MEASURING SYSTEMIC RISK FOR INSURANCE COMPANIES*

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Abstract:

We describe a framework to measure the systemic risk of a financial firm that allows for externalities arising from (i) the contribution of the firm to aggregate capital shortfall, which results in a loss of going-concern values; and, (ii) the undertaking of fire-sales by the firm which destroys the value of assets in place. We use this framework to conclude that since the traditional insurance business involves holding highly diversified assets and is not subject to short-term creditor runs, it is unlikely to be as systemically risky as the banking sector. However, the increasing concentration of insurance firms' portfolios in corporate bonds and structured fixed-income products as well as the increasing proportion of their liabilities that are subject to withdrawals suggests a reconsideration of the insurance sector's systemic risk relative to the banking sector. We discuss empirical implications of our framework that can be used to assess these conclusions.

I. Introduction

The question of whether certain insurance companies, or more broadly the insurance sector, may be systemically risky is controversial. This controversy erupted in January 2015 when Metlife Inc. sued the Financial Stability Oversight Council (FSOC) over their decision to designate Metlife a systemically important financial institution (SIFI).[1] Though the lawsuit involves various legal arguments, Metlife's basic case is that the company, and for that matter the industry, is quite different than the banking sector and, in particular, is not systemically risky. The debate is not specific to practitioner and regulatory circles, but also shows up in the academic literature.[2] In particular, while the academic literature supports the view that banking (and, for that matter, "shadow banking") can be systemically risky, there is no such agreement with respect to insurers, asset managers and other parts of the financial sector. This is partly due to different notions of systemic risk, but also to dissimilar views on the asset and liability side of insurance companies.

One useful way to consider the relative systemic risk of insurance companies is to compare them to banks. Banks have certain characteristics that make them relatively systemically risky. One such characteristic is that banks' assets tend to include loans and securities with values that correlate to the performance of the economy as a whole, or to the economic performance of a specific region, industry, or line of business. Put simply, borrowers are more likely to default on a bank loan when times are hard. Another such characteristic is that banks' business model traditionally involves holding short-term liabilities, such as deposits that can be withdrawn on demand or repurchase agreements, that are more liquid than their assets, such as loans to be repaid on a fixed schedule or asset-backed security holdings. Banks are thus vulnerable to "runs" that occur when depositors or other creditors all withdraw funds at once.

Insurers, traditionally, did not share those characteristics with banks. The underwriting risks of traditional insurers' claim liabilities usually are better diversified than are the credit risks of banks' loan assets. Further, traditional insurers typically experience a loss of liquidity only when they make poor business decisions rather than as an inevitable result of their business

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[1] Previously, the FSOC had designated American International Group Inc. and Prudential Financial Inc. as SIFIs, neither of which were contested.

[2] As an example of this literature, see Acharya, Biggs, Richardson and Ryan (2010), Acharya and Richardson (2014), Cummins and Weiss (2014), Harrington (2014) and Paulson, Plestis, Rosen, McMenamin & Mohey-Deen (2014).

model. Traditional insurers tend to write insurance policies that have fairly high policy renewal rates and require policyholders who cash out policies early to be subject to surrender charges or have the investment values of the policies paid out as annuities over prolonged periods. Insurers who issue only policies with those features are less vulnerable to runs and therefore less systemically risky.

There are good reasons to think, however, that parts of the insurance industry are no longer traditional in the above sense and instead have become more similar to banking, and relatively more systemically risky. Insurance companies are now exposed to more aggregate, nondiversifiable risk than would traditionally have been the case. That exposure comes both from their product offerings and from their investment decisions. As for product offerings, in the lead-up to the financial crisis, some large life insurers aggressively wrote investment-oriented life insurance policies with minimum guarantees and other features that exposed them to risk from movements in equity and other investment markets.[3] Such nontraditional policies can lead to large losses when markets decline – and therefore make the companies more systemically risky. The investments of insurance companies also appear to include more exposure to the risk of market movements than would traditionally have been the case. If such risks materialize (and the risks by nature are more likely to do so during conditions of financial and economic stress), then insurance companies collectively will suffer investment losses. Recent studies suggest that life insurers' holdings are sensitive to interest rates and include exposures to mortgage-backed securities.[4] Becker and Opp (2013) document that a reform of capital requirements for U.S. insurers in 2009 and 2010 led those insurers to reduce sharply (from 90 percent to less than 50 percent) the share of their mortgage-backed securities that were rated investment-grade, choosing instead to purchase riskier ones. Such risk-seeking again parallels the behavior of banks in purchasing residential mortgage-backed securities before the financial crisis. Such findings suggest life insurers now invest in ways that leave them exposed to risk based on the poor performance of the economy as a whole.

In addition, insurance companies are now more vulnerable to runs – that is, to the withdrawal of funds by policyholders who lose confidence in a particular insurer or in insurers

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[3] For example, some insurers sold financial products protecting against losses due to macroeconomic events and other nondiversifiable risks. In the years leading up to the financial crisis, the monoline insurers and American International Group ("AIG") wrote financial guarantees on structured financial products tied to subprime mortgages. (*See* Acharya, Biggs, Richardson and Ryan (2010)).

[4] *See* respectively Brewer, Carson, Elyasiani, Mansur and Scott (2007) and Baranoff and Sager (2009).

generally. That vulnerability comes from a rapid rise in the sale of annuities, particularly variable annuities, which are purchased as withdrawable investment accounts. Paulson, Plestis, Rosen, McMenamin and Mohey-Deen (2014) provides a detailed analysis of this issue, including evidence that approximately 54 percent of life insurers' liabilities are in moderately to highly liquid categories. The study further estimates that 43 percent of the life insurance industry's total general-account liabilities would likely be withdrawn in an environment of "extreme stress," and 31 percent in an environment of "moderate stress." Moreover, over time, some insurance companies have become active in shadow banking which tends to be lightly regulated and subject to significant liquidity and run risks when underlying security or counterparty risks materialize.[5] Examples include insurance companies running large securities lending businesses; using reinsurance to move liabilities from operating companies that sell policies to less regulated (that is, less capitalized) "shadow insurers" in regulation-friendly U.S. States (such as South Carolina and Vermont) and offshore locales (such as Bermuda and the Cayman Islands);[6] and utilizing funding agreements and related products (e.g., funding-agreement-backed notes and funding-agreement-backed commercial paper) which fall into the class of shadow banking activities.

Motivated by the above description of the possible sources of systemic risk for banks and insurance companies, this paper describes the systemic risk model of Acharya, Pedersen, Philippon and Richardson (2015). In particular, we provide a simplified version of the extended model from that paper that incorporate externalities arising from both an aggregate capital shortfall in the economy and fire sales as results of runs on financial firms' liabilities. Intuitively, a financial firm contributes to systemic risk through its contribution to the aggregate capital shortfall and the loss of future financial intermediation in the real economy (i.e., as a "going concern"), and through its liability structure which impacts the likelihood of runs and forced fire sales (i.e., leading to a loss of "current activities" in the real economy). Our contribution is to provide a framework for considering how systemic risk of an insurance company, relates to runs, the nature of liabilities, fire sales, insolvency, and capital shortfalls.

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[5] Shadow banking is a system of financial institutions that resemble banks, or transactions that resemble bank services, because they provide the liquidity or maturity transformation services provided by banks. Shadow banking typically involves borrowing short-term in rollover debt markets, using significant leverage, and lending to or investing in longer-term and illiquid assets.

[6] *See* Koijen and Yogo (2013). Because the liabilities transferred through shadow insurance arrangements stay within the insurer's holding company, there is not the usual risk transfer between the insurer and reinsurer. According to Koijen and Yogo, this type of regulatory arbitrage grew from $11 billion to $364 billion between 2002 and 2012. Such arrangements – which are increasingly widespread – functionally resemble the special-purpose vehicles used by large complex banks during the financial crisis.

