3 Research on Financial Stability

The sections in this chapter survey three areas that are central to the OFR's research agenda: (1) Efforts to develop indicators of threats to financial stability as tools for policymakers; (2) The use of stress tests as a macroprudential tool; and (3) Counterparty risk management, an aspect of firms' internal risk management that is particularly relevant to containing threats to financial stability.

3.1 Cataloguing Indicators and Models of Risks to Financial Stability

The OFR has a mandate to develop and maintain metrics and reporting systems for risks to financial stability. The Office's first working paper catalogued the state of the art in this field (Bisias and others, 2012). Measures proposed to-date seek to provide insights about an aspect of financial instability, generally informed by the recent crisis: for example, the tendency of asset-price bubbles to emerge, the transmission of financial shocks during a crisis, and the risks posed by rapid systemwide growth in liquidity or leverage. However, these measures tend to be limited by the public availability of data. An important goal of the OFR's work will be to identify data needed to improve these measures. This section describes 11 illustrative examples of specific risk metrics and provides evidence on what they would have shown during four prior crises.

Since the crisis, interest in measuring risks to the financial system—as opposed to risks faced by individual institutions—has grown dramatically. In general, such metrics can have three types of value for policymakers:

- **Predictive or ex ante measures** may be able to provide early warnings of a future crisis, for example, by identifying specific vulnerabilities in the structure of the system that may demand a preventive policy, or by identifying potential shocks to the financial system, such as those arising from asset price misalignments;

- **Contemporaneous measures** can alert policymakers on a real-time basis to the level of risks and vulnerabilities, for example, by identifying individual institutions that pose outsized threats to financial stability, or by helping policymakers understand events as a crisis unfolds; and,

- **Ex post measures** support forensic analysis of crises after they occur and can help supervisors in the orderly liquidation of financial institutions that have failed.

This section categorizes into four groups the financial stability measures that analysts have developed since the crisis: (1) Macroeconomic measures, (2) Measures of the vulnerability of individual firms to a shock, (3) Measures of the vulnerability of the financial system to a shock, and, (4) Measures of the interconnections among financial institutions.

We evaluate 11 specific measures as illustrative examples. Because the next financial crisis will not be identical to the last, it is crucial to understand how these models behave in a variety of conditions. To this end, we compare their performance during four historical financial crises, including the 2008 event. The selected measures represent only a small sample from a literature that has grown to hundreds of papers since the crisis.

The 11 measures may reveal structural vulnerabilities but they are less effective at providing early warnings of impending crises—similar to an automobile's speedometer, which does not predict crashes but is still a useful risk indicator. Any systemic risk measure is also limited by a reliance on realized events; false alarms and failures to alert are only identifiable after the fact. On the other hand, all of the measures illuminate some facet of a complicated system and may play a useful role in informing macroprudential policy and decisions. Analysts should use a range of measures. One of the goals of OFR research will be to develop robust software implementations of the most promising models and document their strengths, weaknesses, and appropriate range of application.

The most important lesson of this exercise is the need for better data. The first generation of systemic risk measures to emerge from the recent crisis relied, by necessity, on existing data. But today's data and information systems were not built to monitor threats to overall financial stability. Academic authors are also limited to what is publicly available; heavy use is made of market prices. Neither accounting data nor market data provide information directly on financial interconnections. Accounting respects the boundaries of the firm, and a market price is only one attribute of a transaction in which the counterparties are typically not publicly identified.

The OFR has an important role in gathering new data where necessary to improve this analysis. The OFR will also standardize such data to facilitate systemwide integration and comparisons.

3.1.1 Summary of Measures

As noted, risks to financial stability can be cyclical (particularly with respect to liquidity, leverage, and asset pricing), or structural (meaning, for example, that risky activities may be concentrated in a small number of firms). Currently available measures reflect this diversity of potential sources of threats to financial stability. We group them here into four broad categories:

(1) Macroeconomic Measures, Using Aggregate Data. These measures approach threats to financial stability from the top down: Is aggregate credit growing too fast? Are credit underwriting standards falling? Are asset prices too high relative to fundamentals? In an internal boom-bust cycle, an initial market upswing entices new investors and rising prices until additional capital or investors' nerves are exhausted (Evanoff, Kaufman, and Malliaris, 2012). This process can be amplified by capital rules that encourage banks to increase leverage when the economy is expanding and loan losses are low (Hanson, Kashyap, and Stein, 2011). In the ensuing bust, a credit crunch can occur as participants switch from lending too much to lending too little (Brunnermeier, 2009).

A selling point for some macroeconomic measures is their early-warning potential, which derives from the view that large-scale systemic imbalances should be visible in appropriately constructed aggregate measures (Alessi and Detken, 2011). For example, the Basel Committee proposed an increase in banks' capital requirements when the ratio of a country's total credit outstanding to its GDP rises above historic norms (BCBS, 2010).

(2) Measures of Firm-Level Exposures, Using Portfolio Details. These measures use granular information about individual firms' positions and portfolios to estimate cash flows at different times in the future and under varying circumstances, particularly in the complex world

of derivatives and structured products. Measures in this category include portfolio stress tests and value at risk (VaR) models that assess the losses expected on a given market position over a certain period of time, based on the historical distribution of price movements.

Forward-looking metrics that exploit detailed information about positions and portfolios can help focus regulatory scrutiny on emerging risks and exposures before they begin to appear in financial statements. For example, a put option with a large notional value that is deep out of the money may have the same present value as an option with a smaller notional value when the underlying security is trading close to the exercise price. Yet the two options have very different payoff profiles and risk implications; this fact is difficult to judge based on price alone, without access to the contractual terms and conditions that define the notional amounts and exercise prices.

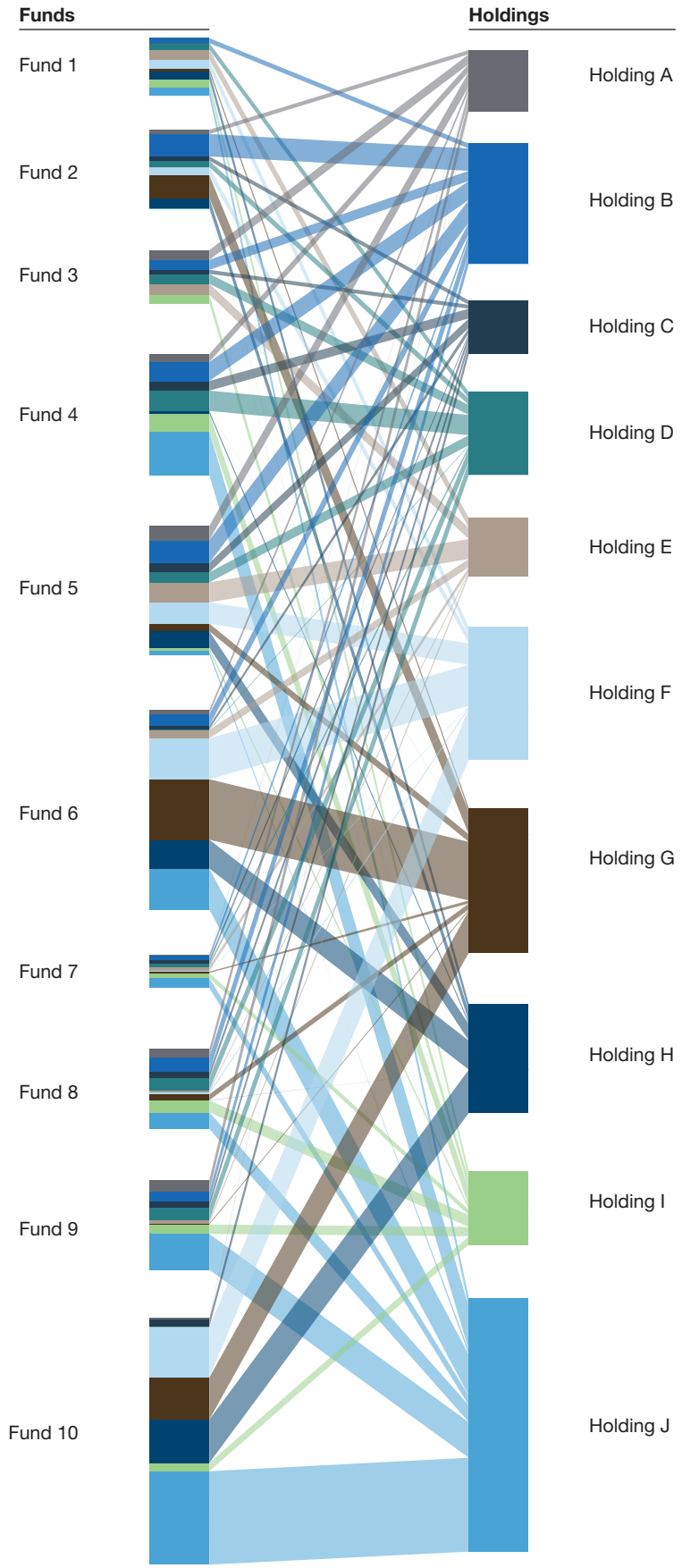
(3) Measures of Market Dynamics, Using Sensitivity Data. These measures go beyond static exposures to gauge the dynamic behavior of market participants, especially in stressful situations when liquidity may be tight.[1] For example, in a crisis, customers may withdraw deposits, and wholesale lenders may refuse to renew their funding. As market participants rush to sell assets to raise liquidity, prices may move precipitously, and the range of possible portfolio adjustments can change markedly. Leverage also magnifies the risk of insolvency.

From a systemic perspective, it is insufficient to consider only firm-by-firm maturity transformation or leverage. Excessive maturity transformation and leverage can arise from within the financial system as investors borrow to profit from rising asset prices, creating a familiar boom-bust pattern. Counterparty exposures also constrain the ability of institutions to adjust their portfolios in a crisis. Ideally, measurement of these dynamic issues would rely on a diverse array of information, including bid-ask spreads, transaction volumes, order flows, and the details of collateral, margin, and netting arrangements. However, such details are not always readily available.

(4) Measures of Interconnectedness, Using Relationship Data. These measures take a network approach to the financial system.[2] To date, these measures have had to make do with traditional data sources, inferring the underlying connections by observing co-movements in market prices. The data requirements for a fully detailed counterparty network model are potentially extensive. A key policy development related to models of interconnectedness is the requirement in the Dodd-Frank Act for large financial institutions to create resolution plans, also known as living wills. These plans must include details on firms' ownership structures, assets, liabilities, contractual obligations, cross-guarantees, collateral pledges, major counterparties, and significant credit exposures. An example of what is possible going forward appears in ***Chart 3.1.1***, which depicts the connections of the largest money market funds to the institutional issuers whose securities they hold. These data only became available in 2010 through the SEC's new Form N-MFP. They can illuminate systemic fragility by revealing which issuers might face funding liquidity issues if a given money market fund experienced a run, or which money market funds would be harmed if an issuer were to default.

These four categories are not discrete; some measures may have characteristics of more than one. They are listed roughly in order of the difficulty of data acquisition. Macroeconomic measures generally use readily available, public data; at the other extreme, the most effective measures of interconnectedness would be informed by confidential information about firms' specific positions, exposures, and counterparty relationships. ***Chart 3.1.2*** shows examples of approaches based on these categories and on the event horizon—that is, whether the value of each measure is ex ante, contemporaneous, or ex post.

Chart 3.1.1 The Money Fund Network: Top 10 Issuers and Top 10 Funds, as of January 31, 2012



Source: SEC Form N-MFP; OFR calculations

US$10 billion

Chart 3.1.2 Examples of Risk Tools by Event Horizon and Data Requirements

	Ex Ante	Contemporaneous	Ex Post
Macroeconomic Measures, Using Aggregate Data	**Macro stress testing** *Alessi and Detken, 2011* *Borio, Drehmann, and Tsatsaronis, 2012*	**Monitoring global funding risk** *Fender and McGuire, 2010*	**Accountability for macroprudential regulators** *Borio, 2010* *Caruana, 2010*
Measures of Firm-Level Exposures, Using Portfolio Details	**Traditional, firm-level stress testing** *Hirtle, Schuermann, and Stiroh, 2009*	**Credit value adjustment, Basel III liquidity rules** *Gray and Jobst, 2010*	**Orderly resolution and living wills**
Measures of Market Dynamics, Using Sensitivity Data	**Monitoring serial correlation and illiquidity** *Getmansky, Lo, and Makarov, 2004*	**Monitoring financial turbulence** *Kritzman and Li, 2010* *Kritzman and others, 2011* *Khandani and Lo, 2011*	**Addressing fire sales in mark-to-market accounting** *Laux and Leuz, 2010*
Measures of Interconnectedness, Using Relationship Data	**Network monitoring, 10x10x10** *Duffie, 2011*	**Systemic risk contributions, CoVaR** *Billio and others, 2010* *Adrian and Brunnermeier, 2011*	**Forensic analysis** *Brunnermeier, Gorton, and Krishnamurthy, 2011*

Efforts to develop these models have already provided some important insights. First, the problem of measuring threats to financial stability is strikingly multifaceted. While crises may play out in a mix of fire sales, institutional defaults, and liquidity crunches, these are typically the final chapter in a longer story. Systemic risk measures tend to focus on the various structural vulnerabilities that may lead to a crisis event, for example, complex network connections among financial institutions, information asymmetries among market participants, asset price bubbles and rapid leverage growth, concentrated or correlated risk exposures, moral hazard and too big to fail institutions, volatility, and external macroeconomic shocks. Financial stability analysts will need to follow a large number of measures. There will never be a single, "bottom-line" index covering everything we need to know.

Second, the recent crisis is a natural focus of attention but is only one data point in a longer history. Measures designed to understand this event may not work as well in others and may produce an undesirable number of false alarms if put to practical use. By applying the measures forensically to a range of historical episodes, we can learn more about both the nature of crises and the measures themselves.

Third, the financial sector and broader economy are complicated, noisy, and continuously evolving; simple aggregates cannot describe the full state of the system. The systemic risk measures described here exploit the structure of the financial system and provide a more detailed understanding of its vulnerabilities.

3.1.2 Evaluation of Measures

For this evaluation, we selected 11 measures that have been proposed by researchers and policymakers and compared their performance. While the analysis is in its early stages and conclusions are preliminary, we can draw some initial lessons. The OFR will publish more detailed analyses, including software implementations, as that research is completed.[3]

The systemic risk measures analyzed are:

- Five **macroeconomic measures:** a set of *financial stress indexes (FSIs),* which use financial market prices to evaluate the level of stress in the financial system at a point in time, and a *GDP stress test*, which tracks large deviations of realized GDP from the forecast level.

- Four measures of **systemic vulnerability:** a *financial turbulence* measure, which measures deviations of stock returns from their joint historical patterns of behavior; an *absorption ratio*, which simplifies the analysis of co-movements in the stock price performance of different financial institutions; and two measures of *market depth*, which estimate the ability of a market to absorb large buy or sell orders without affecting the price quoted for subsequent trades.

- Two indirect measures of **interconnectedness:** the *Conditional Value at Risk (CoVaR)* measure, which estimates the risk to the system posed by individual institutions that have a large market footprint, and the *systemic expected shortfall (SES),* which measures an individual firm's tendency to be undercapitalized during episodes when the financial system overall is undercapitalized.

Every financial crisis has unique causes, yet most current crisis measures, including some of those considered here, were first estimated with the 2008 event in mind. By testing these measures against a range of historical events, we aim to glean some understanding of their sensitivities, forecasting power, reliability, and recommended domain of application.

We analyze each of these measures in four systemic episodes: (1) The 1929 stock market crash that marked the start of the Great Depression; (2) The 1987 stock market crash, an extraordinary shock that had little impact on the economy or financial stability; (3) The 1998 Russian bond default, which contributed to the failure of Long Term Capital Management (LTCM), a large hedge fund, through network connections; and (4) The 2007–2009 crisis, which was marked by excessive leverage, poor underwriting, asymmetric information, network complexity, liquidity crunches, and fire sales.

Chart 3.1.3 shows the results. ***Chart 3.1.4*** summarizes our evaluation of the individual measures, which are described in greater detail below.

Macroeconomic Measures: FSIs

We first consider the financial stress indexes produced by several Federal Reserve Banks, outlined in ***Chart 3.1.5***. These measures have several advantages. First, they measure financial markets directly, rather than extrapolating from GDP forecasts. With the exception of the National Financial Conditions Index, they are derived exclusively from financial market prices. Second, they are higher frequency (daily, weekly or monthly, rather than quarterly), thus providing a more timely signal. Even a few extra days' head start may be enormously valuable in the context of crisis intervention by policymakers.

Developers of FSIs sometimes claim these tools can provide early warnings of financial disruptions. For example, the Cleveland FSI was "flashing red" prior to the Bear Stearns failure in March 2008. The FSIs clearly detected the 1998 and 1987 events. However, even under the best of circumstances, the FSIs cannot be a panacea because they measure the system at an aggregate level. Considerable additional information would be needed to pinpoint the sources of financial stress and to move from an

FSI warning to interventions in specific markets and institutions.

Macroeconomic Measures: GDP Stress Tests

Economy-wide aggregates have two clear advantages. First, many macroeconomic time series are available internationally. Second, while some subtleties are lost in aggregation, systemically threatening imbalances are likely to be large enough to emerge in aggregate data. For that reason, these measures could serve a valuable early warning function.

The aggregate measure we consider is based loosely on the GDP stress test of Alfaro and Drehmann (2009), which seeks to identify large deviations of realized GDP from the forecast level. We consider these GDP surprises as a potential crisis monitoring tool. But there are several reasons not to be hopeful. First, Alfaro and Drehmann note the strong reverse causality as the effects of financial crises feed back to disrupt the real economy. It may be easier to forecast a recession after seeing a financial crisis than to predict a financial crisis after seeing a recession. Second, forecasters typically do not set out to project financial crises at all; rather, they more commonly forecast the mean future level of GDP. Third, forecasting macroeconomic activity—especially turning points such as a financial crisis—is notoriously difficult. For example, in June 2008, after the Bear Stearns failure and just before the failures of Fannie Mae, Freddie Mac and Lehman Brothers, the Federal Reserve's econometric models projected real 2009 GDP growth between 2.0 and 2.8 percent (FOMC, 2008) while the realized value for 2009 turned out to be negative 3.5 percent (BEA, 2012).

