

PERSPECTIVES

On a New Approach for Analyzing and Managing Macrofinancial Risks

Robert C. Merton, Monica Billio, Mila Getmansky, Dale Gray, Andrew W. Lo, and Loriana Pelizzon

At the fifth annual CFA Institute European Investment Conference on 19 October 2012 in Prague, Robert C. Merton gave a presentation on analyzing and managing macrofinancial risk. This article is based on his talk and on research he carried out with his coauthors.

Analyzing and managing macrofinancial risk have become increasingly important over time as global markets have become increasingly more connected. Specifically, analyzing and managing sovereign risk, the risks of financial institutions, and the interactions among sovereigns and financial institutions are important for investors and those responsible for financial stability. This topic is also important for those who are responsible for the traditional areas of monetary and fiscal policies because, as we see in a number of cases, monetary and fiscal policies designed to deal with things like stimulus or consumption demand can actually have unintended

consequences of some magnitude for financial stability and markets. Therefore, I am going to make the case for why we need an integration of monetary, fiscal, and financial stability policies.

In light of the 1997 Asian crisis, the financial crisis of 2008–2009, and the most recent European banking and sovereign debt crisis, we know the focus of those crises was really in credit, money markets, and, to some extent, the plumbing (structure of the systems). I am going to focus my discussion on credit. One particular item of interest that many have concerns about is the accumulation of debt, particularly in Europe and the United States.

I would like to point out another class of government liabilities that do not appear on balance sheets but are real liabilities—government guarantees. These guarantees are significant; for example, in the United States, the Fed guaranteed trillions of dollars of bank and money market fund assets, including guaranteeing \$360 billion of assets for a single bank, Citigroup. It is important to note that these guarantees are insurance policies that have value and are real liabilities of the government, yet they are not on the balance sheet.

To provide an idea of the magnitude of these off-balance-sheet liabilities, **Table 1** lists the liabilities of the U.S. government with respect to credit assets, liabilities, and guarantees. U.S. Treasury debt held by the public was \$9 trillion in 2010; that debt is probably closer to \$11 trillion today. The rest of the right-hand side of Table 1 consists of all the U.S. government guarantees that are not on the balance sheet. To begin, there is about \$1.9 trillion in guaranteed loan financing. Fannie Mae and Freddie Mac are both in receivership; the guarantees relating to

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Editor's Note: Much of the research discussed herein is from the paper "Sovereign, Bank, and Insurance Credit Spreads: Connectedness and System Networks," by M. Billio, M. Getmansky, D. Gray, A. Lo, R.C. Merton, and L. Pelizzon, MIT working paper (forthcoming 2013).

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Table 1. On- and Off-Balance-Sheet Credit Assets and Liabilities of the U.S. Government, 2010
(\$ billions)

Assets		Liabilities	
Direct loans	\$828	Treasury debt held by public	\$9,060
Guaranteed loans	1,867	Off-balance-sheet guaranteed loan financing	1,867
Mortgages guaranteed or held by Fannie Mae and Freddie Mac	5,321	Fannie Mae and Freddie Mac debt	1,453
Other federally backed credit ^a	10,140	Fannie Mae and Freddie Mac mortgage-backed securities	3,868
		Off-balance-sheet financing of other federally backed credit	10,140
		Taxpayer/stakeholder equity	-8,232

^aFDIC, Federal Home Loan Banks, Farm Credit System, Pension Benefit Guaranty Corporation, and Federal Reserve loans and structured investment vehicles.

Sources: Authors' tabulations based on U.S. Treasury financial statements, FDIC and Federal Reserve releases, Office of Management and Budget Analytical Perspectives, and the Federal Housing Finance Agency 2010 Annual Report to Congress; Deborah Lucas, "Credit Policy as Fiscal Policy," working paper (MIT and NBER, 15 November 2011, p. 29).

Fannie and Freddie are just over \$5 trillion. Finally, the off-balance-sheet guarantees of the Federal Deposit Insurance Corporation (FDIC), home loan banks, the Fed itself, and many other federal institutions are estimated at about \$10 trillion. In sum, there is about \$17 trillion in U.S. government off-balance-sheet guarantees. Note that the \$17 trillion represents the amounts being guaranteed, not the actual value of the guarantees. The value of these guarantees, however, can be enormous, particularly in times of stress.

The risks generated by these explicit or implicit guarantees, or structures that look like guarantees, can cause risk to propagate across the various sectors of the economy in nonlinear ways that are rather substantial. Specifically, I am referring to interactions among the household sector, the corporate sector, the financial sector (banks), and the government sector, both domestically and across geopolitical borders. We must understand the nature of these interactions, and only then can we begin to measure and monitor the macrofinancial risks associated with them.

A Primer on Credit

Let's begin with the basics of credit—for example, any kind of simple credit instrument: a loan, a corporate bond, or a mortgage. If we combine a U.S. dollar-denominated risky loan with a full faith and credit guarantee of the U.S. government, then we get functionally risk-free debt, just like a Treasury bond. Although a loan with a U.S. government guarantee does not have the collateral characteristics or tax characteristics of a Treasury bond, it is still considered risk free because if the issuer does not pay, the U.S. government will.

Removing the guarantee component takes us back to the original risky loan. That is, if the two pieces together are risk free and we remove the guarantee, then the result is a risk-free loan minus a guarantee. The key implication is that when an investor buys any bond, loan, or mortgage that has credit risk, the investor is combining two kinds of financial activities that require very different skill sets.

The first financial activity is pure risk-free lending, which equates to the time value of money. It is simple: We lend money now, and we get more money back later (albeit currently not very much more). The second financial activity is writing a guarantee, akin to selling insurance. By owning a bond, one is writing a guarantee on the issuer. Of course, the insurance business is very different from the lending business. The characteristics of the loan determine the relative importance of each of the two distinct activities.

Now, apply this idea to a corporate balance sheet. In its simplest form, a corporation has assets and it has debt and equity.¹ According to the accounting identity, assets equal the sum of debt and equity. Let's consider a very simple zero-coupon corporate loan with a face value of B dollars that is issued with a government guarantee. When the loan matures, one of two things happens: The creditor gets paid what was promised, or the company defaults. What is the value of the guarantee, *ex post*, if the creditor gets paid what is promised? The answer is zero because the guarantee was not needed.