Our main result demonstrates the sense in which insurance companies, in comparison to banks, may or may not produce systemic risk. For example, we show that traditional insurance companies can be systemic, namely as going concerns because their contribution to an aggregate capital shortfall reduces the amount of financial intermediation undertaken in the economy. In contrast, banks contribute to systemic risk both as going concerns but also with respect to their existing assets and activities, causing fire sales within the financial system to have negative effects on the economy. As discussed above, non-traditional insurance companies may also be systemic to the extent that their liabilities are liquid and therefore runnable. The model provides the relevant parameters to begin thinking practically about the systemic risk of insurance companies. In practice, a comparison across both banks and insurance companies should incorporate the amount of the firm's assets, the systematic risk of those assets, the leverage of the firm and the firm's liquidity mismatch, that is, the extent to which the firm engages in shadow banking activities and employ short-term financing.

The paper is organized as follows. In Section II, we provide a detailed discussion of the definition of systemic risk with a specific application to insurance companies. Section III presents the formal model of systemic risk for financial firms, and compares and contrasts the implications for banks and insurance companies. In Section IV, we make some empirical observations. Section V concludes.

II. Defining Systemic Risk

With respect to systemic risk management, the role of a regulatory body is to ensure that stress on the financial system does not prevent any given firm from carrying out its ordinary functions where those functions are critical to the functioning of the real economy. However, in order to regulate and manage systemic risk, one must be able to measure a firm's systemic risk. And in order to measure systemic risk, one needs to be able to take a position and precisely define what it is. In general, a financial firm can be described as systemically risky if it has the potential under stress conditions to cause harm to the broader economy. A conclusion that a firm is systemically risky is different from a conclusion that it is likely to go into financial distress: a firm can be systemically risky but healthy (or can be in poor health but not a significant source of systemic risk). A regulator concerned with systemic risk should ask whether a firm's financial

activities could potentially contribute to a system-wide event such as the financial crisis that struck the U.S. economy in late 2008. That can happen when a firm is so positioned in the market that its distress is likely to cause distress in other firms – including its counterparties, creditors, or customers.

In previous work (e.g., Acharya, Pedersen, Philippon and Richardson (2010)), we argue that the above conditions occur when there is an aggregate capital shortfall of the financial sector.[7] Intuitively, systemic risk arises when there is a breakdown in *aggregate* financial intermediation – that is, the ability of financial firms in the economy as a whole to obtain funds from depositors or investors, and to provide financing to other firms. If one financial firm becomes unable to perform intermediation services, but all other financial firms continue to have ready access to capital, the consequences for the economy as a whole are likely to be minimal – the other firms can simply step into the breach. When capital is low in the aggregate, however, that is not possible.[8] Based on this intuition, Acharya, Pedersen, Philippon and Richardson (2010) build a simple model of systemic risk and show that each financial institution's contribution to systemic risk can be measured as its systemic expected shortfall (SES), i.e., its propensity to be undercapitalized when the system as a whole is undercapitalized.[9] Thus, it is not the individual institution's capital shortfall *per se*, but its contribution to aggregate capital shortfall that matters when attempting to assess its systemic importance. In the academic literature, using alternative measures of systemic risk, the importance of such co-movement is common to most approaches.[10]

The intuition for why the capital shortfall argument carries through to the insurance industry is straightforward.[11] The exposure of insurance companies to various forms of risk, and

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[7] An aggregate capital shortfall of the financial sector occurs when the market value of the equity in the sector as a whole falls below a certain fraction of the market value of the assets of the sector as a whole. It can be described as financial firms generally being under stress.

[8] See, for example, Thakor (1996) and Holmstrom and Tirole (1997) on the theoretical side, and Bernanke (1983), Slovin, Sushka and Polonchek (1993) and Gibson (1995) for empirical observations)

[9] This SES measure of systemic risk has been analyzed in a variety of recent papers. (For example, see Acharya, Engle and Pierret (2013), Acharya, Engle and Richardson (2012), Adams and Gropp (2010), Allen, Bali, and Tang (2012), Benoit, Colletaz, Hurlin and Perignon (2012), Bisias, Flood, Lo, and Valavanis (2012), Brownlees, Chabot, Ghysels and Kurz (2015), Brunnermeier, Dong, and Palia (2011), Engle, Jondeau and Rockinger (2014), Giesecke, and Kim (2011), Hansen (2012) and Huang, Zhou, and Zhu (2012).)

[10] See, for example, Bisias, Flood, Lo and Valavanis (2012), Brownlees and Engle (2010), Adrian and Brunnermeier (2009), Billio, Getmansky, Lo, and Pelizzon (2011), De Jonghe (2009), Huang, Zhou and Zhu (2009), and Goodhart and Segoviano (2009).

[11] See, for example, Acharya and Richardson (2014).

their potential to contribute to a broader shortfall of capital in the financial sector, gives them the further potential to cause impacts on the real (that is, nonfinancial) economy. Life insurance companies are one of the largest investors in the U.S. capital markets and therefore an important source of funding for the U.S. economy. The American Council of Life Insurers ("ACLI") estimates that, at the end of 2013, life insurers held $5.6 trillion in total assets; were "the largest institutional source of bond financing for American business, holding 20% of all U.S. corporate bonds"; and were a significant player in the commercial mortgage market, "financing more than $286 billion, or one-eighth, of U.S. commercial mortgages."[12]

The possibility that a source of financing this large could be withdrawn or significantly impaired is a significant systemic risk; and, of course, the possibility of fire sales of corporate bonds (causing corporate bond prices to fall sharply) would be an even greater risk. Distress in the insurance subsector could make it prohibitively expensive for even AA-rated and AAA-rated firms to issue corporate bonds. There is evidence, for example, that the liquidity of the corporate bond market dropped after the onset of the financial crisis in 2008.[13] Further, there are plausible scenarios in which trouble in the corporate bond market could spread to the banking subsector. Firms unable to obtain financing by issuing bonds would likely draw down on their bank lines of credit as a form of last-resort financing. In doing so, they would trigger massive liabilities for their relationship banks. Healthier banks with adequate capital and deposit bases might be able to meet the sudden drawdowns of credit lines. Moderately risky ones could experience distress. Weakened banks could well run aground.[14] It is natural to conclude that such effects would be even stronger if the insurance subsector was distressed; if at the same time there were a wave of downgrades in the economy; and especially if the banking subsector was also experiencing severe distress – a scenario that, taken as a whole, deserves the title of "systemic risk."[15]

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[12] ACLI, *Assets and Investments in America's Economy*,
https://www.acli.com/Tools/Industry%20Facts/Assets%20and%20Investments/Pages/Default.aspx.

[13] *See* Dick-Nielsen, Feldhutter and Lando (2012). While is an open question what role financial disintermediation on the part of distressed insurers played in the credit crunch in the corporate bond market in the fall of 2008, nevertheless, the impact of the insurance sector's inability to participate in the corporate bond market is now well-documented, even outside the context of a common shock to the economy. For example, Ellul, Jotikasthira & Lundblad (2010) show that, when insurance companies are required by regulation to sell downgraded corporate bonds, those bonds show significant price declines. Moreover, Manconi, Massa, and Yasuda (2012) document that in the second half of 2007, bond mutual funds and insurance firms contributed to the illiquidity of the corporate debt market as losses on the holdings of securitized bonds and commercial mortgage-backed securities transmitted in the form of asset sales or reduced purchases in other holdings, notably of lower-rated securitized and corporate bonds..

[14] See, for example, Acharya, Almeida, Ippollito and Perez (2014) and Ivashina and Scharfstein (2010).

[15] Negative effects on the real economy could also follow directly from insurance companies' unwillingness or inability to supply insurance products, which could cause higher prices and an overall loss of economic welfare.