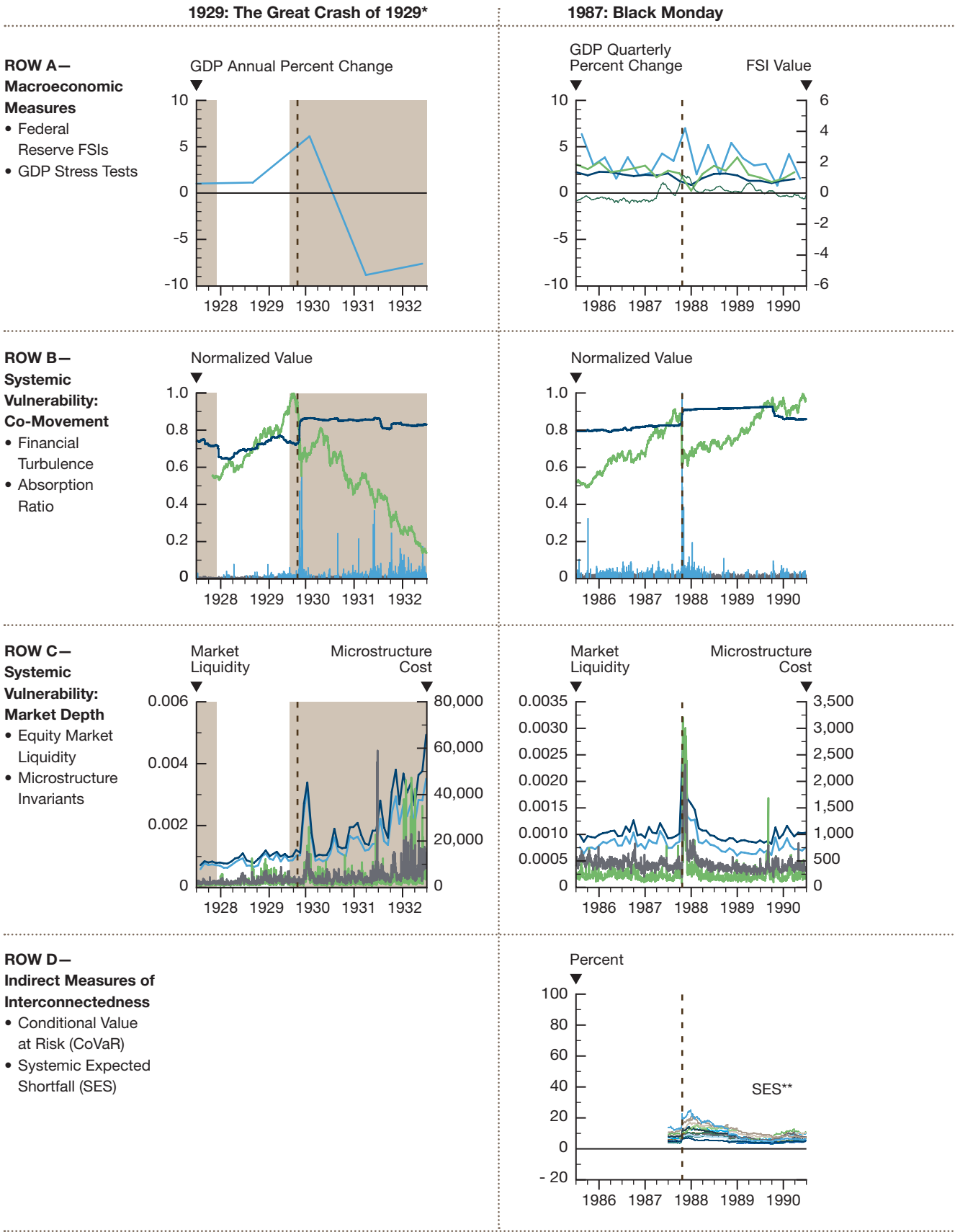
The first row of ***Chart 3.1.3*** compares GDP growth forecasts by professional forecasters with actual GDP growth for the three most recent financial crises. Alfaro and Drehmann average forecast data across 43 crises over many years. Because macroprudential monitors will not have the noise-reducing benefits of averaging over events, we consider only one country and episode at a time. Professional forecasters under-predicted GDP growth before the arrival of recession late in the 1987 and 1998 episodes. Notably, these both turned out to be largely financial-sector events, with little fallout for the real economy, so it is reasonable that forecasters might not predict real-sector implications. For September 2008, forecasts were more accurate leading up to the crisis, but both the timing and magnitude of the GDP shock surprised forecasters, even though the National Bureau of Economic Research would later backdate the start of the recession to the beginning of 2008. The data are much rougher for 1929—professional forecasts are unavailable and, since GDP itself had not yet been defined, GDP has been imputed as an annual number after the fact. With these caveats, we see very high GDP growth in 1929, followed by a sharp collapse in 1930. With hindsight, it is easy for us now to interpret this growth as a reflection of imbalances building up in an overheating economy.

Overall, repurposing GDP forecasts to serve as a financial stability indicator is probably the wrong tool for the job. The same aggregation and averaging that reduces noise, eliminates too much of the nuance and detail necessary for macroprudential risk management. More granular measures are required.

Systemic Vulnerability: Financial Turbulence

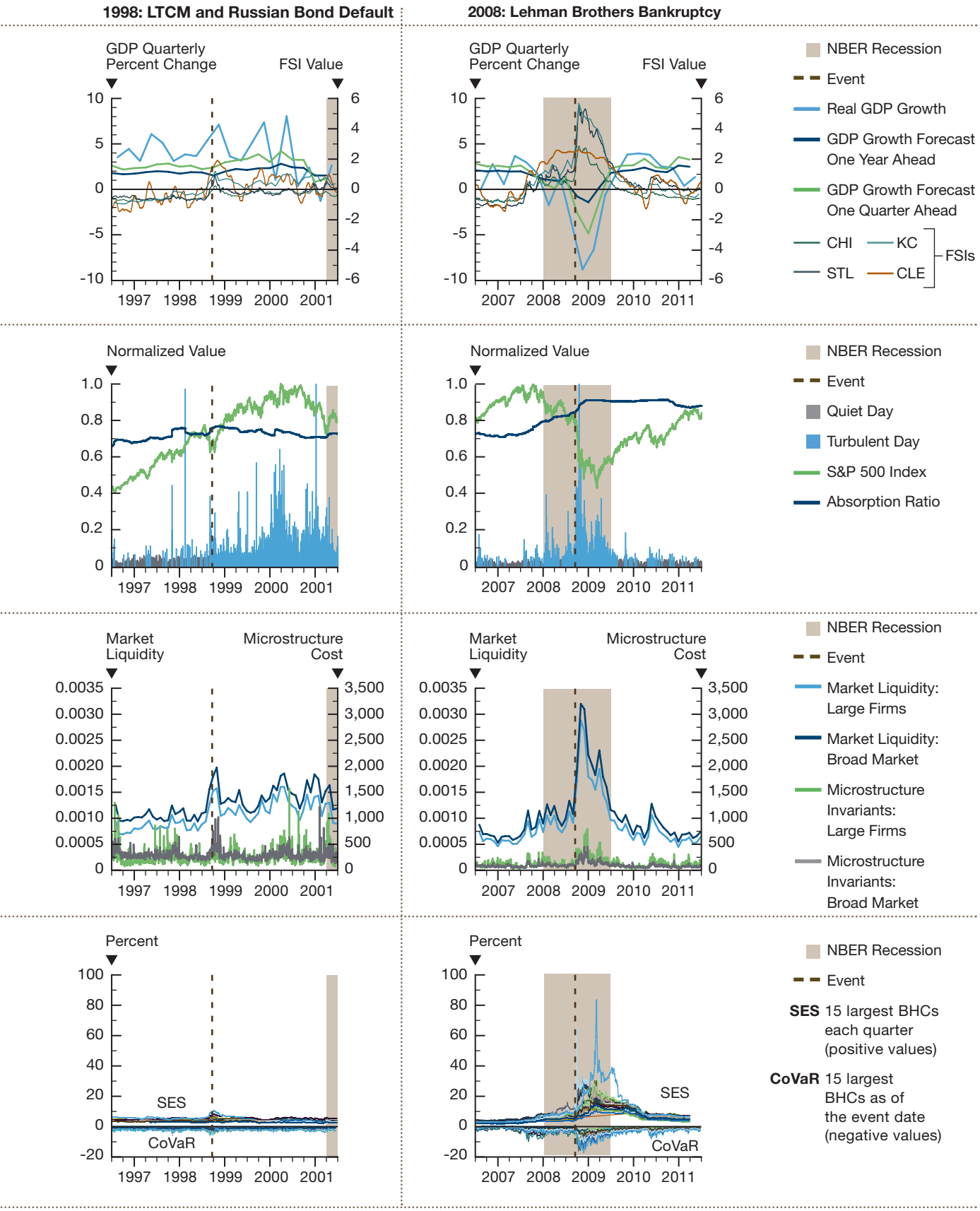
The "financial turbulence" measure defined by Kritzman and Li (2010) seeks to identify extraordinary market moves. Specifically, they look for highly unusual combinations of daily asset class returns. When this method is used, simultaneous "big movers" are more likely than isolated outliers to cause a given trading month to register as "turbulent." The blue and gray bars in the charts in the second row of ***Chart 3.1.3*** show the results for monthly returns on a diverse set of domestic and international indexes of stocks, bonds, and commodities. With the confidence interval set at 75 percent, approximately 25 percent of the bars represent turbulent months. There is a clustering of turbulence around the crisis date. The limited evidence in the figures suggests that this measure

Chart 3.1.3 Behavior of the Measures in Four Crises



** Notes for 1929: Row A: GDP growth is an imputed rearcast. Row B: a full set of 10 Standard Industrial Classification categories was unavailable. Row C: note the difference in scales.*

***BHC leverage data unavailable prior to Q3 1986.*



Sources: Letters [A, B, C, D] indicate table row: Maddison (2003) [A]; Federal Reserve Bank of Chicago [A,D]; Federal Reserve Bank of Cleveland [A]; Federal Reserve Bank of Kansas City [A]; Federal Reserve Bank of Philadelphia [A]; Federal Reserve Bank of St. Louis [A,B,C,D]; CRSP [B,C,D]; Bloomberg [B,D]

Chart 3.1.4 Evaluation of the Measures

		Description	Evaluation of the Model Output
Macroeconomic Measures	Federal Reserve Financial Stress Indexes (FSIs)	Intended to measure accumulating "stress" in the financial system, these are often put forward as early warning indicators of financial crises.	Calculation frequency varies across the FSIs, from daily (Cleveland Fed) to monthly (Kansas City Fed); daily observations are more conducive to contemporaneous monitoring. Actual crises tend to be much rarer than the stresses identified by the FSIs, so there is a tendency to over-predict.
	GDP Stress Tests	Macro aggregates can reveal system-level imbalances. Original study emphasizes that actual crises tend to be much more severe than plausible ex ante forecasts.	Original study averaged the measures across a range of historical crisis events; this is not possible for ongoing monitoring. GDP observations are quarterly, making real-time monitoring difficult.
Systemic Vulnerability: Co-movement	Financial Turbulence	Daily indicator of unusually turbulent episodes in market prices, emphasizing simultaneous large moves in multiple markets.	Exhibits clustering of turbulence over time. Not promising as an early warning measure, but may be useful for contemporaneous monitoring.
	Absorption Ratio (AR)	A measure of co-movement in market prices. Unlike correlation, which tracks co-movement between bilateral pairings, AR tracks aggregate co-movement in a full system of return series.	Based on our analysis of four events, AR tends to drift upward ahead of the crisis and then jump abruptly on the event date, persisting at the new higher level afterward.
Systemic Vulnerability: Market Depth	Equity Market Liquidity	A measure of the stock market's ability to absorb large one-sided order flow without a large impact on prices. This measure is estimated on a monthly basis.	Price impacts of large orders increase in crises. The magnitude of price impact also varies markedly across crises.
	Microstructure Invariants	A higher frequency measure of the price impact of large order flows. Posits a statistical rule for price impact that works across markets and time.	The magnitude of price impact varies strongly across crises. Moving to daily data increases volatility and heavy tails of the measure, with occasional one-day spikes.
Indirect Measures of Inter-connectedness	Conditional Value at Risk (CoVaR)	A measure of distress afflicting a bank and the system simultaneously. Offered as an indirect measure of interconnectedness.	Relies on public equity returns data on bank stocks and therefore on market perceptions of actual risks. Highly sensitive in 2008 but comparatively non-responsive in 1998, which involved banks less directly.
	Systemic Expected Shortfall (SES)	A measure of the propensity of a bank to be undercapitalized when the system as a whole is undercapitalized.	Like CoVaR, relies on bank stock return data, but incorporates leverage more explicitly. SES is sensitive to the 2008 event and relatively insensitive to 1998 and 1987.

Chart 3.1.5 Federal Reserve Bank Financial Stress Indexes (FSIs)

Measure	Description	References
St. Louis Financial Stress Index (STLFSI)	First principal component in a set of 18 weekly financial time series derived from market prices	Federal Reserve Bank of St. Louis, 2010
Cleveland Financial Stress Index (CFSI)	Daily weighted average of 11 financial time series derived from market prices	Oet and others, 2011 Bianco, Oet, and Ong, 2012
Kansas City Financial Stress Index (KCFSI)	First principal component in a set of 11 monthly financial time series derived from market prices	Hakkio and Keeton, 2009
National Financial Conditions Index (NFCI)	Weekly weighted average of 100 measures of financial activity	Federal Reserve Bank of Chicago, 2012

would be weak as an early warning tool but may be valuable in contemporaneous monitoring.

Systemic Vulnerability: Absorption Ratio

It is widely recognized that correlations between returns tend to spike during financial crises as market participants respond in concert to unusually large common shocks. This behavior can be amplified if one firm's forced liquidation of positions depresses asset prices, provoking mark-to-market margin calls that affect market participants more generally. From a modeling perspective, bilateral correlation measures the co-movement among a pair of return series; the absorption ratio (AR) of Kritzman and others (2011) essentially collapses the matrix of bilateral correlations down to a single measure of the more general co-movement of returns. The AR is the proportion of the variance in the system explained or "absorbed" by a fixed number of factors. A higher AR reveals more tightly coupled markets, suggesting that shocks may propagate through the system more quickly. For the 1998 crisis, in which tight coupling of other markets to the Russian bond market caught LTCM by surprise, there was a gradual increase in the AR before the event and a gradual decrease after. Similarly, the AR rose gradually up to September 2008 but then jumped abruptly by more than 10 percent and remained elevated for two years. There was a similar pattern in 1929. Although the sample of four crises is small, the tendency for the AR to rise in advance of a crisis event suggests some promise as an early warning measure.

Systemic Vulnerability: Market Depth

Market depth metrics measure the liquidity of a marketplace, as opposed to the liquidity of a firm or portfolio, by estimating the ability of a market to absorb one-sided order flow (buying or selling) without affecting the price quoted for subsequent trades. The measures we consider here relate back to Kyle's (1985) "lambda," which measures the trading volume required to move the price of a security by one dollar. Khandani and Lo (2011) measure equity market liquidity by calculating a linear regression of daily returns on the product of price and volume, which are then averaged across a cross-section of firms to calculate marketwide lambda. Kyle and Obizhaeva (2011) adjust the data to account for the higher order arrival rates that typically characterize fast-moving markets. Their metric is microstructure invariant, meaning that the method works for a variety of asset classes, not just equities, and over a variety of historical episodes. Market depth is relatively easy to implement because it can be updated using daily or intraday data on prices and volumes.

The third row of ***Chart 3.1.3*** presents these measures applied to U.S. stock prices for all four historical episodes. For each crisis episode, we run both measures on two subsamples of the full universe of daily returns from the Center for Research in Security Prices (CRSP): the largest 5 percent of firms (by market capitalization) and the largest 20 percent of firms. The stocks of larger firms are more liquid—that is, they show less price impact on any given date. The two measures track each other closely. The equity market liquidity metric is monthly because the lambdas are estimated from monthly regressions. The microstructure invariant metric is presented as a daily time series to illustrate the fundamental tension between signals (significant shocks or other market phenomena) and noise (occasional statistical flukes in the data). Distinguishing signals from noise is likely to be difficult for traditional linear statistical models. Although we present the measures as applied to the overall stock market, they can be applied to other asset classes and narrower market segments. Overall, these metrics demonstrate the benefits from tailoring measurement to more granular details of individual securities and markets, and focusing on a narrow risk type, in this case liquidity.

Interconnectedness: CoVaR and SES

CoVaR and SES attempt to measure the connection of individual firms to the larger financial system. As such, they measure interconnectedness. However, lacking direct observation of the individual exposures that create these connections, both use forms of correlation in traded equity prices as an indirect measure. Because they are driven by market prices, both measures can be updated day to day and minute to minute, which has obvious advantages in a crisis.

Value at risk (VaR) measures the smallest expected loss on a portfolio for a given time horizon and confidence level. Adrian and Brunnermeier (2011) propose to extend the VaR methodology to measure a firm's *conditional* value at risk (CoVaR), defined as the VaR of the financial system as a whole, conditional on the firm in question being in distress. The institution's contribution to systemic risk is in turn defined as the difference between its CoVaR conditional on being in distress and its CoVaR in more "normal" times. CoVaR can indicate risks posed by large, complex financial institutions, as well as by smaller institutions acting in concert.

Systemic expected shortfall represents the propensity of a financial institution to be undercapitalized when the system as a whole is undercapitalized (Acharya and others, 2010). But SES is a theoretical construct that cannot be measured directly; researchers must use proxies. One proposed proxy for SES uses the decline in equity valuations of large financial firms during a crisis, as measured by their cumulative equity returns. Leading indicators of SES, such as leverage, can then track ex ante risk.

