: Methodology and Policy Applications." Working Paper. Bank for International Settlements. Basel: BIS.
Wall, Larry. 1989. "A Puttable Subordinated Debt Plan for Reducing Future Deposit Insurance Losses." *Federal Reserve Bank of Atlanta Economic Review* 74 (4): 2–17.

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In response to the global financial crisis, many policymakers have called for supplementing microprudential regulation focusing on institution-specific

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