But what happens if the creditor does not get paid? For now, ignore bankruptcy proceedings (Chapter 7, 11, 22, etc.) and creditor-debtor negotiations and focus on the fundamental principle that if the company does not pay, the creditor receives the assets. What would the creditor get if there were no guarantee? The creditor would receive

whatever the assets are worth, which will be less than the promised amount. With the guarantee, however, the creditor would receive the face value, B . Consequently, the *ex post* value of the guarantee is equal to the promised amount, B , minus the value of the assets, A . Specifically, the payoff function of the guarantee can be written as the maximum of \$0 or the loan face value minus the value of the assets, or $\max(0, B - A)$.

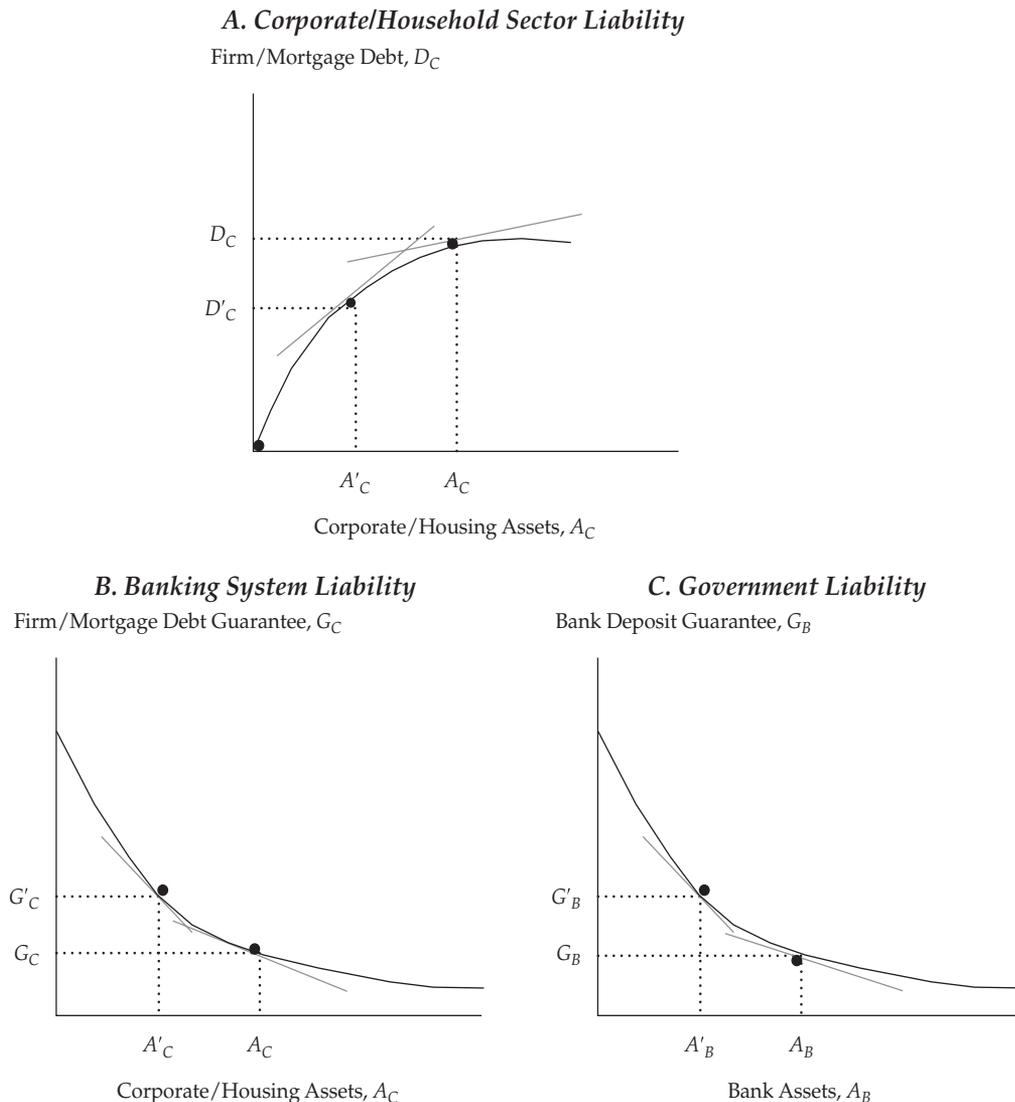
The key implication here is that the payoff function of the guarantee resembles the payoff function of a put option on the underlying assets of the borrower. For a home mortgage bond, the put option is on the value of the house; for a corporate bond, the put option is on the value of the corporate assets. For a sovereign bond, the put option is on the value

of whatever sovereign assets the creditor gets claim to, including taxing power.²

To put this option-based framework into perspective, **Figure 1** illustrates banking sector debt plotted against banking sector assets. Of course, the most important component is driven by the guarantee (i.e., the put option). Remember, risky debt is nothing more than risk-free government debt minus a guarantee/put. So, we will focus on the guarantee/put.

Specifically, let's examine the guarantee that the banks have written to whoever has borrowed from them, whether it is a household or a corporation. Of course, the value of the guarantee/put, *ceteris paribus*, decreases as the value of the assets increases, and it has nonlinear curvature, as shown.

Figure 1. Nonlinear Macro Risk Buildup



Source: Draghi, Giavazzi, and Merton (2004).

Now, suppose we are at A_C , where the value of the guarantee is G_C , and then the value of the assets falls for whatever reason to A'_C . Consequently, the value of the underlying debt goes down, and the value of the guarantee/put rises to G'_C .

Unfortunately, accounting evidence and banking practice suggest that loan values are not actually marked down when asset values decline. In most cases, as long as loans are performing, banks do not change their values when the underlying asset values decline. It's like a person who jumps off the roof of a 50-story building. As he passes the 33rd floor, someone asks him, "How are you doing?" He replies, "Well, right now, just fine." In contrast, market prices tend to reflect what can happen or what will happen, not simply where things are at the current moment.