A comparison of the 1998 and 2008 events is instructive. Both measures register much more weakly for 1998, reflecting the fact that banks and their leverage were less centrally involved. SES is similarly insensitive for 1987. This underscores that different measures highlight different facets of the system and that some recently proposed measures have been calibrated especially to improve our understanding of the 2008 crisis.

Both CoVaR and SES illustrate the information limitations that afflict most of the first-generation systemic risk measures to appear since 2008. Reliance on market prices in a crisis situation is likely to create false alarms (as well as alarms that fail to sound), because market valuations can be contaminated by fire sale effects, spiking uncertainty and risk aversion, and valuation models that were not calibrated for crisis environments. Ultimately, market-based measures must be supplemented with other measures, including direct measures of interconnectedness based on the position and transaction data that the OFR and other FSOC agencies are beginning to assemble.

Data availability also limits our ability to test these models out of sample by applying them to earlier crises. For example, many of the variables used as controls in the Adrian and Brunnermeier (2011) CoVaR estimation did not exist in the 1980s. Where feasible, efforts should be made to fill these historical gaps, for example, by identifying and collecting a historical database of robust control variables to support CoVaR estimation.

3.1.3 Conclusions

The measures evaluated here represent the first generation of financial stability models to emerge since the recent crisis. As such, they show what is possible with legacy information and technology resources available to scholars and policymakers. These legacy data collections rely heavily on market prices, especially equity prices, and firm-level accounting data. Notably lacking are data from over-the-counter markets such as swaps, bonds, and structured products. Also lacking are direct measures of the insurance industry, which is an important locus of contingent exposures. These gaps underscore once again the need for a more comprehensive picture of the financial system. The failure of supervisors to foresee the 2007–2009 crisis, despite an elaborate combination of aggregate analysis, regular examinations, and continuous monitoring at the largest commercial and investment banks, illustrates the need for further investment and research to improve the information sources that they have available to monitor financial stability.

For example, leverage can be a key factor in crisis dynamics. Traditional accounting gives us a measure of firm-level leverage, and the Basel capital standards have made this a focal point of banking regulation. Unfortunately, traditional capital is not well suited for buffering against concentrated contingent exposures, which continue to expand through the growth in derivatives markets and the structuring and fragmentation of contractual exposures. Stress testing can be one way to assess contingent exposures. Ultimately, proper understanding of contingent exposures requires additional details about specific positions and contractual terms that can have a significant impact on net cash flows.

The OFR is well positioned to advance the state of the art in financial stability metrics because of its mandate to track the fragility of the financial system. In part, this mandate motivates our focus on identifying legal entities and the connections between them as necessary building blocks to understanding the financial system as something greater than a simple aggregation of individual institutions.

A key focus of the OFR's research will be to identify data needed to improve the value of measures of threats to financial stability, and to collect them if they are not otherwise available. Such data could, for example, make use of more granular, albeit confidential, information about the credit exposures that large financial firms have to each other.[4] In collecting data to support systemic risk metrics, the OFR will seek to minimize duplication and the burden or cost to the private sector.

3.2 Stress Testing as a Macroprudential Tool

The Dodd-Frank Act requires the OFR to "evaluate and report on stress tests or other stability-related evaluations of financial entities overseen by the [Council] member agencies." To fulfill this role, the Office can: (1) Help to ensure that the necessary data are available; (2) Help to advance the state-of-the-art in stress test methodologies to move from a microprudential to a macroprudential approach; and (3) Contribute to the development and evaluation of quantitative tools that are used to analyze how a stress scenario will affect the financial system.

Stress tests can provide valuable insights into the vulnerabilities and resilience of financial institutions, markets, and even the financial system as a whole. Recent supervisory stress tests have helped supervisors and firms evaluate and improve the adequacy of capital and the quality of risk management processes at individual institutions. For that reason, stress testing has become a valuable microprudential tool.

Macroprudential stress tests should go beyond the scope of microprudential supervisory analysis. They should aim to determine whether the financial system as a whole has the balance sheet capacity to support a normal path of economic activity. Such tests should focus not just on capital adequacy to buffer loan losses, but also on the individual and collective ability of large, complex financial institutions to fund their activities under stress. A key goal is to develop tools that will help avoid runs in wholesale funding markets and fire sales on securities, which could promote a credit crunch and disrupt the economy.

To be sure, the results of supervisory stress tests have been aggregated to serve a macroprudential purpose. For example, the Supervisory Capital Assessment Program (SCAP) subjected the nation's largest banks—accounting for the majority of lending and market-making activities—to identical shocks. These results were used in the spring of 2009 to gauge the capital buffers needed to keep banks well capitalized and able to lend across a range of economic scenarios, including adverse scenarios. Complemented by government backstops like the Temporary Liquidity Guarantee Program implemented in the fall of 2008, the SCAP helped backstop the stability of the system. The program aimed to reduce uncertainty among investors regarding future losses and capital needs and thereby to help improve the banking system's access to private capital. The program also added to the market's understanding of the potential risks to financial stability that could be transmitted through these banks (Board of Governors, 2009).

However, such an approach, while useful, was not completely macroprudential. An important challenge going forward will be to increase the macroprudential value of supervisory stress testing by, for example, incorporating feedback from the financial system to the economy and enhancing the models to allow for runs and fire sales. Ultimately, a macroprudential stress test would ask whether the system as a whole has the capital and liquidity to support lending and to be resilient to shocks.

3.2.1 Macroprudential Objectives of Stress Testing

Typically, microprudential goals for stress testing are defined for individual institutions in isolation, whereas macroprudential goals are defined based on the effects of distress in institutions and markets on each other, as well as on the system as a whole. For example, from a macroprudential standpoint, banks have to be sufficiently capitalized to avoid significantly contributing to contagion from a shock. This may entail higher capital than is necessary for the bank when considered on a stand-alone basis.[5]

Macroprudential stress scenarios should consider both sides of the balance sheet—both assets and liabilities—and take into account the possibility of fire sales. And, because fire sales are liquidity-induced, liquidity rules should be

added to capital requirements as part of the overall framework of macroprudential oversight.

The design and objectives of stress tests vary based on the roles of the entities applying the tests. Financial firms have used stress tests since the late 1980s to evaluate the risk of losses in their trading operations; in many cases, the risk of complex trading positions can be illuminated only by applying discrete shocks to specific risk factors. The widespread losses following the 1998 Russian debt crisis led to a marked increase in firms' use of stress tests to evaluate more comprehensively their exposures to specific shocks.

Financial supervisors have also increasingly used stress tests to evaluate capital sufficiency and risk management practices at individual firms. In some cases, they have looked at the aggregation of those individual stress test results to gain an understanding of the vulnerabilities of the financial system as a whole. In particular, the results generated by institution-specific stress testing, in combination with the scenarios themselves, can be used to generate inferences regarding the way risks are amplified through links between entities in the financial system and how they propagate through the network via feedback cycles.

Stress tests can provide the following benefits to macroprudential supervision, listed in approximate order from the most easily accomplished to the most difficult:

Create an analytical framework for assessing threats to financial stability. Stress tests can help provide a common understanding about issues related to financial stability by bringing together the various stakeholders—macroeconomists, market and credit risk managers, and prudential supervisors.

Develop policy tools. Stress tests can help policymakers gauge the effects of potential policy actions on the financial system.

Identify vulnerabilities and evaluate crisis management and resolution tools. Stress tests can provide policymakers with insights about the likelihood and form of potential crises so that they can consider alternative responses in advance of an actual event.

Serve as an early warning system. Stress tests can add to the identification of vulnerabilities the anticipation of shocks that might occur, a task that in itself is fraught with uncertainty, and is made more complex because the policy and market responses cannot always be anticipated.

3.2.2 Elements of Traditional Stress Tests

Analogous to the practice in engineering, a stress test generally starts with identifying a set of risk factors to be stressed and developing the scenario of shocks to be applied to those factors. The selection of risk factors partly depends on the objective of the stress test. For financial firms, stresses are applied to loan defaults and market factors such as interest rates, equity prices, and credit spreads. In the case of microprudential supervision, in which supervisors are concerned about an institution's ability to withstand adverse macroeconomic conditions, the risk factors tend to be macroeconomic variables related to an economic downturn, such as GDP, housing and commercial real estate prices, consumer spending, and unemployment, as well as certain financial variables such as equities, currency rates, and interest rates.[6] When it comes to macroprudential supervision, which relates to the broader financial system, supervisors are likely to focus on market factors, such as interest rates and equity prices, and on factors that reflect the condition of the institutions such as counterparty risk, leverage, liquidity, and net capital.

Once a comprehensive set of risk factors is identified, the stress test proceeds to shock these factors based on a stress scenario that hypothesizes a large change in their value that might contribute to an adverse or even catastrophic event. Thus, a stress scenario is

not representative of an expected path for the economy or the financial system but rather is a thought experiment, an exercise intended to depict events that are improbable but plausible.

The selection of shocks is only a first step in the stress test. The shocks must be tied to a model of how the shocks feed through to the markets and the financial institutions of concern. For a firm-specific stress test, shocks generate implications for capital requirements, funding sources, and patterns of customer activity in the entities being tested. For a stress test of the overall financial system, shocks simulate outcomes for the entire network of institutions. For a macroeconomic stress test, the model should delve into real economic effects, for example, on capital formation, credit extension, and consumption.

3.2.3 Limitations of Traditional Stress Tests

Two key limitations of traditional stress tests are: (1) The models don't capture fire sales or runs, so the shocks required to produce scenarios with realistically fat tails—aberrations from historical patterns—are unrealistically large, and (2) The shocks themselves are external to the financial system. In turn, external shocks by design mean that the exercise cannot capture the buildup of internal threats to financial stability or feedback loops such as the feedback from losses to balance sheet shrinkage to reduced credit availability. To be sure, stress tests do not answer every question a macroprudential supervisor might have. Federal Reserve Governor Daniel Tarullo noted recently that "stress testing is no more a panacea for the supervision of large financial institutions than capital requirements themselves, or any other regulatory device. By design, the stress tests to date have not covered other sources of stress, such as funding and interest rate risks, which are the subjects of other supervisory exercises." (Tarullo, 2012).

However narrow or broad the objective of a stress test, its quality depends on the definition of stress scenarios. A commonly used approach in specifying scenarios is to draw on historical episodes. Scenarios might simply replicate historical events or they might be expressed as multiples of standard deviations from a historical distribution. History can provide some insights about the market environment during a crisis because most crises have the same directional effects on the critical risk factors and asset classes. For example, crises tend to include a flight to both quality and liquidity in which equity prices drop, credit spreads widen, short-term rates increase, volatility increases, and correlations among similar assets increase.

But, as implied above, there are limitations to relying on historical scenarios. The world changes both in terms of market structure and regulation, so no past event is likely to repeat itself. Any number of changes in risk factors can be applied in stress tests, but the ones that are relevant after the fact might be considered implausible before the fact. Economic relationships change during times of stress: an unexpected shock creates dynamic behavior among diverse market participants, comparable to what is observed with traffic jams or the panic of crowds, and shocks can have a complex and hard-to-predict impact on pre-existing vulnerabilities in the financial system, such as excessive leverage or funding fragility. While modelers tend to think of a crisis as just a bad draw or a fat-tailed event, an alternative view would consider whether a model that relies only on historical events is appropriate.

Financial innovations complicate the task of designing stress tests. To project the complexities of the 2008 crisis, for example, a modeler would have had to fully identify the interconnectedness and risk of contagion caused by new financial products such as credit derivatives, structured credit products, and certain types of short-term funding, particularly repos and asset-backed commercial paper backed by nontraditional assets. However, the prevailing view prior to the crisis was that these innovations were strictly beneficial to the financial system, promoting market liquidity and shifting risk to entities that were better able and willing to bear it. The temptation to

argue that "this time is different" is especially strong during times of extensive financial innovation because financial innovation often holds out the promise of a much better management of risks. Any argument to the contrary is hard to justify because little historical data exists for new products, and if an innovation grows rapidly enough to pose a threat to the system, it almost certainly has been performing well. So innovations can mask critical financial vulnerabilities.

For these reasons, the design of stress test scenarios has understandably been subject to some fundamental rethinking since the 2008 crisis and has moved away from an historical approach. With the benefit of hindsight, it is clear that stress tests prior to 2008 did not anticipate the extreme shocks that occurred during the crisis, failed to shed light on some of the sectors and risk factors that were instrumental in the development of the crisis, and ignored the dynamics among the sectors that were ultimately affected.[7] The boxes accompanying this section explore agent-based models (ABMs), which provide a methodology to address the dynamic nature of financial crises ***(Box C: Using Agent-Based Models to Analyze Threats to Financial Stability)***, and reverse stress tests, which provide an alternative to historical scenarios ***(Box D: Reverse Stress Testing)***.

More fundamentally, the crisis has promoted a reevaluation of the models used to conduct stress tests, reflecting three considerations discussed above. First, models that allow for default, fire sales, and runs are needed. Second, on a related note, models that capture the internal buildup of risks in the financial system are much more likely to help policymakers understand the tail risks and vulnerabilities in the system in response to the external shocks imposed on it in stress tests. Finally, models that capture the cross-sectional or structural vulnerabilities and that look at the interconnectedness of institutions and markets are much more likely to reveal the effects of those shocks on the financial system as a whole (Greenlaw and others, 2012).

3.2.4 The Evolution of Supervisory Stress Tests

Supervisory stress tests have three components: (1) A specification of the stress scenario, including both macroeconomic and financial market disruptions; (2) An analysis of the impacts of the stress scenario on earnings, capital, and liquidity of individual financial institutions and the financial system overall; and, (3) A supervisory follow-up, which can include public disclosure of the results; requirements that firms raise capital, improve their capital or risk management practices, or adjust their business models; and potentially other supervisory actions.

In the U.S., supervisory stress testing began with the Federal Housing Enterprises Financial Safety and Soundness Act of 1992, which required the regulator of the government-sponsored enterprises (GSEs) to employ a risk-based capital test to determine the capital required in the event of specified shocks to property values, credit losses, and interest rates; however, the regulator was not allowed under the legislation to vary the details of the stress events, limiting the usefulness of the exercise. The Basel II Accord of 2004, though not giving an explicit definition of stress testing, required banks to perform stress tests for credit risk, market risk, and liquidity risk.[8] Here the objective remained microprudential: to encourage sound risk management practices.

The Federal Reserve's SCAP exercise in 2009 used stress testing as a tool to determine capital sufficiency during a crisis, as opposed to evaluating the financial landscape during stable times. The Federal Reserve followed up with the Comprehensive Capital Analysis and Review (CCAR) program that uses stress tests as a tool to help evaluate, improve, and give a forward-looking perspective into the internal capital planning processes for large, complex bank holding companies. Similar programs are employed by the International Monetary Fund (IMF), which uses stress tests in a menu of approaches to examine the soundness of banks and the financial sector in its Financial Sector

BOX C. USING AGENT-BASED MODELS TO ANALYZE THREATS TO FINANCIAL STABILITY

Scientists use agent-based models (ABMs) to explain how the behaviors of individual agents can affect outcomes in complex systems such as the emergence of traffic jams, the patterns of flocks of birds in flight, and the spread of epidemics. These concepts may also improve the modeling of financial stability.

Traditional economic and financial models share certain weaknesses: they take a top-down approach, they assume market participants are homogeneous, and they are guided by history. For example, two traditional risk management techniques, value at risk (VaR) and stress testing, estimate potential losses by replicating historical events or by expressing extreme "tail events" based on an historical pattern. Typical economic models assume equilibrium in supply and demand for specific assets based on the expected behaviors of individuals in markets during normal, non-crisis periods; importantly, they assume representative homogeneous individuals who operate rationally.

But traditional models miss critical points about financial crises. Crises tend to emerge from the unleashing of a new dynamic when economic relationships among individuals can change in diverse and complex ways. Historical patterns are not always relevant, and individuals are heterogeneous.

To address these characteristics, an agent-based model analyzes the actions of autonomous agents to predict the "macro" behavior of the system as a whole.

ABMs specify rules that dictate how individual agents will act based on various factors. The rules can vary from one agent to the next and can allow for less-than-optimal behavior. Once the model has specified the initial conditions and the agents' rules, the "world" is let loose and the subsequent events are driven by interactions among agents. The agents are free to act within their computational world, just as their counterparts do in the real world.

Economists have begun to use ABMs to explain components of the financial system based on the expected behavior of diverse market participants. Gilbert, Hawksworth, and Swinney (2009) use an ABM to investigate shocks in the English housing market by simulating interactions among buyers, realtors, and sellers. Thurner (2011) uses an ABM to explore how excessive leverage can both emerge and dissipate within a financial system. In a boom, individual banks may lend with declining collateral requirements (that is, at higher and higher leverage) as they feel safer about asset valuations; in a bust, as banks get more nervous about rising uncertainty in the world, they may stiffen their collateral requirements, reducing leverage. Rarely are banks able to take into account that they all may be behaving similarly and that, as a result, they could actually create the catastrophe they are each trying to avoid.

The Bank of England pioneered the use of ABMs to analyze payment systems, which handle billions of transactions every day and can pose serious threats to financial stability if they break down (Galbiati and Soramäki,

2008). The Bank of Italy introduced an ABM in which banks operating in the midst of a crisis are unable to perform operations such as payments and interbank loan requests over a given timeframe (Arciero and others, 2009).

The characteristics of an ABM directed toward threats to financial stability might include:

Key Agents. The key agents for analyzing threats to financial stability are those that provide funding, those on the other side that use leverage, and those that provide liquidity. The first of these can be represented by money market funds and banks lending in the repo market. The second can be represented by hedge funds. The third can be longer term, unleveraged investors, such as asset managers and pension funds. One valuable feature of an ABM is that the agents can represent actual entities in the financial system, delving into their policies and procedures for responding to various shocks (for example, how banks alter their haircuts in the face of higher volatility in the collateral) and describing each agent's financial condition (for example, capital, positions, and counterparties).