As described in the introduction, a growing body of literature recognizes that insurance companies, like other financial actors, can be systemically risky when they engage in activities that expose them to risk from distress elsewhere in the economy and when they are positioned to transmit to other actors in the economy any distress they experience. (See, for example, Acharya, Pedersen, Philippon and Richardson (2010), Billio, Getmansky, Lo, and Pelizzon (2011), Baluch, Mutenga and Parsons (2011), Acharya and Richardson (2014), and Cummins and Weiss (2012, 2014).) [16] Of particular importance, Cummins and Weiss (2014) apply the SES measure specifically to the U.S. Insurance Industry. While their main conclusion is that core insurance activities tend not to be associated with systemic risk,[17] they find that noncore businesses (such as derivatives trading, offering financial guarantees, asset management, and securities lending) are linked to SES.

Defining a systemic financial crisis so far has focused on a capital shortfall of the aggregate sector. But, more broadly, the failure of a financial firm can be considered *systemic* in nature as long as it has spillover effects on the ability of the financial system as a whole to function. The aforementioned possibility that financial activities could be significantly impaired or asset fire sales could take place does not presuppose an aggregate capital shortfall. Indeed, it is well-known that financial crises can occur when the economy is hit by shocks and financial firms rely sufficiently on short-term financing that there is a risk the financing of these firms does not get rolled over (e.g., Diamond and Dybvig (1984), Allen and Gale (2000) and Diamond and Rajan (2001, 2005)). If a sufficient "run" on a number of firm's liabilities takes place, these firms will be potentially forced to sell assets to cover the financing at potentially fire sale prices. Moreover, absent the availability of long-term capital in the economy, small shocks can lead to runs on the liabilities (Acharya, Gale and Yoralmazer (2009)). These "runs" can lead to a reduction in financial activities of the firm and fire sales which amplify throughout the financial sector, not dissimilar from the impact of an aggregate capital shortfall of the financial system.

For example, consider the following impact of fire sales described by Diamond and Rajan (2005, 2011). When fire sales of financial assets occur, the return on capital for these assets is

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There is growing evidence that capital-constrained financial firms, including insurance companies, may reduce the supply of capital in the face of losses, *e.g.*, Froot (2001), Froot and O'Connell (1999), Garmaise and Moskowitz (2009). It is an open question, however, whether these supply shocks extend beyond the catastrophe insurance area.

[16] That said, there are a number of papers in the literature arguing that insurance companies are *not* systemically risky, see, e.g., Harrington (2009, 2014), Tyler and Horning (2009), Grace (2010) and Park and Xie (2011).

[17] The exception is for some life insurers who specialize in separate accounts and group annuities, and other banking-like products.

high relative to real assets in the economy. In general equilibrium, fire sales therefore increase the required return on capital for real investments, producing rationing on the real side of the economy. This negative externality that lowers real investment only gets corrected when real and financial returns to capital are equilibrated.

Unlike the argument with respect to capital shortfall, it is difficult to make the case that traditional insurance companies are subject to runs. With little chance of runs by policyholders, it is reasonable to conclude that, *ceteris paribus*, banks (and other runnable institutions) contribute more to the systemic risk of the financial system. For example, Chen, Cummins, Viswanathan and Weiss (2012) provide evidence that banks tend to create systemic risk for insurers but not vice versa. That said, there are two caveats to this argument. First, as described in the introduction, there is strong reason to believe that, for certain life insurers, the growth in variable annuities and shadow banking activities have increased the risk of runs. Second, and to the point of this paper, even if a financial firm's liabilities are not runnable, the firm can contribute to systemic risk through its contribution to an aggregate capital shortfall.

The discussion above suggests two possible externalities for the systemic risk of financial firms – a firm's contribution to an aggregate capital shortfall and/or a run on its liabilities (resulting in fire sales). As described above in our discussion of the banking versus insurance sectors, it is likely that these two sources of systemic risk differ within and across financial sectors. As a result, the goal of this paper is to provide a starting framework for analyzing the systemic risk of insurance firms by taking into account both externalities.

III. A Model for Systemic Risk of Insurance Companies and Banks

In this section, we describe the model of systemic risk of Acharya, Pedersen, Philippon and Richardson (2015) that include runnable liabilities. A financial firm contributes to systemic risk through its contribution to two negative externalities – (i) the first corresponds to its contribution to the aggregate capital shortfall ("going concern"), and (ii) the second is based on its liability structure which impacts the likelihood of runs and forced fire sales ("current activities"). Our contribution is to explain how systemic risk of a financial firm, whether it be a bank or insurance company, relates to runs, the nature of liabilities, fire sales, insolvency, and capital shortfalls.

a. Assets and Solvency

We consider N financial firms, indexed by $i = 1, \ldots N$ and three dates $t = 0, 1, 2$, and we normalize the risk free rate to zero. At time 0, firm i has inside equity $w_{i,0}$, issues debt worth b_i, and buys assets worth a_i, subject to the budget constraint, $w_{i,0} + b_i = a_i$. At time 2, the assets pay off $q_i a_i$ but the random gross return q_i is learned at time 1, and the net worth of the firm is $q_i a_i - d_i$.

Once the returns are realized, we group firms into solvent and insolvent ones. We define the insolvency indicator as: $\delta_i \equiv 1 \leftrightarrow q_i a_i < d_i$. The owner of the firm is protected by limited liability and can consume $max(q_i a_i - d_i, 0)$. We also assume that assets have a capital requirement of z. The free or excess capital of firm i at time 1 is therefore $w_i = max(q_i a_i - d_i - z a_i, 0)$.

A firm can therefore be in one of three states:

- Solvent with free capital if $q_i > \frac{d_i}{a_i} + z$,

- Solvent without free capital if $\frac{d_i}{a_i} < q_i < \frac{d_i}{a_i} + z$,

- Insolvent if $q_i < \frac{d_i}{a_i}$.

We define aggregate assets as $A \equiv \sum_i a_i$ and aggregate free capital as $W \equiv \sum_i w_i$.

b. Runs

We assume that a fraction γ of the liabilities can be withdrawn at time 1, and that creditors choose to withdraw when firms are insolvent. To meet the redemptions, the firm must sell a fraction α of its assets at unit price p: $\alpha_i = min\left(1; \frac{\gamma d_i}{p a_i}\right)$.

Creditors anticipate potential losses and price the debt fairly. We assume that γ is an exogenous industry-specific parameter. To be concrete, we will assume that γ is large for banks and small for traditional insurance companies. Note that we select the best equilibrium. Short-term creditors run only on insolvent firms. Equilibria with self-fulfilling runs are also possible and would only reinforce our results.

c. Market for Existing Assets

The assets of insolvent firms can either be sold to solvent firms, or they can be liquidated. For simplicity, we assume that recovery values do not depend on the idiosyncratic component of

asset returns (the general case is treated in Acharya, Pedersen, Philippon and Richardson (2015)). Asset buyers receive a return s and liquidation delivers l with $l < s$. To summarize, asset payoffs are given by:

- q_i if the assets stay inside the firm,
- s if the assets are *bought by another firm*,
- l if the assets are *liquidated*.

Let p be the price at which assets are sold. Because liquidation is always feasible and because buyers must at least break even, we must have $l \leq p \leq s$.[18] We assume a form of cash-in-the-market pricing. The equilibrium price p depends on whether there is enough free capital to buy the assets of insolvent firms (firms that are solvent but without excess capital do not participate in the market). The market clearing condition is $W \geq zp(\int \delta_i \alpha_i a_i - L)$, where L is the quantity of assets that are liquidated (instead of being bought by another firm). We assume the same type of requirement for the firms' own assets and for the purchase of assets from other firms.

d. Discussion of the Model and Systemic Externalities

The key contribution of our paper is to distinguish two types of negative externalities in the financial system.

i. Externality based on existing activities.

This corresponds to the disruption of existing activities. It occurs when existing assets are liquidated. We draw a sharp distinction between sales and liquidations. If a financial firm is liquidated, the failure of its critical infrastructure leads to a negative externality and we assume that the externality is proportional to the quantity of liquidated assets. In other words, the externality is fundamentally linked to the short-term nature of liabilities. In our model, this happens only where there is a run.