The key consideration here lies in the sensitivity of the loan value to the movement in the value of the underlying assets. That is, if the underlying assets drop by a dollar, how much would the guarantee/put go up? Or from the issuing bank's perspective, how much would the liability increase? The answer is the option's delta, which is approximately equal to the slope of the line in Figure 1. If the slope is -0.10 , then a \$1 decrease in the value of the bank's assets would lead to a \$0.10 increase in the value of the guarantee/put.

Now, let's look at the new position after a decrease in asset value. What happens if we have another dollar move from that position? As a result of nonlinearity, the slope is steeper—say, -0.30 —and therefore, the same \$1 decrease will have a greater impact—three times greater in this case—on the value of the guarantee/put. Consequently, a second shock of the same magnitude will have a greater effect than the first shock. This risk property has a jargon term, *convexity*, that comes from the mathematical shape of the price curve. This nonlinear relationship is rarely taken into account when dealing with standard bank loans or mortgage books of business. Of course, convexity is taken into account by everyone in the derivatives business.

This relationship explains one of the things we observed in the crisis that some people found peculiar. A bank reports a loss and then announces, "No more new loans; we're freezing the book." Although the bank—by freezing the book—is not taking on additional risk from new business, a second shock to the same book of equal magnitude will lead to an even greater loss. Same loan, same book—nothing has changed on the balance sheet, but the risk of the book has increased, in some cases dramatically. This nonlinearity is the insidious part of credit. In sum, when people assess credit positions with constant (and thus misspecified) risk parameters over long

periods of time and do not mark to market, events that appear to be 10 sigma in severity can occur far more frequently than expected. Here is what is going on: A 2-sigma event looks like a 10-sigma event because the degree of sensitivity—the delta—has increased substantially and therefore is being measured incorrectly. The cumulative losses in loan value from a series of asset value declines are not recognized along the way but instead are recognized at a single point in time, giving the appearance of a large "surprise" shock preceded by relative loan value stability.

Now, let's take this nonlinearity issue a step further. Even if asset values remain unchanged, if the volatility in asset returns increases, then the value of the guarantee/put increases. The key implication is that asset values do not have to change in order to change the risk profile. Standard models do not typically factor in such consequences. During crises and even during moderate market declines, volatility tends to increase. The implication is that those bank balance-sheet volatilities, especially in times of crisis, can be very large, and therefore, the value of those guarantees can be very large.

How does this analysis of the banking sector relate to governments? The answer lies in the fact that governments generally guarantee the banks, formally with deposit insurance and then implicitly—sometimes not so implicitly—even when they are not required to do so. In essence, these governments are writing a guarantee on the bank assets. But what are the bank assets? Bank assets are effectively short put options, so these governments are guaranteeing a put, which means they are writing a put on a short put.³

A closer examination of the real economics reveals that these government guarantees are being driven by assets in the corporate sector or the residential housing sector. The government has a put on a put on the residential housing sector. If puts are convex, then puts on puts are "doubly convex." If in Figure 1 we were to pierce through the bank assets to the corporate and household assets that are really driving the relationship, we would see a curve of the same shape, but it would be much more convex than the banks' guarantees. The curve would start out very flat when the asset value is high and then get steep very fast as the asset value decreases.

To put this into perspective, consider Thailand in 1997. All was going well in terms of the Thai government's obligations. At the time, sovereign debt prices were pretty insensitive to changes in the underlying asset values. However, when things started to get bad in the real estate sector and then for the banks, they got bad for the government really, really fast. In a short amount of time, a seemingly benign position turned into a very risky position.

The basic lesson on credit is that when a shock to the corporate or housing sector occurs, risk changes and the shock propagates to the banking sector and then to the government sector. The shocks can take place in any sector or simultaneously in different sectors and then propagate to the other sectors. For instance, if the shock begins in the banking sector, it flows to corporations and then to governments.⁴

Feedback Loops

This propagation of risk leads to the next step in evaluating total macroeconomic risks—feedback loops. Consider a government whose credit is currently not pristine. It may have been pristine at one time, but it no longer is. Now, consider the banks in such a country. In addition to holding loans, banks typically also hold their government’s debt. Remember that the government guarantees its commercial banks. That is, the government guarantees its banks, but the banks are also holding government bonds. But by holding government bonds, by owning a bond, one is writing a guarantee on it, whoever the issuer is; the banks are guaranteeing the government in return. The end result is that there are two parties and each one has guaranteed the solvency of the other.

What happens to the banks if, say, the value of the government debt declines for some reason? Because the banks are holding government bonds, the value of the put option that they have written for the government through holding those bonds rises. Consequently, the value of the banks’ assets falls, and the banks thus become weaker. However,

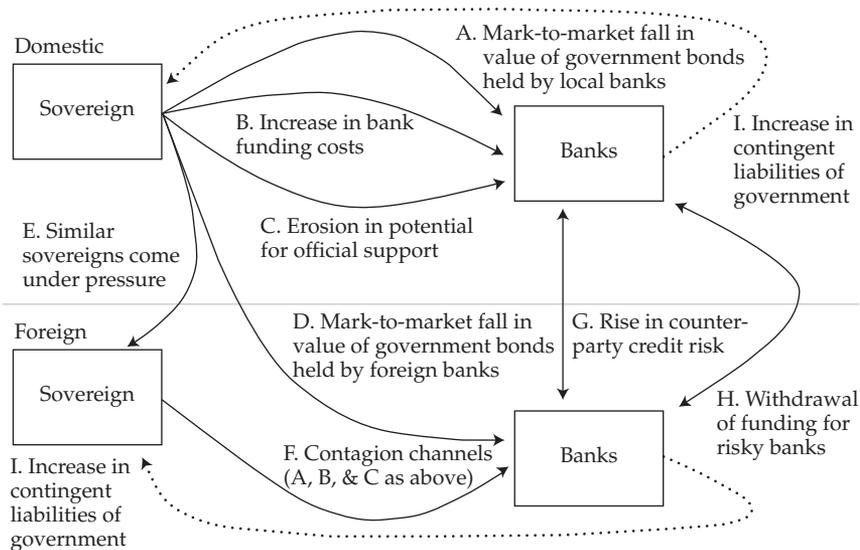
the banks’ becoming weaker means that—because the government has guaranteed the banks—the value of the government guarantee rises, which, in turn, means the government becomes weaker, which feeds back to the banks’ becoming weaker. This sort of feedback loop can lead to some pretty intense cycles.⁵

The propagation of risk gets more complicated in the real world. For instance, consider banks in different countries. Of course, banks in different countries often have credit interactions with each other. A particular bank becoming weak has an impact on other banks, and in fact, banks that do not even do business with the weakened bank may have their credit affected.