Policy Levers. These include minimum haircuts, margin requirements, and capital and liquidity ratios for banks. If a model is extended to the housing sector, the levers would include loan-to-value ratios. Policy levers might also include "circuit breakers" that operate to slow down any liquidity and funding demand to a pace closer to that of the decision process for key liquidity and funding providers.

Shocks and Vulnerabilities. The model should allow for the range of shocks that are typical in causing a crisis. These include a seizing up of liquidity; a fire sale in the face of forced deleveraging with the subsequent funding and liquidity effects; a sudden funding impairment, which is often brought on by a shock to real or perceived creditworthiness or liquidity; and, in the extreme case, the failure of a firm.

Policy Applications. Policymakers can use ABMs to explore major policy changes that diverge far from current policy settings. An ABM with adapting, heterogeneous agents provides a virtual policy experiment, exploring the importance of behavioral adjustments in a given situation. And the features of ABMs make them particularly well suited for analyzing an economy in extreme situations where standard empirical models are likely to fail. ABMs can help analyze issues such as leverage, market crowding, modes of intervention during a crisis, and even the type of data and risk metrics that will be of greatest value in evaluating market vulnerabilities.

Although ABMs have shown value in other fields, particularly for modeling emergent phenomena such as crowd stampedes or epidemics, it can be, as Axelrod (2006) pointed out, a "hard sell" in the community of academic economists, in which mathematical techniques are more common than computer simulations. The OFR is actively engaged with the research and policy communities to understand whether this method can be useful to the OFR and others with responsibility for modeling vulnerabilities of the financial system (Bookstaber, forthcoming).

BOX D. REVERSE STRESS TESTING

A standard stress test sets a scenario and measures the consequences. In contrast, a reverse stress test poses an adverse outcome and identifies the scenarios that lead to that outcome. OFR research is developing methodologies to implement this approach.

A standard stress test might ask: How much would a money market fund lose under a hypothetical combination of rate and spread movements? A reverse stress test would ask instead: How much would rates and spreads have to move for the fund to "break the buck" and drop below its fixed net asset value of one dollar? Similarly, reverse stress tests could ask: What would make a firm insolvent or breach capital requirements?

Reverse stress testing, which originates from industry practice, focuses efforts on scenarios of key importance to a specific portfolio, institution, or set of institutions. It offers potential advantages for interpretation; although the relevance of a hypothetical stress scenario is often open to debate, all parties can agree on the significance of an adverse outcome. The results of a reverse stress test are also potentially more actionable precisely because they spotlight specific vulnerabilities.

Scenario selection is an integral part of all stress testing; for reverse stress testing, it entails identifying the scenarios that lead to a specified adverse outcome. For both types of stress tests, it is useful to think in terms of "factors"—market rates and economic variables, for example—that drive gains and losses. A stress scenario is then defined by a shock to the factors or possibly a sequence of shocks. Scenario selection is the process of choosing factors and shocks.

The directional effect of a shock is often clear. A house price decline will adversely affect a mortgage lender and a stock market decline will generate losses for a stock portfolio. But for portfolios using derivatives, embedded optionality, or hedging, the directional impact may be obscured. A bank that partially hedges its interest rate risk might be insensitive to a modest increase or decrease in rates and yet be vulnerable to large changes in either direction. Flood and Korenko (forthcoming) develop a method that avoids making assumptions about which directions lead to adverse outcomes and instead seeks to explore directions of potential risk comprehensively.

When the available information is sufficient, interest centers on the most likely scenarios leading to a specified adverse outcome. Glasserman, Kang, and Kang (forthcoming) develop a method for estimating the most likely combinations of factor shocks leading to a given outcome and for identifying important sets of factor shocks, rather than a single scenario. Many different combinations of movements in market factors could produce equally large losses, but historical data may make some combinations more plausible than others. Getting the relative severity of various shocks right is important in determining the proper response to vulnerabilities identified by a stress test.

Chart 3.2.1 Sample Stress Variables Used in CCAR 2012

Variable	Stress Case	Peak-to-Trough for 2008 Crisis
Real GDP	-5.2% (Q3 2011–Q3 2012)	-5.1% (Q4 2007–Q2 2009)
Unemployment Rate	Maximum: 13.0% (Q2 2013)	Maximum: 10.0% (Q4 2009)
Chicago Board Options Exchange Market Volatility Index (VIX)	Maximum: 90.50 (Q1 2012)	Maximum: 80.86 (Q4 2008)
Dow Jones US Total Stock Market Index (DWCF)	-51.8% (Q3 2011–Q4 2012)	-47.2% (Q3 2007–Q1 2009)
CoreLogic House Price Index (HPI)	-21.0% (Q3 2011–Q1 2014)	-33.2% (Q4 2006–Q1 2012)*

*To present; trough not yet established.

Source: Board of Governors (2012), OFR calculations

Assessment Program (FSAP), and the European Banking Authority (EBA), which applied a stress test on macroeconomic variables against all countries in the European Union.

SCAP was a one-time supervisory stress test. The supervisors specified the adverse scenario and determined the resulting loss and revenue estimates on a standardized basis using information submitted by each firm. Its purpose was to restore confidence in large U.S. banks during a time of great market turmoil by measuring how much capital the banks would need in an even more stressed environment and then forcing these banks to increase capital accordingly. In contrast, the CCAR is an ongoing program which has already run through two cycles in 2011 and 2012. The CCAR employs stress tests with scenarios specified by the Federal Reserve Board but run by the banks to fulfill a secondary objective of assessing the banks' internal risk management capabilities and capital planning processes. ***Chart 3.2.1*** presents the stress scenario for several of the key variables in the 2012 test along with the peak-to-trough change in these variables during the 2008 crisis.

The stress tests of the European Banking Authority, the IMF, and CCAR all provide insight into the resilience of the financial system, though differing in the specifics of the scenarios, the data available for the tests, the components of the testing done by the entities versus the regulators, and the regulatory targets (for example, capital and leverage ratios). These programs also use similar methods for determining scenarios, and they base the scenarios on market and economic variables ***(Chart 3.2.2)***.

The recent financial crisis has prompted a critical reassessment of these methods because stress tests before the crisis missed important sources of instability, most notably the effects of liquidity risk and credit risk—both particularly manifest in the banks' exposures to the real estate market and off-balance-sheet risks—and the availability of funding to support the banks' leverage. The crisis also dramatically illustrated the force of contagion and related fire sales and thus the importance of following the path of a shock through the financial system.

Chart 3.2.2 Comparison of Key Stress Test Parameters

	U.S. CCAR 2012	U.S. FSAP (IMF)	EU EBA Stress Test
Date	March 2012	July 2010	July 2011
Scope	31 U.S. BHCs with at least US$50 billion in assets, including the 19 that were subject to the SCAP	53 largest BHCs, representing 85 percent of aggregate BHC assets	90 banks in 21 countries, representing approximately 2/3 of total banking assets
Process	Stress tests for the top 19 were conducted by each bank under the Federal Reserve's adverse scenario, and the Federal Reserve conducted its own tests of the banks under both its baseline and severe stress scenarios	A balance sheet-based macroprudential analysis, without detailed supervisory data, a distress-dependency model using CDS data, and a contingent claims analysis to estimate potential government contingent liabilities	Stress tests for all banks were conducted by each bank based on the established stress scenarios and methodology, and were verified by home country supervisors and EBA staff
Target Capital Ratio	5% Tier 1 Common (FRB rules); 4% Tier 1; 8% Total	6% Tier 1 Common	5% Core Tier 1 (EU Capital Requirements Directive)
Key Parameters	Unemployment rate increases approximately 4 percentage points to a peak of 13 percent; equity prices drop by approximately 50 percent; housing prices decline by an additional 20 percent from Q3 2011 levels	Unemployment rate rises 1.1 percentage point to 10 percent; commercial property prices fall by 8 percent; residential property prices decline by 6.6 percent	For each country: unemployment rate increases 3.2 percentage points; commercial property prices decline by 20–40 percent; residential property prices decline by 5–30 percent
Disclosure	Disclosed on aggregate and bank-level basis using a common template	Many results released on a bank-level basis for this test, with consent of U.S. authorities	Disclosed on aggregate and bank-level basis using a common template

Note: The Tier 1 capital ratios used in the various tests are not directly comparable.

Source: Board of Governors (2012), IMF (2010), EBA (2011)

3.2.5 Stress Test Disclosure

Following the SCAP stress test, the Federal Reserve disclosed details of the results on a company-by-company basis using a common template to ensure comparability across bank holding companies. This disclosure of supervisory data was unprecedented but was regarded by the policymakers as essential for the credibility of the exercise among market participants. Dodd-Frank required the Federal Reserve Board to disclose summary results of supervisory stress tests for large banks.[9] The EBA discloses results of Europe-wide stress tests on both the aggregate and bank level, again with a common template for bank-level results.[10] For comparison, the results of the stress tests performed under the IMF's FSAP are disclosed in a manner to preserve the anonymity of the individual banks or are presented only on an aggregate basis.

There are several key issues that underlie the disclosure decision:

Comparability of stress tests across institutions. This has been accomplished for both the CCAR and the EBA stress tests by adopting a common disclosure template.

Consistency in the stress tests demanded by various supervisory agencies. As stress tests become more common, there may be conflicting disclosures and confusion if different stress factors and scenarios are applied.

Focus on the extreme scenarios. The present supervisory stress tests focus on extreme scenarios because they share the objectives of determining capital adequacy and financial stability in the face of market stresses. One concern is that stress tests might turn into an earnings forecasting exercise if they lose their focus on extreme scenarios.

Consideration of the appropriate level of disclosure during normal versus crisis periods. Normal times may not require the same degree of transparency as is needed in times of crisis, and indeed the same level of disclosure may not be desirable. With the uncertainty about the banking system that can arise during times of crisis, there is an immediate benefit to the supervisors' ready assessment of the health of individual banks and to the ability of the market to better differentiate the healthy banks from the weaker ones. During normal times, more consideration can be given to the effect of disclosure on the behavior of banks and the market generally. Along with the benefits of increased market transparency and discipline that come from bank-level disclosure also come potential costs: banks may make poor portfolio choices in order to increase their chances of passing the test (in other words, window dressing); market participants may place too much weight on the public information of stress test disclosure; or the incentive to produce and analyze other information about the banks may diminish. This behavior might lead to gaming the tests to conform to a particular set of rules, making the stress tests far less informative (Goldstein and Sapra, 2012; Tarullo, 2012).

3.2.6 The Future of Stress Testing

The next generation of supervisory stress tests may improve on the current generation by: (1) Introducing new stress factors, (2) Taking account of financial innovations, (3) Incorporating the dynamics of crisis events and the related feedback cycles and non-linearities, (4) Recognizing the variability in the objectives and behavior of financial agents, and (5) Addressing specific market vulnerabilities, such as the potential for fire sales and runs in wholesale funding markets, which requires stressing both sides of the balance sheet.

(1) Stress Factors

The recent crisis has shown that stress scenarios have to include credit risk and liquidity risk, along with the interaction between the two, for example, when solvency concerns cause a shock to systemic liquidity.[11] Funding can dry up because of increased concern about the risk of default; a drop in asset prices, perhaps due to a leverage-induced fire sale that affects the margin requirements for the banking system, thereby increasing funding costs; or a drop in funding liquidity, because uncertainty over counterparty risk and lower asset valuations induce banks and investors to hoard liquidity.

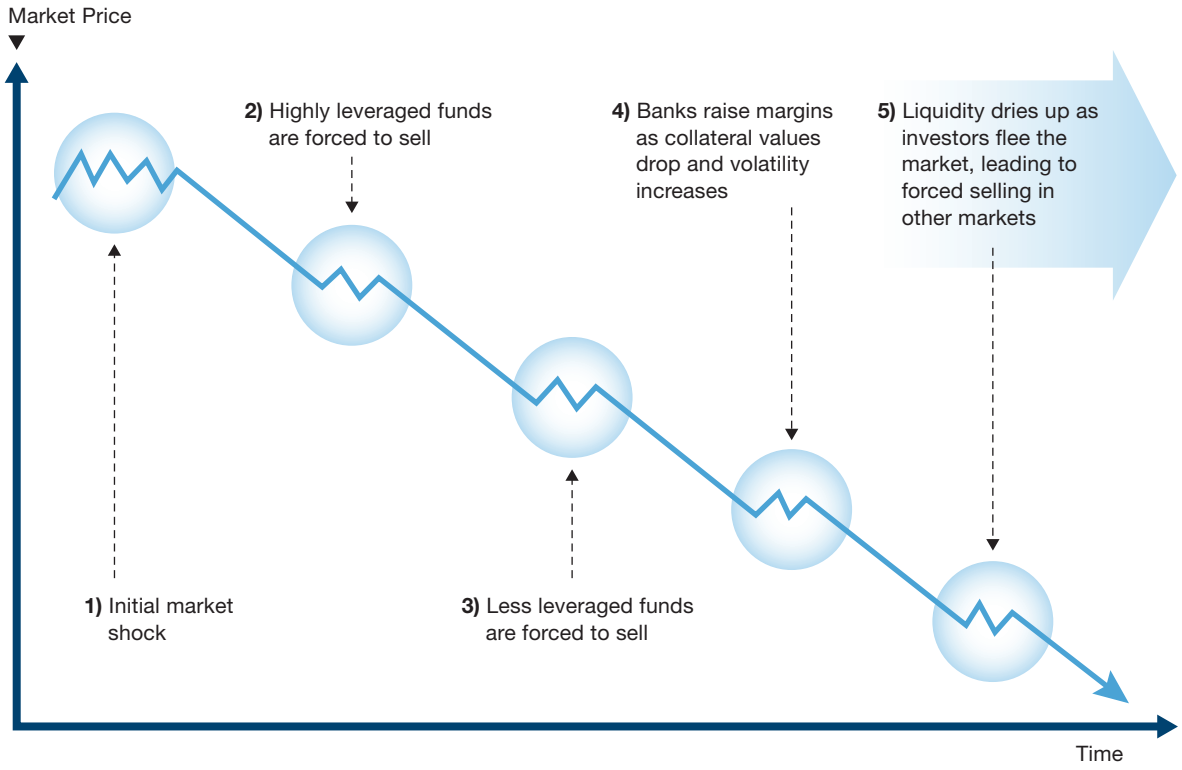
Shocks to individual banks can lead to marketwide reductions in liquidity by increasing counterparty risk or through "liquidity hoarding," in which banks do not extend credit even to high-quality counterparties in order to stay liquid "just in case" during periods of great uncertainty, or sell high-quality assets to meet liquidity needs.[12]

(2) Innovations and Structural Change

Innovations can lead to changes in market relationships and thus may require updates to models employed in stress tests. Innovations also impose difficulties in terms of data. By definition, limited data are available for new products and, further, they are unlikely to span a crisis period, so understanding the

Chart 3.2.3 Fire Sales (Liquidity Cycle)

A fire sale often begins with news that prompts a repricing of assets, combined with a concentration of leveraged funds that are forced to sell to meet margin requirements. As the forced selling sustains downward pressure on prices, margin calls feed back to magnify the effects, forcing additional rounds of selling.



"true" statistical properties is difficult, if not impossible, before the fact. Even less prior information exists about the effect of regulation on new products and markets because of lags in the initiation of regulatory oversight.

(3) Dynamics and Feedback

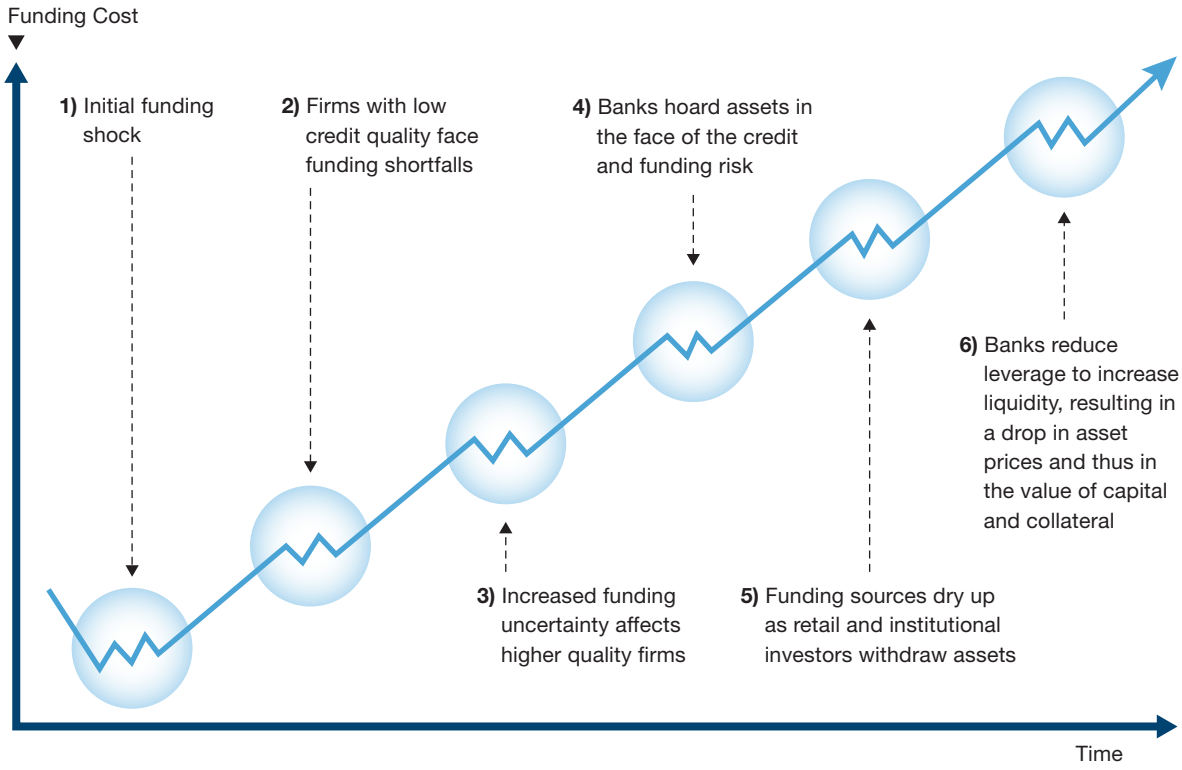
The current approach to stress testing employs models based on the risk models of banks. Risks are taken as external factors and there is no feedback when the actions of banks and others create secondary, ripple effects, or when the initial shocks to the risk factors themselves trigger chain reactions that affect factors outside of the initial set. Feedback effects are difficult to capture because of the granularity of data required, the diversity of behaviors of various market participants, and because current models have difficulty handling their non-linear time-dependent nature.