As described in Section II, fire sales that result in the liquidation of assets can imply that current activities of the firm are interrupted. Examples of such activities include (i) existing loans

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[18] We consider equilibria where solvent firms do not want to sell their assets. This holds as long as leverage is higher that the benchmark return, a condition that is easily satisfied in equilibrium. Formally, we want $\delta_i = 0 \rightarrow q_i > s$, and $\frac{d_i}{a_i} > s$ is a sufficient condition for this to be true.

are not properly monitored anymore, (ii) revolving credit is interrupted, and (iii) existing policies are disrupted. Note that though we define *A* to be the firm's assets, the real meaning of *A* is as the sum of the current activities of the firms.

ii.   Going-concern externality

The going-concern externality arises when financial firms cannot provide some critical new services. The main difference with the previous externality (in III.d.i above) is that the externality can occur even if there are no runs. We assume that the going concern externality arises from an aggregate capital shortfall. For instance, as mentioned earlier, life insurance companies are important buyers of corporate bonds and commercial mortgages. Distress in the entire life insurance industry can then trigger a credit crunch even if insolvent insurers are not force to liquidate their assets. Acharya, Pedersen, Philippon and Richardson (2015) show how this externality arises naturally in a model with ongoing investment demand. In this case, an aggregate shortfall pushes up the required return on new project, leading to a fall in investment.

iii.   The Externality Condition

We incorporate both types of disruptions by assuming that aggregate externalities are given by:

$$Externality = fL + g\psi[1_{W<\overline{W}}(\overline{W} - W)]$$

The fire sale externality is simply proportional to the amount of liquidated assets *L*, which is endogenously determined. The going concern externality depends on the aggregate shortfall of free capital relative to some benchmark $\overline{W}$ (which depends on the size of the economy, etc). The parameter ψ reflects the fact that not all assets of a firm are devoted to systemically risky activities and thus is defined as the fraction of a firm's assets devoted to financial intermediation. For example, $\psi = 1$ is likely for banks while $\psi < 1$ is probably more reasonable for other firms with large financial operations, such as General Electric or General Motors or insurance companies for that matter. For the case of insurance companies, some portion of their assets are devoted to traditional insurance operations which may be uninterrupted even if the insurance company fails and there is an aggregate capital shortfall. That said, for the purposes of the model below, for ease of exposition, we assume all firms are governed by $\psi = 1$. The parameters *f* and *g* capture the severity of the two externalities. A final point is important. In this simple setup the

two externalities are independent, although of course correlated because triggered by some of the same shocks. We will later discuss endogenous interactions between the two externalities based on marking to market and fire sales discounts.

iv. Equilibrium at time 1

For simplicity we will consider an ex-ante symmetric equilibrium where all firms within the same industry choose the same leverage. This implies that, conditional on distress, the liquidation rate is the same. We then define the aggregate rate of distress as $\bar{\delta} \equiv \sum_i \frac{\delta_i a_i}{A}$ and we can then write $W \geq zp(\bar{\delta}\alpha A - L)$.

Our main task is to determine the equilibrium prices at which assets are sold or liquidated. There are two types of equilibria depending on the nature of liabilities. If $s < \gamma \frac{D}{A}$, there is no partial sale because the price is never high enough to pay the short term creditors. Since $s < \frac{D}{A}$, partial sale requires that γ be low enough. The banking model in Acharya, Pedersen, Philippon and Richardson (2010), with $\gamma = 1$, is always in this category. If $s > \gamma \frac{D}{A}$, however, a partial sale is possible when the price is high enough. This new possibility captures some features of the traditional insurance market where liabilities are relatively stable.

In all cases, we will describe the equilibrium with the random variable λ defined as $\lambda \equiv \frac{W}{z\bar{\delta}A}$. This is the ratio of the free capital (potentially levered) to the potential quantity of assets that need to be reallocated. When it falls below 1, there is a shortfall of buyers.

1. Full Liquidation Equilibria

When $s < \gamma \frac{D}{A}$, then there is no partial liquidation equilibrium and we have $\alpha = 1$ for all insolvent firms. There are three regions:

- If $\lambda > s$, then $p = s$ and $L = 0$: no crisis,
- If $l < \lambda < s$, then $p = \lambda$ and $L = 0$: fire sales, but no liquidation,
- If $\lambda < l$, then $p = l$ and L>0: liquidation creates systemic costs.

The quantity of liquidated assets is given by $L = 1_{\lambda < l}\left(\bar{\delta}A - \frac{W}{zl}\right)$.

2. Partial Liquidation Equilibria

If $\gamma\frac{D}{A} < s$, then partial liquidation is possible. The structure of the equilibrium depends on the value of the liquidation price l. If $l < \gamma\frac{D}{A} < s$, then the equilibrium is as follows:

- If $\lambda > \gamma\frac{D}{A}$, then $p = s$ and $L = 0$,

- If $l < \lambda < \gamma\frac{D}{A}$, then $p = \lambda$ and $L = 0$,

- If $\lambda < l$, then $p = l$ and L>0.

If $\gamma\frac{D}{A} < l$, then the equilibrium is as follows:

- If $\lambda > \gamma\frac{D}{A}$, then $p = s$ and $L = 0$,

- If $\lambda < \gamma\frac{D}{A}$, then $p = l$ and L>0.

By combining the various cases, we obtain the following generic proposition:

Proposition: Equilibrium at time 1

- If $\lambda > min\left(\gamma\frac{D}{A}; s\right)$, then $p = s$ and $L = 0$

- If $min\left(\gamma\frac{D}{A}; l\right) < \lambda < min\left(\gamma\frac{D}{A}; s\right)$, then L=0 and $p = \lambda$.

- If $\lambda < min\left(\gamma\frac{D}{A}; l\right)$, then $p = l$ and $L > 0$

The quantity of liquidated assets is given by $L = 1_{\lambda < min\left(\gamma\frac{D}{A}; l\right)}\left(\bar{\delta}min\left(\frac{\gamma D}{l}; A\right) - \frac{W}{zl}\right)$.

v. Equilibrium at Time 0 and the Optimal Taxation of Systemic Risk

As explained earlier, systemic externalities come from liquidation and from going-concern externalities. The planner cares about the externality while private agents do not. Below, we characterize the equilibrium at time 0.

The ex-post value for the owner is the sum of the returns on her own assets $max\,(q_i a_i - d_i, 0)$ and the return on her acquisition $w_i\left(^S/_p - 1\right)/z$. The program of a bank owner is therefore

$$\max_{d_i, \tilde{q}_i} - w_{0,i} - \tau_i + \mathbb{E}\left[(1 - \delta_i)\left(q_i a_i - d_i + w_i\left(^S/_p - 1\right)/z\right)\right],$$

subject to the time 0 budget constraint. Note that we allow the manager to choose a portfolio of assets, i.e., to have an endogenous return chosen in some specified set.

From the planner's perspective, because bondholders are assumed to break even, welfare is measured by equity value net of externalities. The planner's problem is therefore to maximize $P^1 + P^2 + P^3$, with $\quad P^1 = \sum_i \mathbb{E}\big[(1 - \delta_i)\big(q_i a_i - d_i + w_i(^S/_p - 1)/z\big)\big] - w_{0,i} - \tau_i$,

and the externalities $\quad P^2 = -f\mathbb{E}\left[1_{\lambda < \min\left(\gamma\frac{D}{A};l\right)}\left(\bar{\delta}\min\left(\frac{\gamma D}{l};A\right) - \frac{W}{zl}\right)\right]\quad$ and $\quad P^3 = -g\psi\mathbb{E}[1_{W < \bar{W}}(\bar{W} - W)]$.