For example, it is common for banks in one country to hold the sovereign debt of another country. **Figure 2** illustrates that if that foreign country’s government debt declines in value, these banks become weaker because they are writing guarantees on that debt. More interesting, however, is the resulting interaction between the two sovereigns. The banks’ home country is guaranteeing the banks, which means the decline in the foreign debt indirectly worsens the home country’s position. Consequently, the decision to bail out a bank or sovereign affects not only the sovereign and its own banks but also other sovereigns and foreign banks in a significant way.

How do we go about measuring this feedback loop effect? We need to examine the impact of a change in credit risk on the interconnectedness and financial strength of different entities. The measure

Figure 2. Feedback Loops from Explicit and Implicit Guarantees



Source: International Monetary Fund, “Global Financial Stability Report: Sovereigns, Funding, and Systemic Liquidity” (October 2010).

of credit risk used is the expected loss ratio (ELR). In simple terms, the ELR is estimated by dividing the value of the guarantee/put, or how much it costs to insure the bond payments, by the risk-free value of the debt (the cash flows of the debt are treated as risk free). Recall that risky debt is simply a risk-free version of the debt minus the guarantee. In other words, what percentage of the risk-free value of the debt, if it were fully safe, would be paid for by the guarantee? For example, say a risk-free bond is worth 100 but the additional cost of the insurance guarantee is 7; the bond is thus really worth 93. The ELR equals 0.07, or 7%. The higher the ELR, the bigger the credit risk and the more the guarantee costs. There is no need to consider the credit rating of the bond because the cost of the guarantee is sufficient to express its riskiness.

One market measure of this guarantee cost is the price of credit default swaps (CDSs). Using CDS market prices, we can calculate an estimate of the ELR. That is, we divide the price of the CDS, which is the cost of the guarantee/put, by the risk-free value and then convert that ratio to a spread paid out over the life of the debt instrument, which is the CDS spread.

For our purposes, we do not get into the debate over whether the CDS market is manipulated or whether the market is not a good one. Our approach assumes CDS prices are a good indicator; people are buying and selling them and are not coerced or constrained. We use the CDS prices for the ELR of sovereigns, but we do not use the CDS prices to measure the ELR of financial institutions.

Why not just use the CDSs for, say, Bank of America or Barclays? Well, there is a problem because what we really want to know is what the entity's credit risk is. That is, what is the cost of insuring Bank of America's credit? It is important to note that the CDS price takes into account the fact that the government is already guaranteeing parts of these banks. It is certainly guaranteeing the deposits, and in many cases, we know it is guaranteeing a lot more. In fact, in some cases, we believe it is going to bail them out under many conditions, albeit not all conditions.

So, there is already a government guarantee that exists, and therefore, the CDS price does not reflect all the credit risk but only that part borne by the private sector. The way the government guarantee works, the CDS credit is senior in the sense that it is not the first loss. The first loss goes to the government guarantor. If the government steps in and repays the loans, the government is actually paying off everybody else. In essence, the government takes the first loss (after the equity of the institution); the CDS becomes the second loss. Thus, the quoted CDS rate does not reflect the actual level of

default risk; rather, it reflects only the default risk after the first loss. If I personally borrowed money and the government unconditionally guaranteed me, my own CDS price would be zero even though I do not have zero credit risk. Of course, that price would be distorted given the reality about me. We define the *fair value CDS* spread measure as the ELR for the entire credit risk of the institution, and it replaces the CDS market price with a price, which is usually higher than the CDS market price, that more accurately reflects the true total credit risk.⁶

We thus measure this fair value CDS spread another way. Our methodology is to use a market-tested contingent claims analysis (CCA) technology based on the Merton (1974) credit model as applied by Moody's KMV to determine an estimate of the guarantee or put value for the institution. In our approach, to extract the ELR for the fair value CDS, we use the market value for equities in the various banks, insurance companies, and so forth because the government guarantees typically protect the debt but not the equity.⁷ In the case of the Bear Stearns bailout in March 2008, for example, the market price of equity went down and the market price of debt went up, contrary to standard theory, which holds that the prices of both securities should move in the same direction. Why? The government interceded and essentially protected debt with a guarantee at 100 cents on the dollar. In essence, we use this option-based framework to derive an estimate of what the CDS price would have been had there been no government guarantee.⁸

The right-hand side of a balance sheet (the liabilities) can be thought of as a claim against the left-hand side (the assets). Liabilities are all linked to the same assets; there are just different rules that are applied for splitting the assets under various conditions. That insight means that debt and equity ought to move in certain ways together. Credit is not bearish on the company and equity bullish; they are both bullish on the company and ought to move the same way. However, Bear Stearns's credit and equity moved in opposite ways because the Federal Reserve and the U.S. Treasury intervened with additional assets that supported the debt but did not protect the equity. It was a missing piece in the structure.

To quantitatively estimate feedback effects of credit, we perform Granger causality tests. In short, we take the ELR of entity X at time t and relate it to the ELR of entity Y at time $t + 1$. For example, if entity X is a sovereign, then we look at the sovereign's ELR and relate it to the ELR of entity Y —perhaps a domestic bank or another sovereign's bank—in the next period (month). Then, we estimate the model in the other direction. If something happens to the credit of domestic bank Y , how does

it affect sovereign X 's credit? Equation 1 presents the formal Granger causality test.