One important example of feedback relates to simultaneous deleveraging by financial institutions. An attempt by a large number of intermediaries to reduce leverage may backfire as asset prices plunge. Further, financial institutions may have trouble rolling over their short-term funding when the value of their collateral declines, triggering forced sales.

These dynamics can lead to contagion, both across markets and across institutions holding similar assets. And, when liquidation is no longer possible within similar markets, institutions in need of cash may seek to sell assets in unrelated markets, creating the same feedback effects in those markets. These paths for contagion are difficult to anticipate within a conventional framework because the affected markets may not have been correlated historically. ***Charts 3.2.3*** and ***3.2.4*** illustrate the multi-stage feedback dynamics that can occur

Chart 3.2.4 Runs (Funding Cycle)

A run often begins with concerns about counterparty creditworthiness and a drying up of liquidity, which boost funding costs, placing strains on vulnerable firms. The rise in funding costs promotes further concerns about counterparty risk and ever-wider funding spreads.



in the case of a liquidity shock and a funding shock, respectively.[13]

(4) Heterogeneous, Disaggregated Agents

Agents in the financial system operate according to their own governance procedures, risk management structures, and business cultures. Consequently, their reactions to any event will not be uniform and are unlikely to conform to abstract notions of optimal behavior. Such behaviors are complex, and current supervisory models do not attempt to predict them.[14] Instead, today's models generally are estimated at an aggregate level, or use firm-level data and are estimated uniformly across entities.

For issues of financial stability, however, the task of incorporating heterogeneous behaviors into stress tests is not as daunting as it may appear. Such an analysis would have to consider only a small number of representative financial entities, and their "rules of market engagement" can be determined through an analysis of governance structures and interviews with key decision makers. It therefore may be possible to overcome some of the limitations of the paucity of historical data about market participants' behavior during shocks, especially shocks that fall outside the range of recent history.

The heterogeneity of banks can pose problems for aggregating and comparing stress test results. Each bank applies its own models to the exercise, so there is no common frame of reference. One proposal to facilitate an apples-to-apples comparison of stress tests is to have each bank perform a stress test on a standard portfolio that has the sorts of assets the banks tend to hold, and then report the results for the overall portfolio and for segments of the portfolio. The variation of the banks' results for this standard stress test will provide some

transparency into their internal methodology. If a bank shows a loss for this stress test that is small relative to those of other banks, then its other stress test results are likely to be relatively optimistic as well. The standardized test will provide the banks with essential information for moving toward a consistent, comparable set of methodologies (Pandit, 2011).

(5) Stress Scenarios

Stress test scenarios face the difficulty of being most important when complacency is highest. Before the 2008 crisis, few would have taken seriously a test that assumed that credit default swap spreads would rise by as much as a factor of 10. Adverse scenarios thus have to extend beyond the market's comfort zone while at the same time not doing so arbitrarily. An outsized 300 basis point swap spread does not happen without context. The stress test must take into account the broader context and general nature of the current environment—the level of leverage, the areas of crowding, and the sources of funding—and then at a fundamental, structural level show how the interactions of market participants could, due to vulnerabilities in that environment, lead to an unanticipated market result.

3.2.7 Conclusion

It is crucial to enhance stress-testing methodologies to incorporate the modeling of feedback and secondary effects following initial shocks. A shock in one market may propagate into a second, seemingly unrelated market if the institutions with significant exposure in the first market also are heavily positioned in the second. These interactions can lead to an overall effect that is more than the sum of the individual shocks.

Improving stress tests requires a deep understanding of the exposures of various financial entities and the potential for changes in their access to market funding. Simply put, stress tests need to be improved to more accurately capture crisis dynamics. Doing so also requires something more than the partial equilibrium framework of the current generation of models. One line of research involves macroeconomic models that embed a more explicit financial system, including banks and capital markets and allowing for default, fire sales, and runs (Goodhart and others, 2012). Another promising area lies in the application of agent-based models, as described in ***Box C***.

The objectives of stress testing for the OFR represent a second step after the CCAR. CCAR applies a basic set of assumptions about changes in the banks' business lines when confronted with a shock, assuming, for example, no changes in the loan portfolio or in the position on the trading book. A stress test to expose vulnerabilities in the financial system as a whole requires the modeling of interactions. The enhanced stress-testing methodology should account for a host of potential channels of risk propagation, including interdependence among financial firms through clearing and settlement systems, common exposures, collective patterns of behavior, and broader market failures, such as externalities and moral hazard, all of which have the potential to amplify shocks and spill over into the real economy. This is the focus of the OFR's thinking and work.

3.3 Counterparty Risk Management: Best Practices and Unmet Challenges

The Dodd-Frank Act charges the OFR with promoting best practices in risk management, and counterparty risk management is especially important to that mission. Strong counterparty risk management by individual financial institutions provides a stabilizing buffer against the propagation of shocks through the financial system; poor counterparty risk management can turn the failure of an individual firm into a systemic event. As part of its work in this area, the OFR is also contributing significantly to the improvement of counterparty risk management by helping establish a global Legal Entity Identifier (LEI).

The financial system depends on companies honoring their commitments to each other in market transactions. Failure of a company to do so can cause significant losses to its own counterparties and can threaten a chain reaction among interconnected market participants.

This section highlights lessons learned from the financial crisis and ongoing changes in the measurement and management of counterparty risk. This overview covers current trends in this critical area and highlights an evolving focus on credit value adjustment (CVA) as a tool for market participants and financial regulators in quantifying counterparty risk. The financial system and its oversight both stand to benefit from best practices in the implementation and application of this important tool.

Counterparty risk is sometimes construed narrowly to refer to exposures in over-the-counter (OTC) derivatives trading. The discussion here takes a much broader view that includes many other types of counterparty relationships. Domestic prime brokers, for example, are generally prohibited from transacting in OTC derivatives, but their relationships with their hedge fund clients expose both parties to risk. Money market funds face counterparty risk through their exposures to bank deposits, repurchase agreements, and other debt instruments, and through the third-party guarantees that are sometimes attached to these instruments. Failures in any of these and in many other types of counterparty relationships can have ripple effects on financial stability.

A crucial prerequisite to counterparty risk measurement is the proper identification of counterparties. The OFR's work to help establish a global LEI is thus an essential component of the OFR's risk management mandate. While this section focuses on counterparty risk, ***Box E*** highlights the OFR's broader mission to promote best practices in risk management.

3.3.1 Historical Context

Counterparty risk is not a new phenomenon. The collapse of Long-Term Capital Management (LTCM) in 1998 heightened awareness of the risks that market participants face through their exposure to counterparties. LTCM's counterparties were particularly exposed to the hedge fund through OTC derivatives positions. LTCM's failure led to the formation of the Counterparty Risk Management Policy Group, a consortium of commercial and investment banks, which issued its first report in 1999. The principles put forward in that report—on transparency, risk assessment, reporting, documentation, collateral management, and the integration of market and credit risk—remain as relevant today. A second report, published in 2005, put particular weight on improving the operation of the credit default swap (CDS) market, which had grown since the first report from insignificance to become a $10 trillion market. International bank supervisors, working through the Basel Committee on Banking Supervision, introduced a series of requirements for banks to hold extra capital as a buffer against the counterparty risks arising from OTC derivatives, repo transactions, securities lending, and margin lending. Basel III substantially increases these capital requirements.

The recent financial crisis served as a reminder of the importance of counterparty

BOX E. BEST PRACTICES IN RISK MANAGEMENT

The Dodd-Frank Act charges the OFR with promoting best practices in risk management, a mission the OFR pursues through its research and through discussions with industry participants and academic experts.

Effective risk management relies on a combination of quantitative tools, data management, and governance procedures. This box highlights some critical dimensions of best practices in risk management. These topics are further explored in an OFR working paper (Flannery and others, 2012).

Risk Governance and Incentives

A strong culture of risk governance is a necessary ingredient of effective risk management. Key elements of a strong risk culture include adequate resources and independence for the risk function; a board of directors with the proper information and expertise to understand the firm's risk-taking; and compensation schemes that align the risks taken by individual units with the long-term objectives of the firm. Despite some progress, the overall performance of the financial industry on these dimensions needs improvement.

Liquidity Risk Management

Excessive reliance on short-term funding amplifies shocks to the financial system. Repo markets, money market funds, asset-backed commercial paper, securities lending, and rehypothecation—the reuse of collateral by a broker to borrow for its own use—all came under stress during the financial crisis, and firms with the greatest reliance on these funding sources were among those at greatest risk. Avoiding similar errors in the future will require regulatory changes and improvements in firms' management of their funding sources, with appropriate contingencies to function through times of market stress.

risk management. A central episode was the liquidity squeeze experienced by the major investment banks when their counterparties, including hedge funds that were their prime brokerage clients, suddenly demanded their funds. Prime brokers provide a range of services to hedge funds and traditionally earn fees by rehypothecating fund assets held as collateral—that is, re-using the collateral for securities lending or as collateral for the broker's borrowing. During the crisis, investment banks had trouble meeting the large number of requests by hedge funds for cash and collateral. Thus, while the LTCM failure focused attention on the risks that investment banks face in the event of a hedge fund failure, the events of 2008 illustrated the risks that hedge funds face in their dealings with investment banks. The financial industry has responded to heightened concern for counterparty risk with greater use of custody accounts to hold fund assets, tighter controls on rehypothecation, and diversification across multiple prime brokers.

The near-failure of American International Group (AIG) also illustrated the threat to financial stability that can result from inadequate counterparty risk management. Through a combination of over-reliance on credit rating agencies, market opacity, and weak supervision, AIG was able to take on enormous positions by selling credit protection,

Data and Information Technology

The financial crisis has highlighted the varied level of integration that firms have achieved in their risk management infrastructure. Some of the firms that fared best had developed a firmwide view of their risks, aggregated across diverse lines of business. Most large complex financial institutions have not yet fully developed this capability.

Market Risk and Credit Risk

These are the traditional focal areas of risk management and in many respects they are the best developed aspects of the field. An important lesson of the financial crisis is the need to build longer horizons into market risk and credit risk measurement to capture the behavior of financial markets under a range of business conditions.

Operational Risk

As highlighted in the 2012 FSOC annual report, strong cybersecurity is a key element of protecting financial stability and an ongoing challenge for financial institutions. The Flash Crash on May 6, 2010—when the Dow Jones Industrial Average plunged nine percent and then recovered within minutes—pointed to the new types of operational risk that emerge from high-speed trading and highlighted the importance of a sound infrastructure. Ensuring the prevention of unauthorized trading and fraud also should remain a priority for operational risk management.

The Micro-Macro Interface

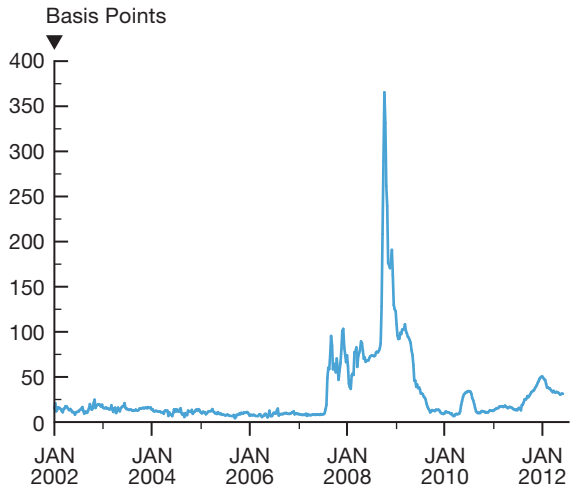
Firm-level risk management focuses on risks to a single institution. But actions that a single institution may take to mitigate its risks—withdrawing funding, selling impaired assets, or exiting a market—can amplify risks in the system as a whole when undertaken simultaneously by many firms, as in the case of a classic bank run. Indeed, risk management practices that may seem sound in isolation can have procyclical effects when widely adopted. Because of its broader mandate, the OFR has a particular interest in the macroprudential implications of firm-level practices.

and its counterparties apparently failed to recognize the magnitude of the accumulating risk until it was too late. This led to a cliff effect as downgrades of AIG triggered collateral requirements it could not meet. The Dodd-Frank Act seeks to prevent the accumulation of risk into such concentrated exposures; in particular, it provides a process for regulators to designate a large financial institution for additional financial supervision based on the systemic implications of its potential failure.

Despite the decade of attention to counterparty risk that passed between the failures of LTCM and Lehman Brothers, the recent crisis changed the market's assessment of counterparty risk, as reflected in market prices and practices. The failures and near-failures of large financial institutions led market participants to demand greater compensation for bearing the risk of potential failures of their counterparties.

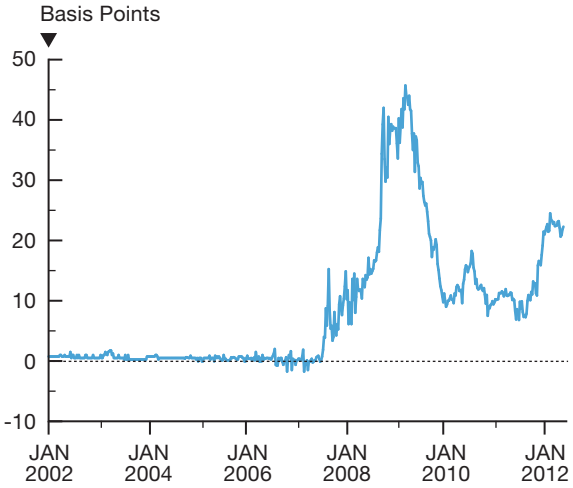
This pattern is evident, for example, in the LIBOR-OIS spread, a measure of counterparty risk in the banking system ***(Chart 3.3.1)***. The OIS (overnight indexed swap) rate is tied to the overnight federal funds rate; the swap involves an exchange of interest payments only, not principal, and thus reflects minimal credit risk. In contrast, three-month LIBOR (the London Interbank Offered Rate) embeds the risk banks face in lending to each other

Chart 3.3.1 Three-Month USD LIBOR-OIS Spread



Source: Bloomberg

Chart 3.3.2 USD LIBOR Basis Swap: Three-Month versus Six-Month



Source: Bloomberg

for three months. The difference is thus widely viewed as a measure of the premium for bank credit risk. The spread was small and stable until the summer of 2007, skyrocketed in 2008, and continues to be larger and more volatile than it has been historically. A similar pattern is evident in the basis swap rate between six-month LIBOR and three-month LIBOR ***(Chart 3.3.2)***. This spread measures the risk that a bank—an average bank from the LIBOR panel—will be unable to roll over its short-term debt because of a decline in its credit quality; as noted in Section 2.2, the integrity of the LIBOR setting process has recently come into question.

More recently, the market's new assessment of counterparty risk can be seen in sovereign credit default swap spreads ***(Chart 3.3.3)***—historically very low, but now elevated even for developed economies. Sovereigns have traditionally been free from collateral requirements in their swaps with banks, but the debt management offices of Hungary, Ireland, Portugal, and Sweden have agreed to two-way collateral agreements with banks in the past year, and other countries may follow. This trend reflects both a general push toward expanded use of collateral and a change in the market's perception of sovereign risk.

These changes in market prices and practices reflect some of the lessons learned about sources of counterparty risk through the financial crisis. We next describe measures to manage this risk, articulating the OFR's initial areas of focus as we begin to discharge our mandate to develop best practices for risk management and to supply analytical support to policymakers considering choices for improving the rigor of market participants' risk management activities.

3.3.2 Mitigants to Counterparty Risk

Financial institutions mitigate counterparty risk through a combination of firm-specific practices, market structure, and financial transactions. This subsection discusses specific practices, current developments, and issues requiring further attention by firms and regulators.

Internal Controls

Effective counterparty risk management, like all effective risk management, begins with internal procedures, proper controls, and strong risk governance. For counterparty risk, this entails rigorous monitoring of counterparty credit, a thorough procedure for setting and enforcing risk limits, and proper controls for managing collateral and complying with all terms of credit support agreements with counterparties. Achieving these objectives presents data management challenges for large diversified

financial firms that may face the same counterparty or affiliated counterparties across many lines of business. Establishing an LEI will facilitate the process of integrating counterparty risk from multiple affiliates and subsidiaries and will help firms monitor their exposures more consistently and comprehensively.

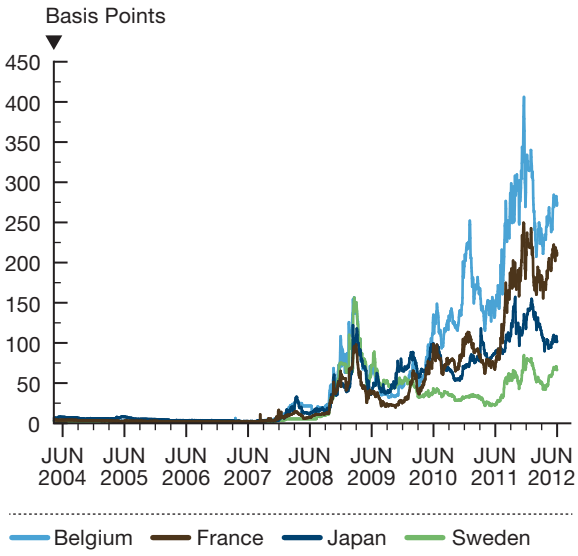
Credit analysis is a core risk management function of nearly all financial intermediation. In eliminating regulatory reliance on credit rating agencies, Section 939A of the Dodd-Frank Act also put greater responsibility on firms to take ownership of credit risk assessment. The financial regulatory agencies issued a series of proposed and final rules in 2011 to address the removal of credit ratings from regulations; a thrust of these rules is to avoid using credit ratings as seals of approval and thus to put greater weight on due diligence. Credit analysis is too critical to be outsourced.