With respect to the fire sale externality, P^2, to shorten the notation, let us denote by χ the occurrence of a fire sales crisis: $\chi \equiv \left\{\lambda < \min\left(\gamma\frac{D}{A};l\right)\right\}$. Then we can rewrite $P^2 = -f\mathbb{E}\left[\bar{\delta}\min\left(\frac{\gamma D}{l};A\right) - \frac{W}{zl}\middle|\chi\right]\Pr(\chi)$. Recall that $A \equiv \sum_i a_i$, and $W \equiv \sum_i w_i$, and $\bar{\delta} \equiv \sum_i \frac{\delta_i a_i}{A}$.

Therefore, $\bar{\delta}\min\left(\frac{\gamma D}{l};A\right) - \frac{W}{zl} = \min\left(1;\frac{\gamma D}{lA}\right)\sum_i \delta_i a_i - \frac{1}{zl}\sum_i w_i$.

The planner's solution can therefore be decentralized with the following tax system

$$\tau_i^f = f\Pr(\chi)\left(\min\left(1;\frac{\gamma D}{lA}\right)a_i\Pr(\delta_i|\chi) - \frac{1}{zl}\mathbb{E}[w_i|\chi]\right)$$

where $w_i = \max(q_i a_i - d_i - za_i, 0)$ is the free capital of firm i.

The tax has two parts because, during a crisis, a firm may either contribute to systemic risk through being "forced" to liquidate assets at a cost to the overall system or mitigate systemic risk by being healthy enough to purchase some of the assets, thus avoiding liquidation. In the context of the model, the first expression is captured by $a_i\Pr(\delta_i|\chi)$ and represents the amount of assets dumped in a saturated market. It is equal to current assets times the probability of insolvency, conditional on a systemic crisis. It is not linear in negative equity as, for example, marginal expected shortfall would be. This is because, in the model, we assume that default creates a discrete jump in liquidation. The second expression $\mathbb{E}[w_i|\chi]$ is the expected excess capital of the firm in a systemic crisis. It contributes negatively to the tax since it gives credit to the firm for its contribution to clearing the takeover market if the firm is solvent despite the systemic crisis.

With respect to the going-concern externality, it is possible to show that the tax is equivalent to the systemic risk tax solved for and presented in our previous work (Acharya, Pedersen, Philippon and Richardson (2010)). Specifically, the systemic risk tax associated with the aggregate capital shortfall externality is

$$\tau_i^g = g\psi\Pr(W < \bar{W})\mathbb{E}\left[\frac{\bar{W}}{N} - w_i\middle|W < \bar{W}\right].$$

In the cross-section, the optimal tax is directly proportional to systemic expected shortfall, i.e., the firm's expected capital shortfall in a crisis, namely when there is an aggregate capital shortfall.

The above breakdown of systemic risk is useful for analyzing and comparing the banking sector to the insurance sector. A defining feature of the banking sector is that most liabilities are runnable (γ is large) and assets are illiquid (l is low), implying $\min\left(1; \frac{\gamma D}{lA}\right) = 1$, whereas, for traditional insurance companies, liabilities are more stable and assets more liquid, implying $\min\left(1; \frac{\gamma D}{lA}\right) = \frac{\gamma D}{lA} < 1$. *Ceteris paribus*, this means that banks may impose higher systemic risk than insurance companies even if the banks have less assets and less chance of insolvency, i.e., $a_{banks}\Pr(\delta_{banks}|\chi) < a_{insur}\Pr(\delta_{insur}|\chi)$.

Therefore, in comparing insurance companies to banks, we have provided a formal framework that explains how traditional insurance companies can be systemic, namely as going concerns because their contribution to an aggregate capital shortfall reduces the amount of financial intermediation undertaken in the economy. Of course, as described above, a particular insurance company's contribution depends on whether their assets are involved in the financial intermediation process. Consider the case of a poorly capitalized insurance company which collects premiums and simply pays them out to policyholders as these holders' claims become due. With little involvement in financial intermediation, such as an investor in corporate bonds and mortgage-backed securities or offering financial guarantees, it is not clear that this firm's distress in a time of crisis has systemic consequences. This insurance company is arguably no different than any other corporation engaged in real economy activities. Rather, it is the role of insurance companies in the financial intermediation process that highlights their importance as a going concern.

In contrast, banks contribute to systemic risk both as going concerns but also with respect to legacy assets, causing fire sales within the financial system with knock-on effects to the economy. Non-traditional insurance companies may be systemic to the extent that their liabilities are liquid. In practice, a comparison across both banks and insurance companies should incorporate their contribution to an aggregate capital shortfall, and the extent to which they engage in shadow banking activities and employ short-term financing.

Note that an interesting point of comparison between banks and traditional insurers can be seen in comparing the two extremes of whether the liabilities can be run on, i.e., ., $\gamma = 1$

versus $\gamma = 0$. In the latter case, insurers never engage in fire sales and can potentially help mitigate the crisis by purchasing assets. For example, the firm, Berkshire Hathaway, which has considerable insurance operations, might be considered an example of this type of firm. However, the insurance firm can still become insolvent and contribute to an aggregate capital shortfall.

This paper has presented the simplified version of the model of Acharya, Pedersen, Philippon and Richardson (2015) in order to analyze systemic risk with the possibility of both capital shortfalls and of runs and fire sales. In the setting above, the two externalities are assumed to be independent. However, there are two important reasons why these externalities may not be independent in practice, namely marking to market with endogenous runs, and strategic capital allocations with fire sales. With respect to the former reason, we have assumed that runs only take place if the firm is insolvent, based on long-run true value. If instead we assume insolvency on a mark-to-market basis, then the fire sale price would in fact matter for solvency. This would increase the runs and make them endogenous to the fire sales. It would also deplete capital and increase the going concern externality. With respect to the latter reason, the two externalities could interact to the extent that the same capital could be used to make new loans or to buy distressed assets. Fire sales then create an opportunity cost for making new loans. We could extend the model in our framework by modeling explicitly the new loans, with return R. The arbitrage condition would be $R=s/p$. Any fire sale, even before it hits the price l, would then raise the cost of fund for new loans (see, for example, Diamond & Rajan (2012)).

IV. Empirical Implications

In this section, we briefly describe empirical implications of the model. Taking the model literally, the systemic risk of a financial firm is comprised of two components:

- Going Concern Externality x (fraction of assets involved in financial intermediation) x (probability of an aggregate capital shortfall) x (firm's expected capital shortfall conditional on a crisis, i.e., when there is an aggregate capital shortfall).
- Runs Externality x (probability of a fire sale crisis) x [(a firm's quantity of assets) x (probability of insolvency conditional on a fire sales crisis) scaled by the fraction of assets that must be sold minus (the expected capital of the firm relative to required capital conditional on a fire sales crisis).

This result highlights the particular functional role of runnable liabilities, liquidity of assets, the quantity of assets, leverage, capital requirement, probability of insolvency in a crisis, probability of a crisis, and expected capital shortfall of a firm in a crisis. The result incorporates in a specific way, therefore, how the systemic risk of a firm is related to standard intuitive measures such as high leverage, systematically risky assets and/or activities, and liquidity mismatch.

Putting aside the issue of how to measure the relative cost of the going concern externality versus the runs externality, all the other parameters of the model are in theory measurable, albeit some with substantial noise such as the probability of a crisis. Importantly, because parameters like the probability of a crisis do not vary across firms, relative measures of systemic risk across firms can be developed.

Indeed, NYU Stern's Systemic Risk Rankings published by NYU's Volatility Institute provide estimates of the expected capital shortfall of global financial firms given a systemic crisis. (See http://vlab.stern.nyu.edu/welcome/risk/.) NYU Stern Systemic Risk Rankings approximate this amount of capital (i.e., SRISK) by estimating how much (if any) does a firm's market value of equity fall below a fraction of the firm's total assets when a crisis hits. Figure 1 provides time-series estimates of SRISK for the current three most systemic insurance companies, Metlife, Prudential and Lincoln National, taken from NYU's site. Note these measures of systemic risk focus just on the going concern externality and assume the same ψ in Section III.d.iii (in other words, the same fraction of assets tied to financial intermediation).