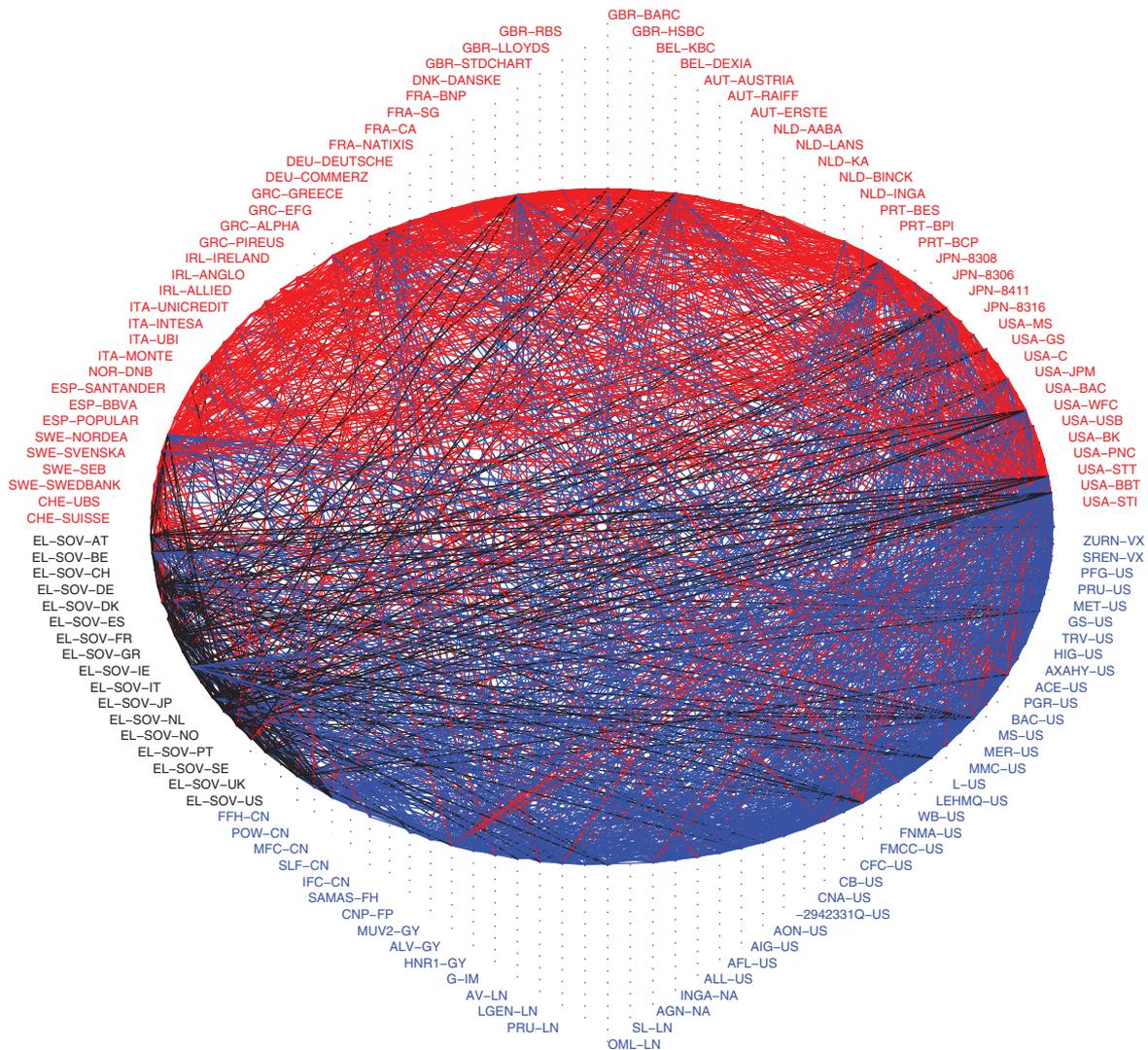
$$\begin{aligned}
 X_t &= \sum_{j=1}^m a_j X_{t-j} + \sum_{j=1}^m b_j Y_{t-j} + \varepsilon_t. \\
 Y_t &= \sum_{j=1}^m c_j X_{t-j} + \sum_{j=1}^m d_j Y_{t-j} + \eta_t.
 \end{aligned}
 \tag{1}$$

If the set of b_j coefficients is statistically significant, then Y influences or "Granger-causes" X ($Y \rightarrow X$). Similarly, if the set of c_j coefficients is significant, then X influences or "Granger-causes" Y ($X \rightarrow Y$). If both sets of coefficients are significant, then there is mutual influence between Y and X . Of course, Y and X can be any pair of entities. It is important to understand that, in addition to assessing general

connectedness between two entities, we are assessing the *direction* of the connectedness; for example, it may be that Y influences X but X does not influence Y .⁹

Figure 3 illustrates the connectedness between 17 sovereigns, 63 banks, and 39 insurance companies prior to the 2008–09 crisis (July 2004–June 2007) using our fair value CDS spreads for the banks and insurance companies. For the sovereigns, we do not have equity, so we use actual market sovereign CDSs because we assume no one is guaranteeing their debt and thus the CDS should reflect the total credit risk of the sovereign. That is, we treat the sovereigns as if no one is guaranteeing them. If we were to do this analysis with, say, the eurozone in a world where the eurozone is guaranteeing sovereigns, then we would have to make adjustments

Figure 3. Connectedness of Sovereigns, Banks, and Insurance Companies, July 2004–June 2007



Source: Billio, Getmansky, Gray, Lo, Merton, and Pelizzon (forthcoming 2013).