Risk management ultimately relies on proper incentives and governance, a point stressed in a recent OFR working paper (Flannery and others, 2012). The independence, influence, and incentives afforded the chief risk officer matter as much as the methodologies employed. Recent supervisory guidance on counterparty credit risk management begins by detailing the responsibilities of the board of directors, senior managers, the risk management function, and independent auditors in ensuring the effectiveness of firm-level risk management (OCC and others, 2011). ***Box F*** highlights some significant failures of risk governance at MF Global that contributed to its collapse and the loss of funds by its customers.

Netting and Collateral

Regular participants in the OTC derivatives market often accumulate a large number of transactions with a single counterparty, and some of these transactions may partially offset each other. Under a netting agreement, one party pays the other the net amount owed on a portfolio of derivatives, instead of each party making a gross payment to the other. Netting thus reduces the size of the exposure each party faces from a potential default of the other party.

Chart 3.3.3 Sovereign 5-Year CDS Spreads



Source: Bloomberg

Chart 3.3.4 illustrates the idea. Party A owes Party B $100 on one swap, and Party B owes Party A $80 on another swap. Under a netting agreement, the payments would be offset and Party A would pay just the difference of $20 to Party B. This reduces B's exposure to A from $100 to $20, and it eliminates A's exposure to B.

Collateral agreements also protect creditors from loss in the event of default of an obligor. When a swap (or a portfolio of derivatives) is collateralized, the parties to the swap agree to exchange collateral as the market value of the swap moves in favor of one party or the other. With more frequent updating of the collateral level, the payments to be exchanged are typically smaller, and this reduces each party's exposure to a default of the other. Title VII of the Dodd-Frank Act and the OCC's proposed margin rules mandate collateral for most swaps that are exempt from central clearing and call for stricter rules on segregation and rehypothecation of collateral to ensure its availability as a buffer against the spread of shocks through the financial system.

BOX F. LESSONS FROM THE COLLAPSE OF MF GLOBAL

On October 31, 2011, MF Global Holdings Ltd., the parent of the broker-dealer and futures commission merchant MF Global Inc., filed for bankruptcy—the fifth largest failure of a financial institution in U.S. history. The company had placed large bets on European sovereign debt, increasing its exposure as market prices continued to fall. Long after incurring losses, the company was unable to account for $1.6 billion in customers' funds in the aftermath of its failure.

MF Global's high-profile collapse offers lessons in several areas: (1) Compliance and corporate governance, with the company's deficiencies culminating in its failure to safeguard customer funds; (2) Liquidity management, in the use of short-term funds to finance bets on Europe; and (3) Macroprudential analysis, as the incident provides an opportunity to evaluate what helps prevent the failure of a large firm from becoming a threat to financial stability.

Compliance and Corporate Governance

Following its failure, MF Global was unable to account for over $1.6 billion in customer funds amid allegations that the firm used customer assets to cover its losses. The apparent failure to properly segregate customer funds followed a pattern of lapses in compliance and governance.

According to Congressional testimony, as the firm raised its limits on European sovereign debt exposure from $1 billion to $4.75 billion between September 2010 and January 2011, the chief risk officer (CRO) voiced concerns to the chief executive and the board of directors. His concerns went unheeded and he was replaced by a new CRO in January 2011 (Roseman, 2012a). The position was effectively demoted, as the new CRO reported to the chief operating officer rather than to the chief executive, and projects to enhance risk management were shelved (Stockman, 2012). All of this should have been a red flag, signaling a culture in which the CRO position was not sufficiently independent and empowered to restrain decisions by senior management that put the firm at risk.

There had been earlier signals. In 2008, the company incurred a $141 million loss due to unsupervised trading by a single employee. In 2009, the CFTC, its regulator, imposed a $10 million fine on the firm for "significant supervision violations." The commission said that between 2003 and 2008 it had warned MF Global about major compliance issues, noting, "MF Global failed in four separate instances to ensure that its risk management, supervision and compliance programs comported with its obligations to supervise diligently its business as a CFTC registrant." (CFTC, 2009). Repeated incidents of poor internal controls delayed the firm's acceptance as a primary dealer. According to data compiled by the National Futures Association, fines imposed by the CFTC and various exchanges made MF Global one of the highest fined firms among its peers (Beyers, 2011).

Taken together, these and related incidents indicate an environment with a weak culture of

compliance and risk management. A firm with better internal controls and governance could have avoided MF Global's fate and protected customer assets. Better management is a necessary element of proper risk control.

Liquidity Management

MF Global's losses and ultimate collapse resulted from leveraged bets. The firm borrowed to invest in European sovereign debt, financing its purchases through repo agreements. It reportedly used "repo-to-maturity" agreements through which MF Global was able to borrow funds, using the bonds as collateral, until the bonds would come due. Accounting rules permitted these repo transactions to be treated as sales, obscuring the firm's leverage, but ultimately leading to a revision of capital charges in the summer of 2011. In Congressional testimony, the first CRO said the firm engaged in window dressing—presenting the firm favorably in its public financial statements—by reducing leverage at reporting dates, and he noted that this became more difficult as the firm took on less liquid positions (Roseman, 2012b). As the market value of the bonds declined amid continuing concerns about deteriorating circumstances in Europe, the firm received margin calls it could not meet.

Different investors can reasonably have different views on whether to buy particular assets, in this case European bonds. But sound risk management requires anticipating the liquidity needed to sustain an investment strategy and avoiding excessive and opaque leverage. MF Global was ultimately undone by poor liquidity management of a concentrated bet on European sovereign debt.

Macroprudential Analysis: Not a Systemic Event

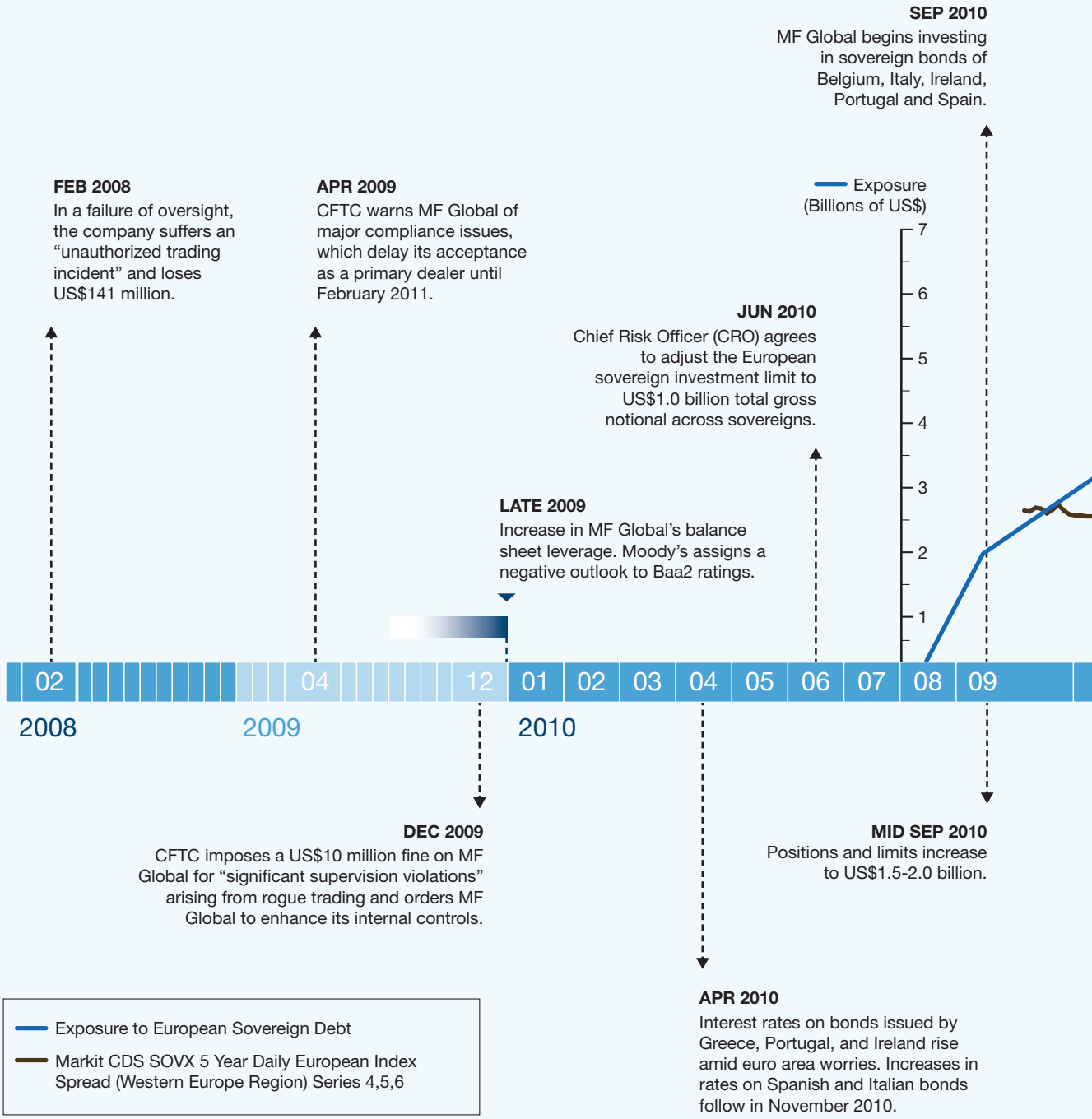
MF Global's customers have paid a high price for the firm's errors. Nevertheless, it is worth reflecting on why this failure of a major financial firm did not have the systemic repercussions associated with the failures of 2008.

Size is undoubtedly an important factor—at $41 billion in assets, MF Global was roughly a tenth the size of Bear Stearns, which was in turn about two-thirds the size of Lehman Brothers. But concentration of risk is also significant. In 2007-2008, markets grew increasingly aware and concerned about the scope of transactions tied to real estate, particularly subprime lending, and no financial institution seemed safe.

Had many other dealers or hedge funds held large positions similar to MF Global's, the firm's collapse might have resulted in greater spillover effects. Indeed, Jefferies, a firm of roughly similar size and services, suffered a loss of market confidence and a 20 percent drop in its share price in intraday trading as investors feared—without justification, it turned out—that the firm might be engaging in similar activities. Such fears were contained as MF Global's leveraged exposure did not reflect the position of U.S. financial institutions generally.

This episode is an important reminder that greater transparency and effective counterparty risk management are essential principles to counter the threat of contagion and the risk that the consequences of a failure would ripple throughout the financial system. Better data management and data standards would support these principles.

Chart F.1 The Lead-Up to the Collapse of MF Global



Source: Markit, Haver Analytics, Congressional Hearings, and news reports

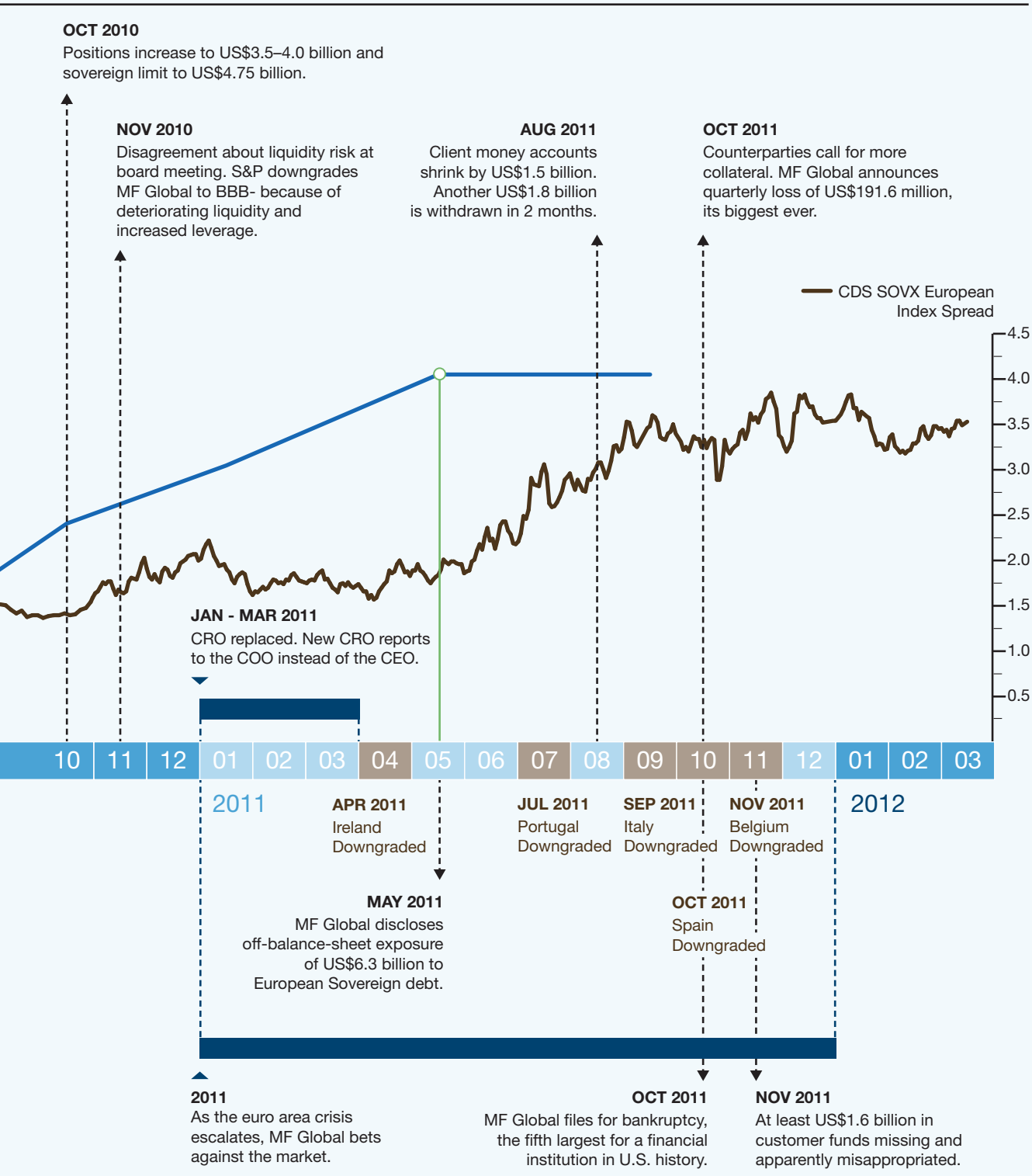

OCT 2010
Positions increase to US$3.5–4.0 billion and sovereign limit to US$4.75 billion.
NOV 2010
Disagreement about liquidity risk at board meeting. S&P downgrades MF Global to BBB- because of deteriorating liquidity and increased leverage.
AUG 2011
Client money accounts shrink by US$1.5 billion. Another US$1.8 billion is withdrawn in 2 months.
OCT 2011
Counterparties call for more collateral. MF Global announces quarterly loss of US$191.6 million, its biggest ever.
CDS SOVX European Index Spread
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
JAN - MAR 2011
CRO replaced. New CRO reports to the COO instead of the CEO.
10 11 12 01 02 03 04 05 06 07 08 09 10 11 12 01 02 03
2011
2012
APR 2011
Ireland Downgraded
JUL 2011
Portugal Downgraded
SEP 2011
Italy Downgraded
NOV 2011
Belgium Downgraded
MAY 2011
MF Global discloses off-balance-sheet exposure of US$6.3 billion to European Sovereign debt.
OCT 2011
Spain Downgraded
2011
As the euro area crisis escalates, MF Global bets against the market.
OCT 2011
MF Global files for bankruptcy, the fifth largest for a financial institution in U.S. history.
NOV 2011
At least US$1.6 billion in customer funds missing and apparently misappropriated.

Chart 3.3.4 Illustration of Payment Netting Between Parties A and B

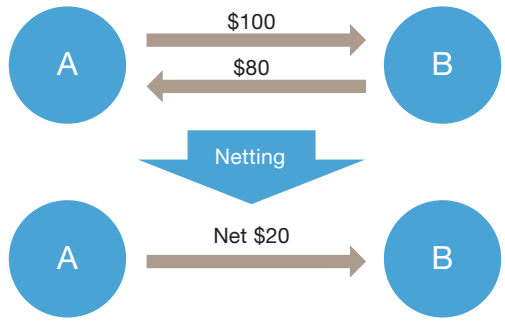
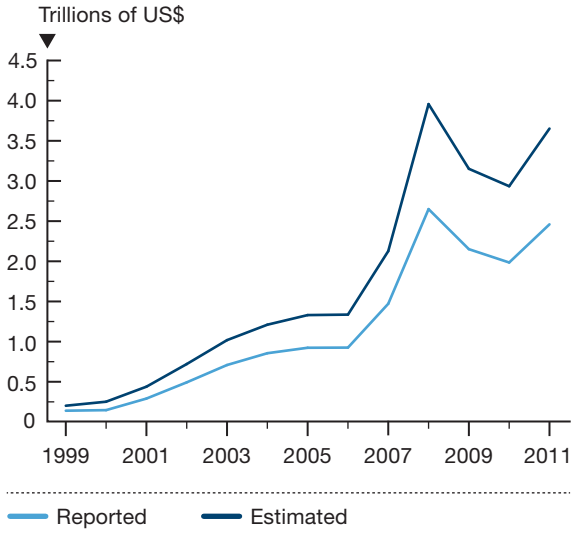


Chart 3.3.5 Total Collateral Outstanding in OTC Derivatives Markets



Source: ISDA

Chart 3.3.5 shows total collateral outstanding in OTC derivatives markets as reported to the International Swaps and Derivatives Association (ISDA) and as estimated by ISDA to correct for nonparticipation in the ISDA survey. The decline following 2008 is due to several factors: the shrinking of the market, counterparty consolidation, and greater use of central clearing. These trends generally enhance financial stability.