There are two interesting points from Figure 1. First, there is considerable difference in magnitude of the going concern risk for Metlife and Prudential versus Lincoln National. This difference has grown since the financial crisis. Interestingly, FSOC has designated Metlife and Prudential as SIFIs but not Lincoln National. Second, unlike the banking sector, the SRISK does not decrease after the financial crisis, but instead has been at a similar or higher level since 2011. In a similar vein, Acharya and Richardson (2014) show that, before the crisis, the insurance subsector's percentage of the U.S. financial sector's total quasi market value of assets and total SRISK are similar (approximately 20%). After the crisis, however, the insurance has become – on a relative basis, in terms of its total assets – a more systemically risky financial subsector. That is, whether due to regulation or to voluntary risk reduction in the aftereffect of the crisis, the banking subsector has become (and, since that time, has generally remained) *better* capitalized and *less* risky relative to the insurance subsector.

Tables 1A and 1B demonstrate this result in a slightly different way. Taking the current 12 most systemic financial firms in terms of a going concern, Table 1A and 1B document how these firms' SRISK has changed compared to before and after the financial crisis. Some observations are in order. First, of the 12 firms with highest SRISK, six of them are now insurance companies, the most over the last decade. It is certainly true that the fraction of insurance company assets involved in financial intermediation may be less than banking and therefore the going concern externality due to insurance may be somewhat lower. Nevrtheless, the delta of systemic risk of the insurance sector has been increasing. Second, this finding is confirmed in Tables 1A and 1B. The SRISK of 5 of 6 insurance companies has increased since before the crisis and 4 of 6 since after the crisis. This contrasts with the five large banking institutions. While 3 of the banks' SRISK has increased since before the crisis, all of the banks' SRISK has declined subsequent to the crisis. The fact that there has been a "changing of the guard" so to speak should not be surprising. If the amount of financial assets are somewhat fixed, and the banking sector has reduced its role, then other parts of the financial system must pick up the slack. Insurance companies are clearly part of the story. Finally, Table 1B shows that the increase in SRISK of the insurance sector is not because market equity values have declined or asset risk has increased, but rather higher SRISK is due to an increase in leverage. In other words, systemic risk (in the form of going concern risk) has been transmitted to the insurance sector through leverage which may be a red flag for regulators.

Along with the going concern externality, it is possible to make progress on whether there is a run externality for insurance companies. Two key parameters are (1) whether an insurance company's liabilities are runnable, and (2) the probability of an insolvency in a crisis. With respect to (1), most notably, Paulson, Plestis, Rosen, McMenamin and Mohey-Deen (2014) provide an algorithm for analyzing runs by developing a framework for breaking life insurers' liabilities into categories of illiquid, moderately liquid and highly liquid. They document over 50% of liabilities are in the moderate to high categories, and estimate that over 40 percent of the life insurance industry's liabilities would likely be withdrawn in an environment of "extreme stress." Rather than performing a full-blown analysis of runnable liabilities, however, we instead simply comment on one firm, namely Metlife. According to FSOC's filings on Metlife, as of December 2013, Metlife had written approximately $100 billion of variable annuities; had $49 billion of $308 billion general account liabilities withdrawable without penalty; had $52 billion of funding agreements and $35 billion of funding agreement backed notes and commercial paper;

and securities lending of around $30 billion. These magnitudes are consistent with the aforementioned general findings on liabilities of the life insurance sector by Paulson, Plestis, Rosen, McMenamin and Mohey-Deen (2014).

It is sometimes argued that runnable liabilities are not important for insurance companies because many of the relevant state regulators have authority to step in and prevent redemptions. This argument actually reinforces the case for some insurance companies contributing to systemic run risk in much the same way deposit insurance for banks is a regulatory response to possible bank runs. Whether these regulations are optimal is an open question, but they exist because of the run threat. Setting up gates to prevent redemptions, however, has clear costs. It reduces liquidity by tying up the funds of the policyholders, and, because of this cost, may make runs more likely. That is, the regulation encourages policyholders to be the first to redeem before the gates are set up, leading many policyholders to run prematurely.

As a final comment on the run externality, note that the second key parameter is the probability of insolvency conditional on a crisis. This too is measurable. Putting aside the price of risk, the simplest way would be to back out the probability of default from traded securities such as credit default swaps. To coincide with the above focus on Metlife, Figure 2 documents Metlife's CDS premium over the past decade alongside the total SRISK of the U.S. financial system (which represents the estimate of the financial sector's undercapitalization in a stress situation). Two points are of interest. First, from September 30, 2008, through June 1, 2009, the premium never fell below 400 basis points. For comparison purposes, over the last 20 years, the median spread of high-yield (so-called junk) bonds has been 560 basis points. Second, there is a remarkable relation between MetLife's CDS and the financial sector's SRISK throughout the 10-year period. That suggests MetLife's financial distress is at its highest when the estimate of aggregate capital shortfall is high. As seen by the systemic risk model's formula at the beginning of this section, higher insolvency probability ceteris paribus increases the run externality. Acharya and Richardson (2014) document a similar finding by comparing the average CDS premium of insurance firms against aggregate stock market values.

V. Conclusion

On the one hand, a growing body of literature recognizes that insurance companies, like other financial actors, can be systemically risky when they engage in activities that expose them to risk from distress somewhere in the economy and when they are positioned to transmit this distress to other actors in the economy. On the other hand, insurance companies, especially those engaged in purely traditional activities, would seem to be quite different than banks in this regard. This paper provides a theoretical framework to analyze and compare different types of financial firms along a number of dimensions.

Working off the systemic risk model of Acharya, Pedersen, Philippon and Richardson (2010, 2015), we propose and implement a more precise definition of systemic risk. Our model incorporates two negative externalities arising respectively from an aggregate capital shortfall in the economy and fire sales as results of runs on financial firms' liabilities. a financial firm contributes to systemic risk through its contribution to the aggregate capital shortfall and the loss of future financial intermediation in the real economy (i.e., as a "going concern"), and through its liability structure which impacts the likelihood of runs and forced fire sales (i.e., leading to a loss of "current activities" in the real economy).

The resulting model highlights the conditions under which one firm may be more systemically risky than another firm. Specifically, a comparison across both banks and insurance companies should incorporate the firm's size, the risk of the firm's assets in a crisis, the leverage of the firm and the firm's liquidity mismatch, that is, the extent to which the firm engages in shadow banking activities and employ short-term financing. Since many of these characteristics are publicly available for financial firms, the model in this paper has practical consequences. We provide several empirical observations to illustrate this point.

References

Acharya, Viral, Heitor Almeida, Filippo Ippollito and Ander Perez, "Credit Lines as Monitored Liquidity Insurance: Theory and Evidence", *Journal of Financial Economics,* 2014, 112, 287-319

Acharya, Viral, Christian Brownless, Robert Engle, Farhang Farazmand, and Matthew Richardson. 2011. Measuring systemic risk . In Chapter 4, pp. 87-120, *Regulating Wall Street: The Dodd-Frank Act and the New Architecture of Global Finance*, eds. Viral Acharya, Thomas Cooley, Matthew Richardson and Ingo Walter, Hoboken, NJ: John Wiley & Sons

Acharya, Viral, Robert Engle and Diane Pierret. 2013. Testing macroprudential stress tests: The risk of regulatory weights. *Journal of Monetary Economics* 65: 36-53.

Viral V. Acharya, John Biggs, Matthew Richardson & Stephen Ryan, "Systemic Risk and the Regulation of Insurance Companies," *in Regulating Wall Street: The Dodd-Frank Act and the New Architecture of Global Finance* 242 (Viral V. Acharya, Thomas Cooley, Matthew Richardson & Ingo Walter eds., 2010)

Acharya, Viral, Douglas Gale, and Tanju Yorulmazer (2009), "Rollover Risk and Market Freezes", *Journal of Finance,* 2011, 66, 1175-1207.