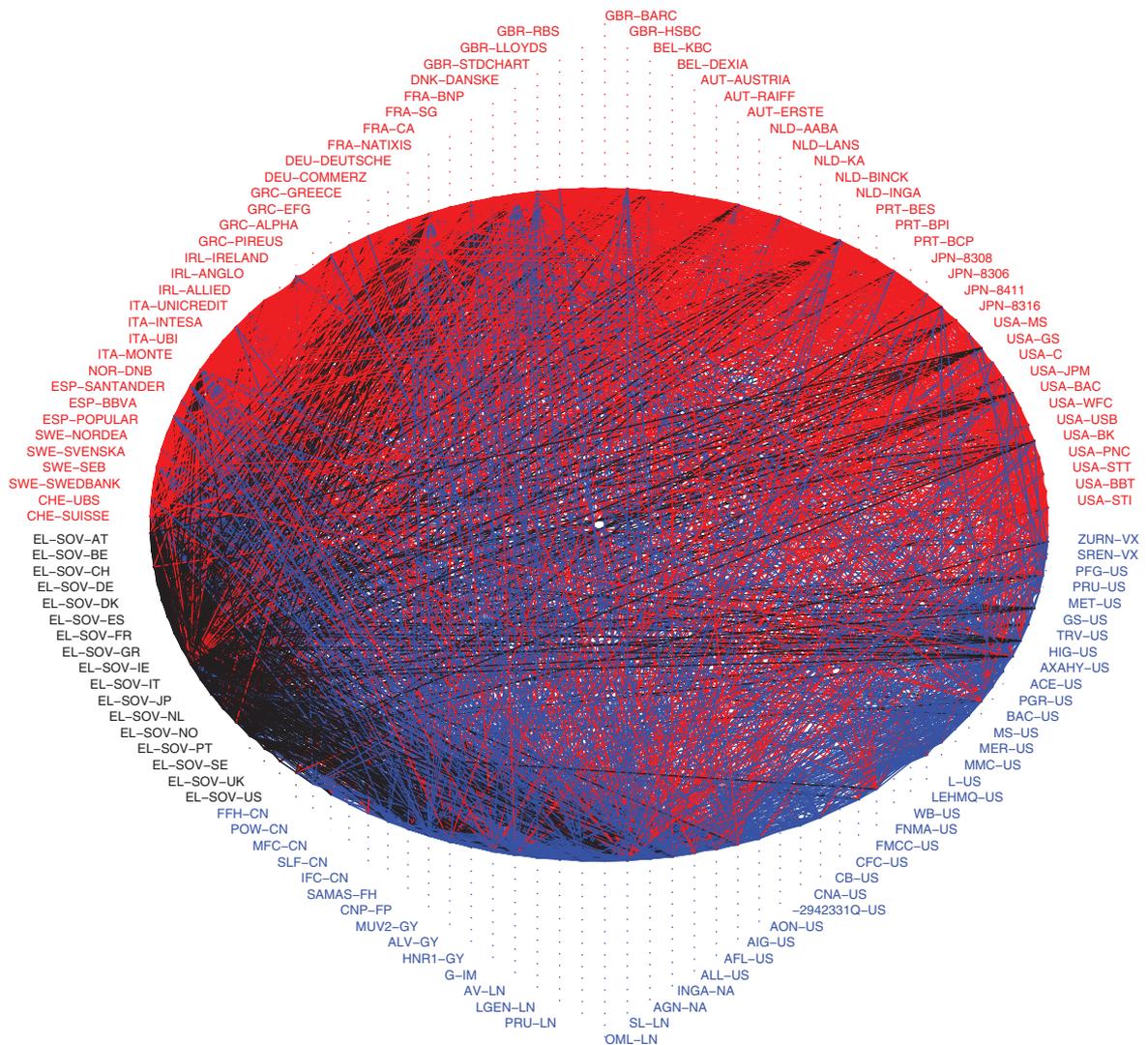
for the CDSs for the same reason that we did with banks and insurance companies—because now there is another guarantor of the sovereign, just as there is for the financial institutions.

Focus on the density of the mass and the colors of the lines in Figure 3, not the detailed print. This is like looking at a map of the world, so do not attempt to look for the detail akin to a given city, let alone a street. Banks from all around the world are in red, insurance companies are in blue, and sovereigns are in black. The density of the lines represents all the connections; thicker lines represent more significant connections among entities.

Now, let's look at the connectedness of these same entities more recently. Figure 4 illustrates the connectedness of the same set of banks, insurance companies, and sovereigns just after the most

intense period of the crisis (April 2009–March 2012). Again, focus on the density of the mass. To begin, Figure 4 reveals much greater density—connectedness—everywhere. Note that this illustration is not a reflection of how much business or how many transactions the entities do with each other; rather, it shows connectedness related solely to their impact on the credit of one another. Second, banks (red lines) and sovereigns (black lines) are more noticeable and have a greater reach across the globe than in Figure 3. In short, the post-crisis environment has a much greater intensity of connectedness in terms of credit sensitivities than before. Is that a bad thing? Not necessarily. There may be lots of connections that are a result of more efficient, more connected financial markets. Is it indicating that the system is more vulnerable?

Figure 4. Connectedness of Sovereigns, Banks, and Insurance Companies, April 2009–March 2012



Source: Billio et al. (forthcoming 2013).

Probably. We just need to understand that we are in a different place—not necessarily a bad place, just a place where things are much more connected.

To provide a country-level perspective, **Figure 5** illustrates the connectedness of Greece in August 2008. Again, these are all the connections with other sovereigns, with insurance companies, and with banks. Clearly, Greece was fairly connected.

Note that the data reveal that in March 2012, the United States had very little connectedness with any of the banks or sovereigns in Europe. So, although the United States is a major player in the financial system, it had very little connectedness, neither influencing nor being influenced by the credit risk changes in institutions or other sovereigns. In contrast, at that time, Italy was highly connected.

How does the degree of connectedness between the different types of entities vary over time? Our data suggest that it varies quite substantially over time for the three different network connections (i.e., banks to sovereigns, sovereigns to banks, and sovereigns to sovereigns).¹⁰ As in