Properly managed collateral offers one of the most effective ways to mitigate counterparty risk. However, it also introduces greater liquidity needs for swap participants. The collapse of MF Global was due, at least in part, to the firm's failure to maintain a liquidity buffer to meet collateral needs, for which it allegedly raided customer accounts. The near-demise of AIG in 2008 was accelerated by a cycle of collateral calls by AIG's counterparties triggering rating downgrades, thereby prompting further collateral calls. Thus, collateral can convert counterparty risk to liquidity risk, and the market's evolution toward greater use of collateral must be accompanied by a corresponding focus on new liquidity needs and liquidity risk management. Demands for collateral are also potentially procyclical, reducing the availability of credit in times of elevated market stress.

Central Clearing

The vast OTC swap market is the aggregation of bilateral exposures that are largely opaque to outsiders. ***Charts 3.3.6*** and ***3.3.7*** show the evolution of the gross market value and notional amounts of OTC derivatives outstanding, respectively, as reported by the Bank for International Settlements. These exposures are opaque because participants do not know the counterparties their own counterparties are exposed to, or how those exposures are managed. Title VII of the Dodd-Frank Act requires that eligible swaps be cleared through central counterparties (CCPs), and the CFTC and SEC are formulating rules for swaps and security-based swaps (CFTC, 2011; SEC, 2010). Some customized or bespoke derivatives will continue to trade over-the-counter but these will be subject to higher capital requirements and margin requirements.

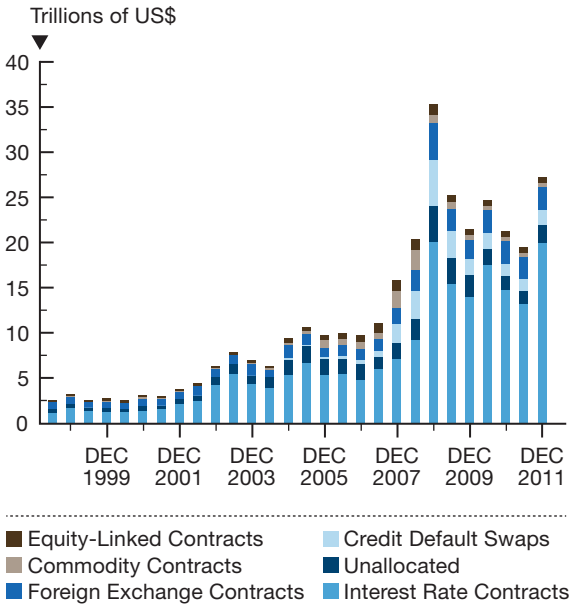
With central clearing, a single trade between two counterparties is replaced by a pair of trades through the CCP. The CCP's positions offset each other, and the two original counterparties face the CCP rather than each other ***(Chart 3.3.8)***. This mechanism is similar to the approach that futures and options exchanges have long taken to guarantee trades through margin requirements, default fund contributions from members, and their own capital. In combination with additional

reporting requirements to regulators and market participants, the move toward central clearing brings greater transparency to the derivatives market and reduces the direct exposures among the dealers that dominate the OTC market. Enhanced price transparency helps level the playing field for end users of derivatives and will enable the OFR to develop a more comprehensive map of potential risks in the financial system.

Central clearing reduces bilateral exposures and bilateral risk, but it also may concentrate risk in clearinghouses. The failure of a major clearinghouse—one to which large financial institutions have significant exposures—is potentially disruptive to the functioning of the financial system. To mitigate counterparty risk, a CCP must be well-capitalized and must have effective operations for pricing, margining, collateral management, and default management. The success of central clearing will depend, in part, on the right mix and distribution of CCPs. Economies of scale and expanded netting opportunities argue for fewer CCPs. On the other hand, a market structure based on a small number of CCPs would present questions about implicit guarantees or moral hazard and would limit the potential benefits to market participants of competition and diversification. Views differ on whether each CCP should specialize in a single product category, like credit default swaps, or provide clearing for a broad range of products (Duffie, 2012).

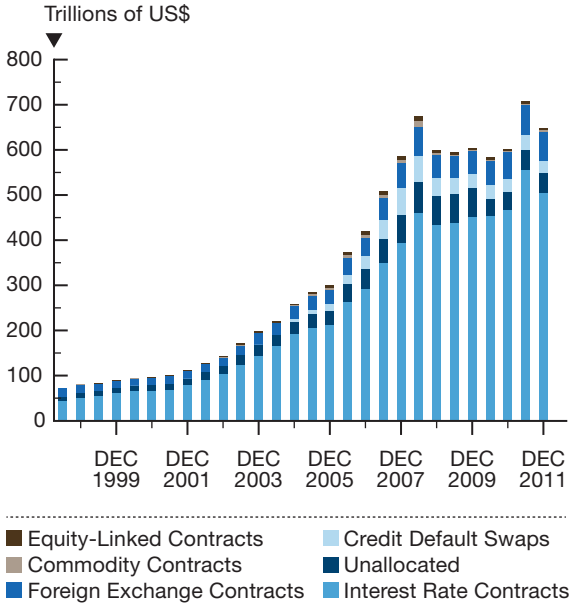
Jurisdictional concerns may trump economics and lead to a proliferation of central counterparties internationally; central banks may insist on oversight of derivatives denominated in their currencies for fear that they may be called upon to provide liquidity to a CCP. The move to central clearing will continue to require the focus of risk managers and regulators as these competing considerations are resolved. To give impetus to a global infrastructure for central clearing, the Financial Stability Board (FSB) has developed four safeguards that are necessary conditions to

Chart 3.3.6 Gross Market Value of OTC Derivatives Outstanding



Source: BIS

Chart 3.3.7 Notional Amounts of OTC Derivatives Outstanding



Source: BIS

Chart 3.3.8 Credit Default Swap OTC and Through a Central Counterparty

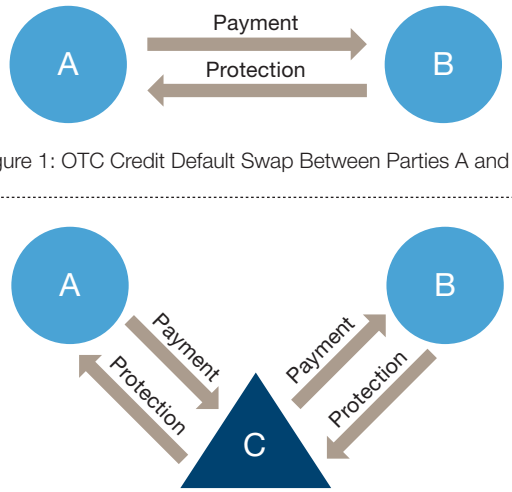
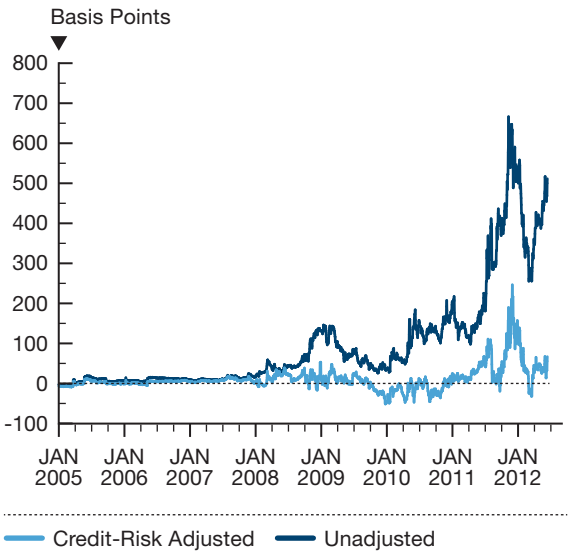


Figure 1: OTC Credit Default Swap Between Parties A and B

Figure 2: Credit Default Swap Through Central Counterparty C

Chart 3.3.9 Spread Between Italian and German Bond Yields



Source: Bloomberg, OFR calculations

strengthen global CCPs in the areas of access, oversight, resolution, and liquidity. The G20 Leaders endorsed the progress of the FSB at their summit in Los Cabos in June 2012.

Two closely related areas of focus for the OFR are the operation of the tri-party repo market, which is concentrated in two clearing banks, and the securities lending market, which relies on a relatively small number of lending agents. In both cases, the concentration of counterparty risk introduces vulnerabilities.

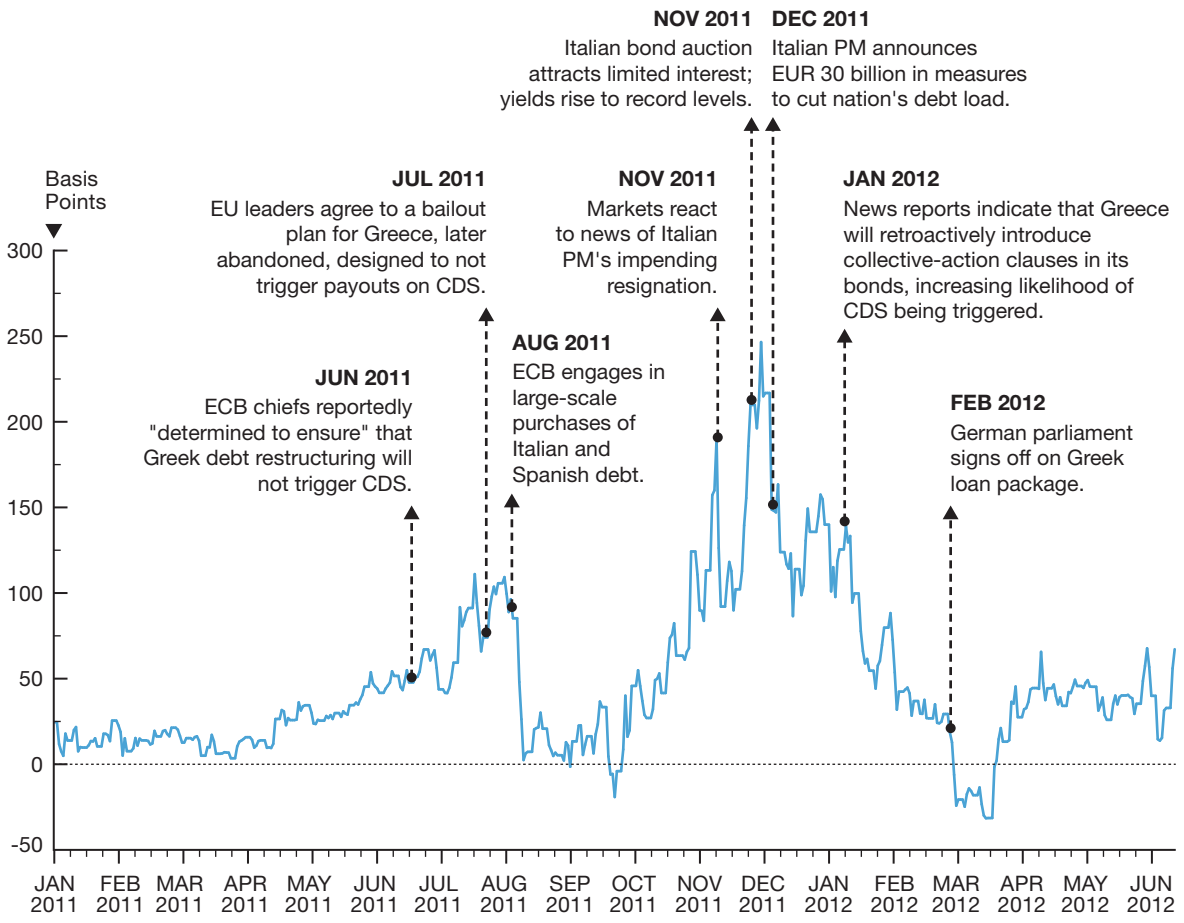
Hedging

Besides collateral requirements, the main tools for hedging counterparty risk, including issuer risk, are various types of third-party guarantees, including bond insurance, lines of credit, mortgage insurance, and credit default swaps. Each of these mechanisms provides a creditor with protection against the default of an obligor; however, each also introduces new counterparty risk through exposure to the guarantor.

Some have argued that sovereign CDS have lost their hedging effectiveness due to political pressures to restructure debt without triggering CDS payouts. Such pressures were alleged in the course of negotiations about Greek debt in 2011 and early 2012, although an ISDA determinations committee ultimately declared an event of default in that case. Uncertainty about the conditions that will trigger a payout reduces the hedging effectiveness of CDS and is likely to result in higher interest costs for the affected sovereigns. ***Charts 3.3.9*** and ***3.3.10*** show the credit-risk-adjusted spread, a measure of the market's view of CDS effectiveness. If market participants expect that CDS on Italy are likely to pay out in an event of default, for example, the credit-risk-adjusted spread between Italian and German bonds should be close to zero. The movement in the spread in recent years reflects market concern that a future Italian default could be structured to avoid triggering CDS.[15]

A simple CDS contract has limited value in hedging the counterparty risk in a swap portfolio because the exposure in the portfolio changes with market rates whereas the payout of the CDS contract in the event of default remains fixed. This issue is addressed by a contingent CDS contract, in which the payout varies with the exposure being hedged. Financial Accounting Standard FAS 157 requires this type of alignment for hedge accounting, and ISDA issued new documentation and procedures for

Chart 3.3.10 Spread Between Credit-Risk-Adjusted Italian and German Bond Yields



Source: Bloomberg, OFR calculations

contingent CDS transactions in February 2012, so this is a market that may have the potential to grow. Like many financial innovations, it carries both potential benefits and risks. The valuation of contingent CDS relies on the joint modeling of credit risk and market risk.

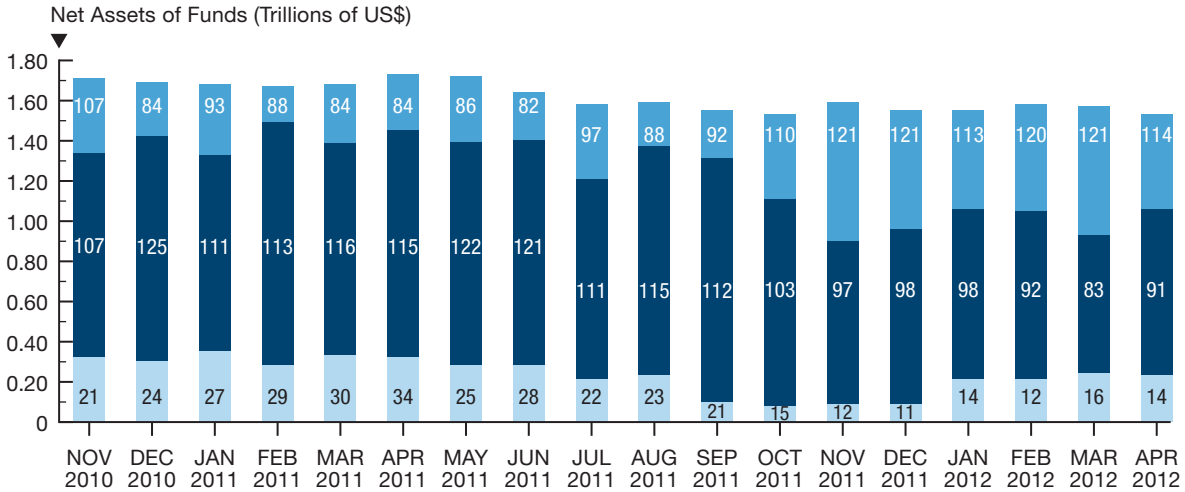
Counterparty Diversification

A simple but important tool in managing counterparty risk is spreading transactions across counterparties. The prudent number of counterparties is heavily dependent on context. As noted in Section 3.3.1, hedge funds traditionally relied on a single prime broker, but since the failures of Bear Stearns and Lehman Brothers, they have increasingly spread their business. In OTC derivatives markets, a handful of major dealers are dominant, making counterparty diversification difficult and creating a greater role for central clearing.

Chart 3.3.11 illustrates counterparty concentration among money market funds. The chart shows the vulnerability of funds to a default of their counterparties. The most vulnerable funds would break the buck—fall below the $1 net asset value by more than half a cent—if any one of 30 or more counterparties defaulted; the less vulnerable funds would break the buck if any one of 10 to 19 counterparties defaulted. The analysis assumes 40 percent recovery on all unsecured lending by the funds and full recovery on all repo transactions. ***Chart 3.3.12*** shows the total exposures of U.S. money market funds to different regions.

These two charts highlight the importance of understanding relationships and affiliations. Even a fully diversified portfolio could present counterparty risks that are not apparent on the surface, if it leads back through a web of

Chart 3.3.11 Prime MMFs' Vulnerability to Counterparty Failure



Number of different counterparties which could each cause fund to break the buck if they failed.

10-19 Counterparties 20-29 Counterparties 30+ Counterparties

Note: The height of each bar represents net assets; the number in each bar represents the number of funds in each category.
Note: Excludes exposure through repurchase agreements, ABCP, and VRDN guarantees. Prime funds only, assuming a 40 percent recovery rate, based on the actual net asset value of each fund's stated portfolio.

Source: SEC Form N-MFP, OFR calculations

counterparties to a concentrated set of guarantors.

Intangibles: Confidence and Implicit Guarantees

The most important element of counterparty risk may be the most difficult to quantify—market confidence, which can vanish abruptly and trigger failure. A loss of confidence may be a rational response to new information, and yet it can reach a tipping point unpredictably, leading to a cascade of adverse consequences. A loss of confidence played a role in the failures of Bear Stearns, Lehman Brothers, and MF Global, as it did historically in bank runs. Advancing best practices in risk management and monitoring threats to financial stability require developing a greater understanding of the dynamics of confidence and how greater visibility on capital, liquidity, leverage, and interconnections can promote confidence and stability. These important elements of market psychology fall outside of traditional economic modeling.