Viral V. Acharya, Lasse H. Pederson, Thomas Philippon & Matthew Richardson, *Measuring Systemic Risk* (May 2010), working paper.

Viral V. Acharya, Lasse H. Pederson, Thomas Philippon & Matthew Richardson, *Online Appendix to Measuring Systemic Risk* (September 2015), mimeo.

Acharya, Viral, Robert Engle and Matthew Richardson. 2012. Capital shortfall: A new approach to ranking and regulating systemic risks. *American Economic Review, Proceedings & Papers* 102: 59-64;

Acharya, Viral V. and Matthew Richardson, (2014). Is the Insurance Industry Systemically Risky?. In Chapter 9 of *Modernizing Insurance Regulation*, eds. John Biggs and Matthew Richardson and Ingo Walter, Hoboken, NJ: John Wiley & Sons.

Tobias Adrian & Markus Brunnermeier, Federal Reserve Bank of New York, Staff Report No. 348, *CoVaR* (Sept. 2008; rev. Sept. 2014),

Adams, Z., R. F¸ss, and R. Gropp (2010) Modeling Spillover E§ects Among Financial Institutions: A State-Dependent Sensitivity Value-at-Risk (SDSVaR) Approach. Working Paper, European Business School;

Allen, Franklin, and Douglas Gale, 2000, Financial contagion, *Journal of Political Economy* 108: 1–33.

Allen, Linda, Turan G Bali, and Yi Tang. 2012. "Does Systemic Risk in the Financial Sector Predict Future Economic Downturns?" Review of Financial Studies, 25(10): 3000–3036;

American Council of Life Insurers, *Assets and Investments in America's Economy*, https://www.acli.com/Tools/Industry%20Facts/Assets%20and%20Investments/Pages/Default.aspx

Etti G. Baranoff & Thomas W. Sager, *The Impact of Mortgage-Backed Securities on Capital Requirements of Life Insurers in the Financial Crisis of 2007-2008*, 34 Geneva Papers on Risk & Ins. 100-18 (2009)

Bo Becker & Marcus Opp, NBER Working Paper 19257, *Regulatory Reform and Risk-Taking: Replacing Ratings* (July 2013)

Benoit, S, G Colletaz, C Hurlin and C Perignon (2012), A theoretical and empirical comparison of systemic risk measures, working paper;

Bernanke, Ben. 1983. Nonmonetary effects of the financial crisis in the propagation of the great depression. *The American Economic Review* 73(3): 257-276.

Billio, Monica, Mila Getmansky, Andrew Lo, and Loriana Pelizzon. 2011. Econometric measures of connectedness and systemic risk in the finance and insurance sectors. Ca' Foscari University of Venice Department of Economics Working Paper No. 21/WP/2011.

Bisias, Dimitrios, Mark Flood, Andrew Lo, and Stavros Valavanis. 2012. A survey of systemic risk analytics. Office of Financial Research Working Paper No. 0001.

Elijah Brewer III, James M. Carson, Elyas Elyasiani, Iqbal Mansur & William L. Scott, *Interest Rate Risk and Equity Values of Life Insurance Companies: A GARCH-M Model*, 74 J. Risk & Ins. 401-23 (2007)

Christian Brownlees & Robert Engle, *SRISK: A Conditional Capital Shortfall Index for Systematic Risk Assessment* (Jan. 2015), working paper.

Brownlees, Christian, Ben Chabot, Eric Ghysels and Christopher Kurz. 2015. Back to the future: Backtesting systemic risk measures during the Great Depression and historical bank runs. Working paper, Federal Reserve.

Brunnermeier, M. K., G. N. Dong, and D. Palia. 2011. Banks Non-Interest Income and Systemic Risk. Working Paper, Princeton University;

Chen, Hua, J. David Cummins, Krupa S. Viswanathan, and Mary A. Weiss. 2012. "Systemic Risk and the Inter-Connectedness between Banks and Insurers: An Econometric Analysis." *Journal of Risk and Insurance*, forthcoming.

Cummins, J. David and Mary Weiss. 2014). Systemic risk and regulation of the U.S. Insurance Industry. In Chapter 7 of *Modernizing Insurance Regulation*, eds. John Biggs and Matthew Richardson and Ingo Walter, Hoboken, NJ: John Wiley & Sons.

De Jonghe, Olivier. 2009. Back to the basics in banking? A micro-analysis of banking system stability. National Bank of Belgium Working Paper No. 167.

Diamond, Douglas W., and Phillip H. Dybvig, 1983, Bank runs, deposit insurance, and liquidity, *Journal of Political Economy* 91, 401–419.

Douglas W. Diamond and Raghuram G. Rajan (2001). Liquidity Risk, Liquidity Creation,and Financial Fragility: A Theory of Banking," Journal of Political Economy 109(2), 287-327.

Douglas W. Diamond and Raghuram G. Rajan (2005). Liquidity Shortages and Banking Crises, The Journal of Finance, <u>Volume 60, Issue 2, </u>pages 615–647, April 2005

Douglas W. Diamond and Raghuram G. Rajan (2011). Fear of Fire Sales, Illiquidity Seeking, and Credit Freezes, The Quarterly Journal of Economics (2011) 126 (2): 557-591.

Jens Dick-Nielsen, Peter Feldhutter & David Lando, *Corporate Bond Liquidity Before and After the Onset of the Subprime Crisis*, 103 J. Fin. Econ. 471-92 (2012)

Andrew Ellul, Chotibhak Jotikasthira & Christian T. Lundblad, *Regulatory Pressure and Fire Sales in the Corporate Bond Market*, 101 J. Fin. Econ. 596-620 (2011)

Engle, Robert F. 2002. Dynamic conditional correlation: A simple class of multivariate generalized autoregressive conditional heteroskedasticity models. *Journal of Business and Economic Statistics* 20: 339-350.

Engle, Robert F. 2014. Dynamic conditional beta. Working paper, NYU Stern School of Business.

<u>Engle</u>, Robert, <u>Eric Jondeau</u> and <u>Michael Rockinger</u>. 2014. Systemic Risk in Europe, *Review of Finance*. 19: 145-190;

Kenneth A. Froot, *The Market for Catastrophe Risk: A Clinical Examination*, 60 J. Fin. Econ. 529-71 (2001)

Kenneth A. Froot & Paul G. J. O'Connell, "The Pricing of U.S. Catastrophe Reinsurance," *in The Financing of Catastrophe Risk* ch. 5 (Kenneth A. Froot ed., Univ. of Chicago Press 1999)

Mark J. Garmaise & Tobias J. Moskowitz, *Catastrophe Risk and Credit Markets*, 64 J. Fin. 657-707 (2009)

Gibson, Michael. 1995. Can bank health affect investment? Evidence from Japan. *The Journal of Business* 68 (3): 281-308.

 Giesecke, Kay, and Baeho Kim. 2011. Systemic Risk: What Defaults Are Telling Us, *Management Science* 57: 1387 – 1405;

Glosten, Lawrence R., Ravi Jagannathan and David Runkle. 1993. On the relation between the expected value and the volatility of the nominal excess return on stocks. *The Journal of Finance* 48 (5): 1779-1801.

Goodhart, Charles, and Miguel Segoviano. 2009. Banking stability measures. IMF Working Paper No. WP/09/4.

Hansen, Lars P. 2012. Challenges in identifying and measuring systemic risk, NBER working paper;

Scott E. Harrington, "Designation and Supervision of Insurance SIFIs," *in Modernizing Insurance Regulation* ch. 8 (John H. Biggs & Matthew P. Richardson eds., 2014).

Holmstrom, Bengt, and Jean Tirole. 1997. Financial intermediation, loanable funds, and the real sector. *The Quarterly Journal of Economics* 112 (3): 663-691.

Huang, Xin, Hao Zhou, and Haibin Zhu. 2009. A framework for assessing the systemic risk of major financial institutions. Finance and Economics Discussion Series, Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board of Washington D.C., No. 2009-37.