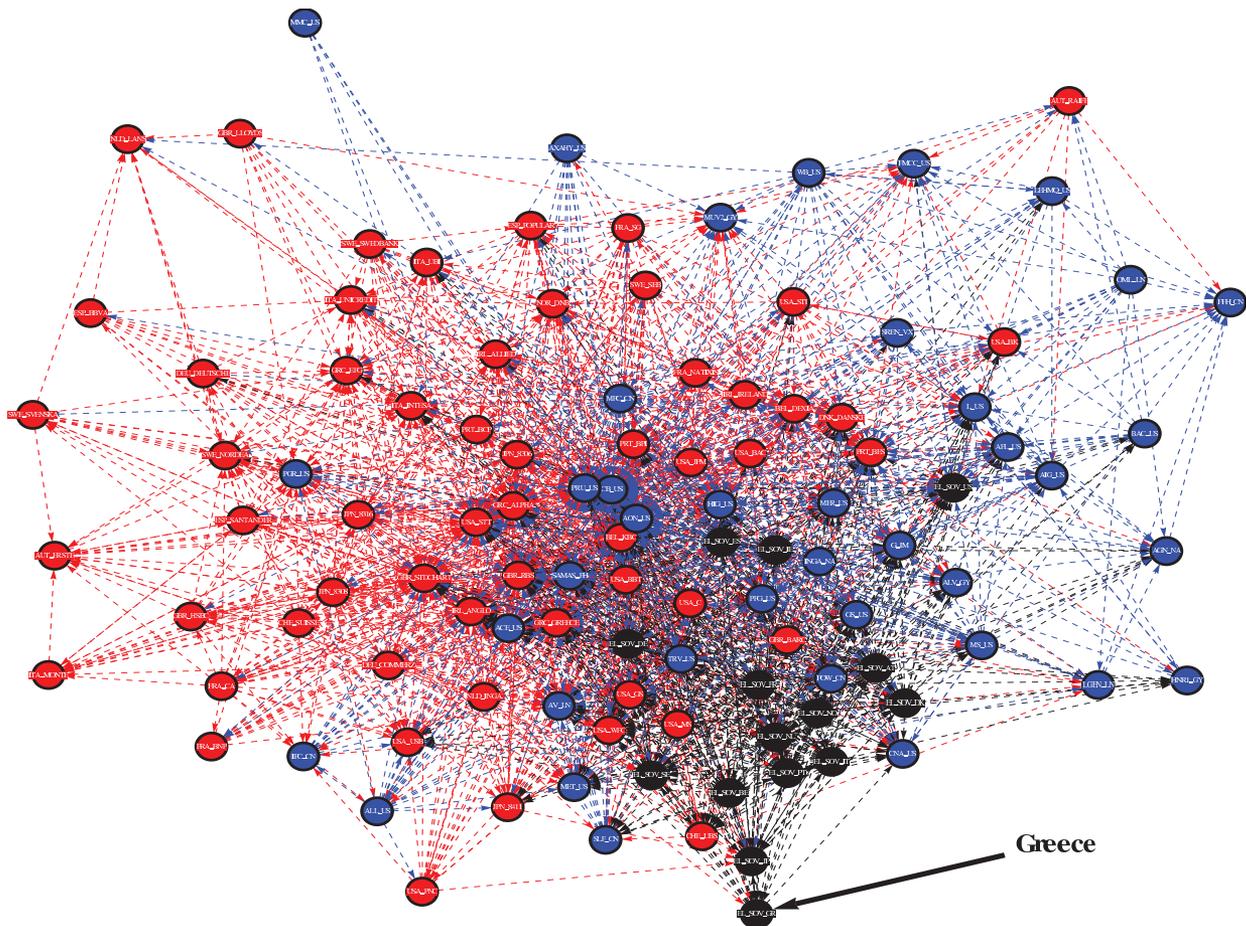
our earlier demonstration of the nonlinear nature of the risk exposures of credit, these dynamic changes in risk exposures would be expected in response to changing asset values and volatilities, either up or down.

Certainly at this early stage of our research, one should be cautious in taking these measures of connectedness as actual paths of causality among sovereigns and institutions on which revised investment decisions or corrective policy might be considered. Instead, these maps of connectedness should be viewed as raising questions about what is going on in the system that may not otherwise be transparent. Subsequent investigation using other information sources and models would then inform what, if any, steps should be taken.

Conclusion

I have discussed a structure for assessing macro-financial risk—particularly financial system credit risk and sovereign credit risk—and shown how one might go about measuring and monitoring

Figure 5. Connectedness of Sovereigns, Banks, and Insurance Companies to Greece, August 2008



Source: Billio et al. (forthcoming 2013).

the connections. The data suggest that the degree of connectedness across different types of entities changes over time—hence the need for models that capture this dynamic in order to monitor the connectedness of the system.

I began this conversation by saying that we really need an integration of monetary, fiscal, and financial stability policies rather than managing them in isolation. A case in point is the United States, where the central bank's policy has been to keep interest rates incredibly low. I am not interested in debating how much the Federal Reserve can control rates; if it cannot control rates, then of course it does not matter what it does. But if the Fed can control rates, that control coupled with quantitative easing means that it is controlling not only short rates but also long rates.

The Fed has announced plans to keep long rates low through 2014. The Fed may be keeping long rates low in the interest of stimulating consumption or increasing investment, which may be good reasons, but it is not considering the unintended consequences of keeping long rates much lower than they otherwise would be. One of those unintended consequences relates to pension fund accounting. A fair market value estimate of the amount of accrued U.S. public employee pensions that would be “underwater” if we closed them down today is enormous—over \$3 trillion, or 20% of U.S. GDP. Much of that amount is not from the pension assets having declined or even the chronic underfunding; rather, it's the result of long rates coming way down (pension liabilities rise as long-term interest rates decrease). Today, 30-year U.S. Treasury Inflation-Protected Securities are yielding only about 60–65 bps, and not too long ago, they were at 38–40 bps. Think about how many millions of dollars would be needed to generate a typical inflation-protected pension income over a long period of time.

Remember those government guarantees? In the United States, the Pension Benefit Guaranty Corporation guarantees corporate pension benefits—another one of those government guarantees not on the balance sheet. There is, however, no parallel guarantor of public employee benefits. When some of these pension plans fail, who is going to write the check? I am not saying that the Fed should not have the low-rate policy; I'm saying that it should understand that such a policy will have unintended impacts. These impacts may have been second order at one time, but they are no longer that way. We need a system that takes into account all the feedback and nonlinearity; current systems consist mostly of linear models and tell us very little about risk propagation. I have no doubt that such systems can be built.

I believe this is an important growth area for future research. We need analysts to research and guide our understanding of these systems, particularly outside the United States and other Anglo-Saxon environments.

Question and Answer Session

Robert C. Merton

Question: When central banks perform stress tests, do they take into account the nonlinear relationship between collateral and loan value?