Huang, Xin, Hao Zhou, and Haibin Zhu. 2012. Systemic risk contributions. *Journal of Financial Services Research* 42 (1): 55-83.

Ivashina, Victoria, and David S. Scharfstein. "Bank Lending During the Financial Crisis of 2008." *Journal of Financial Economics* 97, no. 3 (September 2010): 319–338.

Ralph S. J. Koijen & Motohiro Yogo, NBER Working Paper 19568, *Shadow Insurance* (Oct. 2013),

A. Manconi, M. Massa, and A. Yasuda, "The Role of Institutional Investors in Propagating the Crisis of 2007–08," *Journal of Financial Economics* 104, no. 3 (2012): 491–518.

Anna Paulson, Thanases Plestis, Richard Rosen, Robert McMenamin & Zain Mohey-Deen, 2014, "Assessing the Vulnerability of the U.S. Life Insurance Industry," *in Modernizing Insurance Regulation* , (John H. Biggs & Matthew P. Richardson eds., 2014) .

Slovin, Myron, Marie Sushka, and John Polonchek. 1993. The value of bank durability: Borrowers as bank stakeholders. *The Journal of Finance* 48 (1): 247-266.

Thakor, Anjan. 1996. Capital requirements, monetary policy, and aggregate bank lending: Theory and empirical evidence. *The Journal of Finance* 51 (1): 279-324.

The Volatility Inst., NYU Stern, http://vlab.stern.nyu.edu/welcome/risk/

Table 1: Changes in SRISK from A: 1/31/2007 & B: 8/31/2009 to 8/21/2015

Table 1A and 1B document the SRISK changes of the ten highest SRISK financial firms (as of 8/21/2015) from two dates: A: 1/31/2007 (before the financial crisis) and B: 8/31/2009 (after the financial crisis). We estimate SRIS econometrically using market data on equities and balance sheet data on liabilities. It is possible to show that[19]

$$SRISK_{it} = E(Capital\ Shortfall_i | Crisis) \approx [k(1 - L_{it}) - (1 - k)(1 - LRMES_{it})L_{it}]A_{it}$$

where k is the prudential level of equity relative to assets (8% in this example), L is the ratio of market value of equity to quasi-market value of assets of the firm (i.e., market value of equity plus book value of assets minus book value of equity) defined as A, and LRMES is the long-run marginal expected shortfall (i.e., the decline in expected equity value if there is another financial crisis).

A. 1/31/2007

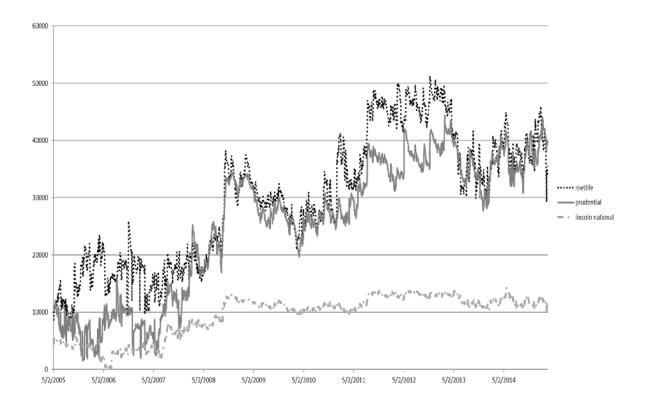| Institution	SRISK (t)	SRISK (t - 1)	Δ SRISK	Δ(DEBT)	Δ(EQUITY)	Δ(RISK)
Bank of America Corp	69,365.4	-41,273.2	110,638.5	45,832.8	37,108.3	27,697.5
Citigroup Inc	41,170.7	-23,491.2	64,661.9	-12,368.4	63,051.5	13,978.8
Prudential Financial Inc	40,021.9	6,176.3	33,845.7	24,495.7	3,507.0	5,843.0
MetLife Inc	39,247.3	20,087.6	19,159.7	26,872.2	-3,641.2	-4,071.3
JPMorgan Chase & Co	36,517.1	-24,215.2	60,732.2	77,813.1	-38,709.9	21,629.0
Morgan Stanley	27,068.5	56,162.3	-29,093.8	-26,803.6	8,477.3	-10,767.5
Lincoln National Corp	12,714.3	2,877.3	9,837.0	5,437.7	3,052.1	1,347.2
Goldman Sachs Group Inc/The	12,301.2	32,859.6	-20,558.4	-2,503.8	2,508.9	-20,563.6
Principal Financial Group Inc	7,095.2	458.7	6,636.5	6,142.4	452.6	41.5
Genworth Financial Inc	6,580.4	-2,550.0	9,130.4	-328.3	7,072.1	2,386.5
State Street Corp	5,973.1	-2,991.0	8,964.1	13,822.2	-3,238.4	-1,619.7
Hartford Financial Services Group Inc/The	4,494.5	7,026.3	-2,531.8	-7,034.5	6,732.4	-2,229.7

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[19]See http://vlab.stern.nyu.edu/welcome/risk/.

B: 8/31/2009

Institution	SRISK (t)	SRISK (t - 1)	Δ SRISK	Δ(DEBT)	Δ(EQUITY)	Δ(RISK)
Bank of America Corp	69,365.4	102,499.0	-33,133.7	-8,149.4	-6,889.8	-18,094.5
Citigroup Inc	41,170.7	114,845.2	-73,674.5	-6,754.8	-47,508.9	-19,410.8
Prudential Financial Inc	40,021.9	24,637.2	15,384.8	24,922.3	-6,132.1	-3,405.5
MetLife Inc	39,247.3	27,905.0	11,342.3	27,726.0	-10,170.6	-6,213.1
JPMorgan Chase & Co	36,517.1	72,134.0	-35,616.9	26,921.4	-34,222.4	-28,316.0
Morgan Stanley	27,068.5	32,592.6	-5,524.1	10,017.8	-12,865.5	-2,676.4
Lincoln National Corp	12,714.3	10,448.3	2,266.0	6,103.6	-1,938.0	-1,899.6
Goldman Sachs Group Inc/The	12,301.2	22,174.4	-9,873.2	-4,754.7	1,442.6	-6,561.1
Principal Financial Group Inc	7,095.2	7,055.4	39.8	7,011.8	-3,241.0	-3,731.0
Genworth Financial Inc	6,580.4	6,656.2	-75.7	-113.5	682.4	-644.6
State Street Corp	5,973.1	582.6	5,390.5	10,524.9	-1,972.4	-3,161.9
Hartford Financial Services Group Inc/The	4,494.5	19,217.8	-14,723.3	-4,520.1	-6,063.9	-4,139.3

Figure 1: The Relative Going Concern Externality of Insurance Companies

Figure 1 graphs the SRISK over the last decade for the three insurance companies with the highest SRISK as of May, 2015. We approximate this amount of capital by estimating how much, if any, does a firm's market value of equity fall below a fraction of the firm's total assets. We can estimate this measure econometrically using market data on equities and balance sheet data on liabilities. It is possible to show that[20]

$$SRISK_{it} = E(Capital\ Shortfall_i|Crisis) \approx [k(1 - L_{it}) - (1 - k)(1 - LRMES_{it})L_{it}]A_{it}$$

where k is the prudential level of equity relative to assets (8% in this example), L is the ratio of market value of equity to quasi-market value of assets of the firm (i.e., market value of equity plus book value of assets minus book value of equity) defined as A, and LRMES is the long-run marginal expected shortfall (i.e., the decline in expected equity value if there is another financial crisis).

Figure 2: CDS Premium of Metlife

Figure 2 graphs the CDS premium of Metlife alongside the aggregate SRISK of the U.S. financial sector over the last decade. The CDS premium of Metlife represents that of a five-year CDS contract and is represented on the right-hand side in basis points, while the aggregate SRISK is simply the sum of the SRISKs of each financial firm in the U.S. and is represented on the left-hand side in $1,000s.