Merton: Because I do not perform stress tests for central banks, I do not know precisely what they do. I suspect they do not. Even if they perform 10 stress tests, how many scenarios are left to consider? The answer is an uncountable number; an uncountable number minus 10 is still an uncountable number. I am not criticizing stress tests, but without a correct structure, running scenarios is very limited. The direct answer to this question is that I believe the models used are models of certainty; that is, they do not address nonlinearity. If I'm wrong, I will be very happy, but as far as I know, these stress tests do not build in uncertainty. Simply adding an error term and doing Monte Carlo simulation runs of models of certainty does not account for the structural effects of changing uncertainty along each path of those simulations. And these effects are first order. Such simulations do not take into account the fact that when the assets fall, the exposures get really big. If exposures get large, it is like being in a trade you cannot hold. If the trade gets too risky, you have to either scale it down or get out. Theoretically, if you could keep the trade on, it might work out. However, how many people have gone to the graveyard because they couldn't hold on? There's a huge amount of interest from central banks and ministries of finance around the world in the work of my coauthor, Dale Gray, who is a pioneer on this topic. They are paying attention, but at the moment, I do not believe their stress testing adequately takes uncertainty into account.

Question: Is there anything we can learn from the Long-Term Capital Management (LTCM) experience?

Merton: Do you have about two hours? I'll tell you this: I've never written or publicly said anything about LTCM except for answering questions like this one. First off, there was nothing new; that's the first part of the answer. There were lots of mistakes made, some of them unintended consequences. Everybody understood that the positions were very large. All the financing was basically term financing; none of it was overnight. That was

prudent, but it was also part of what created the panic—because the other sides could not get out. Normally, if you have overnight financing, they say pull the lines and let them go. But they could not pull them. The fact that LTCM kept terming everything out meant when they wanted to get out they could not. There are a bunch of little things like that.

The bigger thing, which is a mystery, was the solution for LTCM. If it were not for the loss of the nail—lose the nail, lose the shoe, lose the horse, lose the leader, lose the battle, lose the war—perhaps there would have been a different outcome. Warren Buffett, AIG, and Goldman Sachs made a bid for LTCM of \$4 billion. We probably would not be asking any questions about LTCM today had that been consummated. Unfortunately, the legal format in which the deal was structured made it impossible for LTCM to do it. Did we want to do it? You bet. We attempted to convey that. Where was Buffett? He was on a ship with Bill Gates in Alaska with a 1998 cell phone, which did not work. Would his lawyers change the structure of the deal without his approval? Not for \$4 billion. So, it did not happen. In the end, the consortium got LTCM for \$3.6 billion. As for those who called this a bailout, it seems to me that if Warren Buffett was willing to pay \$4 billion, then \$3.6 billion was hardly a bad deal for the consortium. Everything I report here is public; indeed, it is discussed in a recent biography of Buffett. There is no hidden story here.

What is the most important thing that happened with respect to public policy? Equity was injected into LTCM—so much so that existing equityholders were essentially wiped out. So, all the people who had control or financial interest basically lost everything—a very stiff penalty. However, keeping LTCM together preserved and contained the risk. As long as it stayed together, it was a rather modest risk. The fear was that if LTCM defaulted, then everything would come apart and suddenly what was basically a modest *net* risk would become a much larger *gross* risk. For example, a classic on-the-run/off-the-run trade is a long 29 year against a short 30 year. The variation in the difference of those two is typically something small, maybe about 4 bps. The variation of each one in isolation could be 70 bps, but when they are married, it is 4 bps. If default occurs, because the two are not held with the same entity, everybody grabs collateral; everybody ends up with 70 bps of volatility they did not want. In some sense, it is really 140 bps because they are at different institutions.

LTCM was not special: Most financial institutions are relatively hedged. I do not mean in a precise matched sense; that is not their business. But when you look at the character of their assets and liabilities, they are close; that is why they can have such high leverage. But if they split apart, even with mark-to-market collateral and all the rest, we get a very different risk profile. By injecting equity, all financing and derivative contracts are preserved and the risk is kept together and manageable.

I believe the Fed understood that reality in 1998, and I give them credit. Of course, it was not pleasant for me. It is not a lot of fun to watch everything you have disappear and not be able to do much about it, but that is life. The point is that I thought the Fed did a good job. There were no guarantees to anyone, no winks, nothing else. They just coordinated bringing a bunch of people together who did not like or trust each other and said, “You can work this out, but if you do not, it is going to be a mess.” And they did.

If there is a lesson, it is really a question. I understand that Lehman Brothers is different from LTCM and that 1998 is not 2008. To this day, however, I do not understand why the Fed did not try to do a similar thing for Lehman Brothers. I am not being critical; perhaps the Fed could not. I guess it is a way to impose discipline: Make the decision makers lose everything. The question I ask is, Do you want to bring on the havoc that goes along with that decision?

Frankly, with all due respect—and you may disagree—I do not think creditors of big banks can provide much discipline on monitoring all the risks that exist. It is difficult enough for people on the inside. That is just an opinion. Indeed, there is some question as to whether people on the inside—such as the CEO and the chief financial officer, who in principle have access to anything they want in the bank—fully understand the risks. I am not saying creditor discipline is not a good thing. I am saying that a more practical way to deal with this problem is that if you can essentially wipe out the equityholders and the management—the people making the decisions—then that is where the penalties should be. I know that is an open debate, but that is my lesson from LTCM.

This article qualifies for 0.5 CE credit.

Notes

1. Similarly, a household has operating assets plus a house as total assets, mortgage plus other loans as debt, and net worth as equity. The house is, however, the primary collateral asset for the mortgage.
2. See Merton (1974).
3. See Merton (1977) and Draghi, Giavazzi, and Merton (2004).
4. See Gray and Malone (2008).
5. See Gray, Merton, and Bodie (2006, 2007).
6. There can be exceptional circumstances in which the CDS price reflects a higher ELR than the total risk if its sovereign is in such a bad credit situation that there is a fear that the sovereign will either force the bank to buy its debt or otherwise extract value from the bank to improve its own credit circumstances.
7. The data source used for the fair value spreads in this analysis is Moody's KMV CreditEdge.
8. See Gray and Malone (2012) and Schweikhard and Tsesmelidakis (2012) for more on this concept.
9. For more information on this type of analysis, see Billio, Getmansky, Lo, and Pelizzon (2012).
10. There are many other ways to look at interconnection and feedbacks; for example, Gray, Gross, Paredes, and Sydow (forthcoming 2013) used bank, corporate, and sovereign credit risk indicators in a 17-country global vector autoregression framework that includes macro variables.

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