Perceived implicit guarantees are, by definition, intangible, and they are potentially destabilizing because they are unfunded and unpredictable in times of stress. The fixed share price offered by money market funds has drawn scrutiny as a perceived guarantee. Mass redemptions by money market fund investors in September 2008, after the Reserve Fund was unable to maintain a fixed share price, prompted the creation of the Treasury's Temporary Money Market Fund Guarantee Program, turning an implicit guarantee into a government guarantee.

Chart 3.3.13 compares asset levels for money market funds that are sponsored by banks and funds that are not. The chart begins at the end of the Treasury's program and distinguishes share classes with minimum investments of at least $100,000 from those with smaller minimum investments, which is a rough measure of the difference between institutional and retail accounts. Among share classes with the smaller minimum investment, the outflow from non-bank-sponsored funds is much larger than from bank-sponsored funds. In contrast, the share classes with a larger minimum investment show a large inflow to non-bank-sponsored funds between June 2010 and May 2011. Many factors influence these flows, including interest rates and the performance of other asset classes, but

the figure suggests the possibility of a perceived guarantee at bank-sponsored funds among smaller investors. The institutional flows are much more volatile and suggest that large investors may be more willing to move between types of funds as yields and perceived risks vary.

3.3.3 Credit Value Adjustment

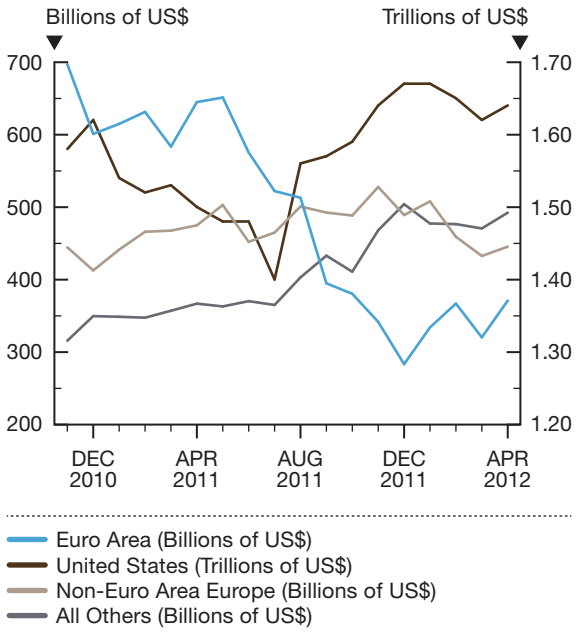
Industry practice and regulatory proposals have adopted credit value adjustment as a key measure of counterparty risk (BCBS, 2011; Cesari and others, 2010). CVA seeks to price the counterparty credit risk incurred by banks and broker-dealers through derivatives portfolios. Strong counterparty risk management is essential to financial stability, and CVA is an important barometer of the level of counterparty risk between pairs of market participants as viewed by the participants themselves. However, the evaluation of CVA presents both practical and conceptual challenges, and the increasing reliance on CVA requires continuing focus on fine-tuning the underlying principles and improving data management and standards.

The CVA Concept

CVA adjusts the market value of a swap or portfolio of swaps to reflect a counterparty's default risk. To illustrate this idea, suppose Party A has entered into an interest rate swap with Party B. In the absence of any default risk, Party A could value the swap off a risk-free yield curve. However, the possibility that Party B may default at some future date lowers the value of the swap to Party A. CVA seeks to quantify this effect.

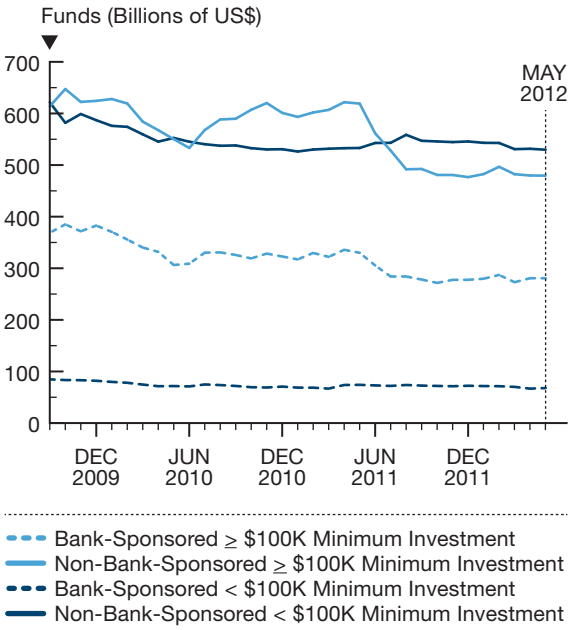
At inception, an interest rate swap is ordinarily designed to have zero net value to both parties. As interest rates vary over time, the swap could take on a positive value for either party. For example, if A is paying a fixed rate and receiving a floating rate from B, then an increase in the floating rate increases the value of the swap to A. The counterparty risk that A faces thus results from the combination of two factors: the possibility that interest rate moves increase the value of the swap to Party A and that Party B defaults. If the same interest rate movements

Chart 3.3.12 Total MMF Exposures by Region



Source: SEC Form N-MFP, OFR calculations

Chart 3.3.13 Money Market Fund Net Assets by Share Class Category and Sponsor Type



Note: Depiction of data starts at September 2009 to coincide with the expiration of the U.S. Money Market Mutual Fund Guarantee Program (September 18, 2009) and the Federal Reserve Money Market Investor Funding Facility (October 30, 2009).

Source: Morningstar, OFR calculations

that increase the swap value to Party A also make it more likely that Party B will fail (perhaps because B has a lot of floating-rate debt), then the combination produces "wrong-way risk" for A. If interest rates moved in the opposite direction, turning the swap into a liability for A rather than an asset, then A would not face any risk from a default by B.

As this example illustrates, a CVA calculation to price counterparty risk requires the integration of the following elements:

- a model of market risk factors (interest rates in the example above);
- a model of default risk (the risk that B will default); and,
- a model of the co-movement of market risk and credit risk factors (because B's default results in a loss to A only if interest rates increase).

The integration of market risk and credit risk—the last of these three elements—is the greatest modeling challenge to effective CVA calculation. The scale of the problem for large financial institutions with thousands of positions also poses a significant computational challenge, with CVA calculations often running overnight.

The foregoing discussion has taken the perspective of firm A; this is a unilateral CVA calculation. If A and B were both dealers, then B would have a mirror image perspective on the swap. The firms would have to use *bilateral* CVA calculations—incorporating the default risk of both parties—in agreeing on a price. This would add a fourth element to the CVA modeling challenge because of the reliance on the co-movement of A's default risk with B's default risk, as well as with market risk factors.

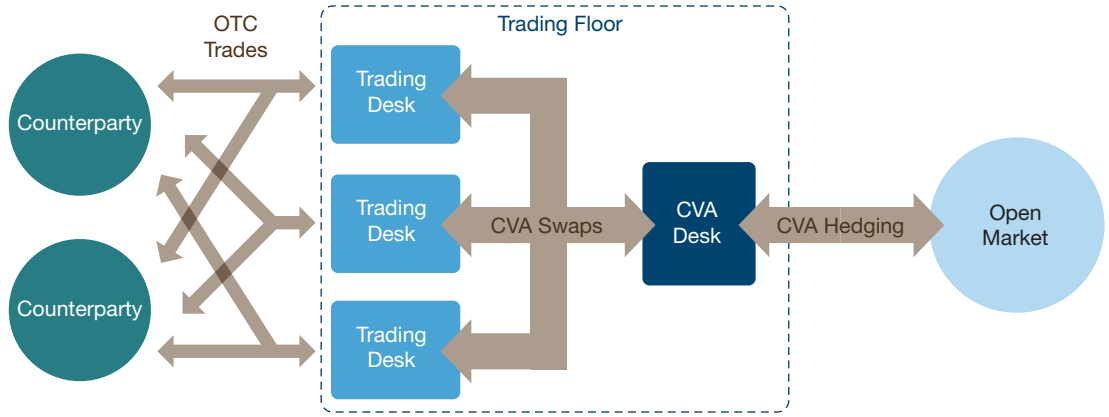
Centralized Counterparty Risk Management and Oversight

An effective CVA calculation aggregates all transactions a firm has with a counterparty, taking into account netting agreements, enforceability of these agreements, and collateral requirements to evaluate the path of future potential exposures. This leads to a single number quantifying the total counterparty risk a firm faces with each of its counterparties.

Financial firms with diverse trading activities are increasingly using this concept to centralize counterparty risk management. Individual trading units transacting with multiple counterparties "swap" their counterparty risk to a central CVA desk, which effectively charges them a fee for off-loading their counterparty risk. This internalizes the cost of counterparty risk at the level of the trading desk and allows the CVA desk to manage firmwide counterparty risk. The CVA desk may, for example, buy CDS protection on counterparties to hedge the firmwide CVA for that counterparty ***(Chart 3.3.14)***. This process allows for comprehensive firm-level counterparty risk management, but it also raises the stakes for the reliability of CVA modeling by pinning the pricing and hedging of counterparty risk on this number. Overreliance on this type of modeling, especially if it contains material flaws, could create a false sense of comfort, leading to greater risk-taking.

Because CVA aggregates and centralizes counterparty risk, it represents a potentially valuable tool for monitoring threats to financial stability arising through inter-firm exposures. From a systemwide perspective, counterparty risk is a network phenomenon—firms are nodes, and nodes are connected when they trade with each other. CVA measures the exposure on each edge of the network as quantified by the firms themselves for their internal risk management. CVA values could be viewed together with gross and net notional exposures to give a more nuanced perspective on potential buildups of counterparty risk. Gross and net exposures measure the sizes of potential losses, but CVA seeks to measure the market price for offloading exposure. As such, it is more sensitive to changes in market conditions as a gauge of financial stability.

Chart 3.3.14 CVA Hedging



Potential Pitfalls

Model Risk. The main obstacle to accurate CVA calculation lies in capturing co-movements between market risk and credit risk. The challenge is magnified by the need to address swap portfolios exposed to multiple sources of market risk with transactions that may extend 5 to 30 years. Little information is available to quantify the correlation between interest rates, exchange rates, and other market factors on one hand and the creditworthiness of a counterparty on the other hand. Moreover, correlation is a limited measure that cannot account for the full complexity of dependence between market risk factors and credit risk factors.

A weakness in integrating market risk and credit risk is that it leaves a firm exposed to "wrong-way risk," the possibility that a counterparty's credit declines just as the exposure to that counterparty increases. This scenario can occur, for example, when a dealer enters into an energy swap with an energy company and the dealer's side of the transaction increases as energy prices fall.

These considerations leave CVA exposed to a high degree of model risk, that is, vulnerability to errors that result from poor modeling assumptions. The OFR is developing methods for incorporating robustness to model uncertainty in risk calculations. These techniques identify model elements that contribute most to model risk and quantify their impact on risk measurement. In the case of CVA, a particular vulnerability lies in the dependence between a counterparty's CDS spread—a measure of its credit risk—and the value of a swap portfolio.

Data Management. Calculating a single CVA number for a counterparty requires aggregating all the ways a firm is exposed to that entity, incorporating all relevant netting agreements, and capturing terms and conditions of all transactions with the counterparty. This presents an enormous data management challenge and requires firms to continue to invest in technology. An LEI standard and the development of instrument identifiers will help simplify the CVA process and, more importantly, enhance its reliability.

Ambiguities. Although conceptually simple as a measure of counterparty risk, CVA poses some subtleties in its implementation and interpretation. For example, default risk in CVA is typically measured through CDS spreads but sometimes through internal credit ratings, particularly when no liquid CDS spreads or bond yields are available for a counterparty. CDS spreads reflect a market price for default risk whereas ratings ordinarily try to capture empirical default frequencies and recovery rates. Market risk measures, such as value at risk, are ordinarily based on empirical observations. Ambiguities also arise in measuring exposure at default. The exposure

is understood to be the replacement value of a derivative, but there is no consensus on exactly what this means and whether, for example, this replacement value should itself reflect default risk in the replacement counterparty. The handling of alternative events that may terminate a swap without a default raises the prospect of further discrepancies. It is in the financial industry's interest to resolve these ambiguities, and the OFR can help promote best practices on these issues.

Incentives. Many media accounts have noted instances of banks reporting mark-to-market profits as a result of a *decline* in their credit quality through a debt value adjustment (DVA). DVA is similar to CVA, but it applies to the price of a firm's own debt. A mark-to-market gain from deteriorating credit quality is an inevitable consequence of CVA and DVA pricing and fair value accounting; it is the mirror image of the loss a bank takes when the credit quality of its counterparties declines. In October 2011, Goldman Sachs reported it was hedging the impact of these fluctuations in its own credit spreads by selling CDS protection on other, presumably correlated financial institutions (Moyer and Burne, 2011). The net effect of such transactions is to increase overall counterparty risk in the financial system solely to modulate fluctuations in accounting figures.

Performance in Extremes. Market risk capital under Basel III includes a charge for counterparty risk tied to a CVA value at risk calculated at 99 percent confidence over a one-year horizon. Indeed, the European Banking Authority found the CVA charge to be one of the main drivers of increased capital needs anticipated for large European banks under Basel III (EBA, 2012). In principle, measuring the CVA value at risk requires recalculating CVA for multiple dates within the one-year horizon across a wide range of potential market scenarios—wide enough to reliably capture the worst 1 percent of potential outcomes. The challenges in calculating CVA at a single point in time, capturing the risk in a potentially large and long-dated portfolio of swaps, are thus greatly magnified when the procedure is extended to map the potential evolution of CVA over a one-year horizon and stressed to the worst 1 percent of market and credit scenarios.

Potential Spirals. CDS spreads are used to calculate CVA and CDS contracts are used to hedge CVA. In the absence of sufficient CDS liquidity, this sets up a potential downward spiral, with widening CDS spreads (for a sovereign, say) increasing the hedging demand, and hedging demand widening the spread.

Myopia. Even if calculated accurately, CVA captures, at best, the immediate cost of a counterparty's default. This is a myopic view in the sense that it does not capture the potential follow-on effects of such a default. One default can trigger financial distress at other firms and elevate counterparty risk across the financial system. A comprehensive macroprudential view of counterparty credit risk must incorporate these rippling, network effects, as well as the direct impact of a default.

3.3.4 Conclusion

The OFR has a mandate to promote best practices in risk management. Under the broad category of risk management, counterparty risk management is of special importance in ensuring the resilience of the financial system because it addresses the linkages of the financial system. Failures of counterparty risk management allow losses at one institution to propagate to others through the interconnections among financial intermediaries; strong counterparty risk management provides a buffer against threats to financial stability.

This chapter has taken a broad view of counterparty risk to include not just risks in over-the-counter derivatives markets but also issuer risk, exposures through third-party guarantees, repurchase agreements, and relationships between prime brokers and hedge funds. These linkages and transactions arise to meet the needs of the financial system and to enable the financial system to provide

services to the broader economy. These same linkages create potential vulnerabilities if not properly managed. The elements of effective counterparty risk management include strong internal controls and governance, netting agreements, collateral, hedging, and central clearing. As the challenges and tools of counterparty risk management continue to evolve, market participants can benefit from a coordinated effort to address some of the challenges highlighted in this section. The OFR's current work in helping establish a global LEI is also an important step in strengthening counterparty risk management by standardizing the identification of counterparties.

This chapter has highlighted an evolving focus on CVA as a key measure of counterparty risk in both market practice and financial regulation. If evaluated correctly, CVA provides a valuable barometer of vulnerabilities in the financial system. But important questions remain around the principles and practice of CVA calculation. Improvements in this area can benefit all market participants and enhance supervision. The OFR, working with other FSOC members and the financial services industry, can help advance these efforts.

Endnotes

1. CGFS (2011) examines the macroprudential issues surrounding liquidity crises and liquidity management. Tirole (2011) surveys the underlying economics.

2. Eisenberg and Noe (2001), Billio and others (2010), and Gai, Haldane, and Kapadia (2011) seek to understand contagion effects caused by financial firms' contractual relationships, such as counterparty credit risk exposures or liquidity guarantees. Cont, Moussa, and Santos (2010) and Haldane (2009) also consider the ramifications of network complexity as a factor in systemic fragility.

3. The historical approach has also been adopted recently by others, including Kyle and Obizhaeva (2012), Brave and Butters (2012), and Lo and Zhou (2012). CoVaR and systemic expected shortfall cannot be applied to the 1929 event, because investment banks from the period did not trade publicly, while commercial bank stock prices are not readily available in digital form.

4. For example, Duffie (2011) proposes asking 10 large financial institutions to report their 10 largest net bilateral exposures and to stress them under 10 scenarios. Brunnermeier, Gorton, and Krishnamurthy (2011) propose a two-step "risk topography" analysis. First, regulators would accumulate a panel of participants' individual risk exposures (changes in firm value) as well as liquidity sensitivities (changes in "effective cash") to various shock scenarios defined on a space of external factors. The second step would aggregate firms' individual valuation and liquidity responses into a systemwide picture of risks, where those exposures diversified in the cross-section of firms should be of less concern than systemically concentrated exposures. Both proposals combine forward-looking risk analytics and network effects and neither can be implemented with the data available today.

5. This also means that from a macroprudential standpoint, "even solvent banks may be required to refrain from depleting capital if the system as a whole does not meet the higher macroprudential criteria. For shareholders, one dollar inside the bank should be worth more than one dollar in dividends. But, in any case, supervisors should consider more than just private benefits and costs. Had U.S. supervisors suspended dividends in the summer of 2007, $80 billion of capital could have been retained in the 19 banks that were subject to the 2009 Supervisory Capital Assessment Program. That sum is roughly half of the public recapitalization funds that these banks received." (Greenlaw and others, 2012).

6. In the CCAR, large BHCs must perform four stress tests to provide an indication of the effect of the stresses on revenues, losses, reserves, and pro forma capital levels: a BHC-defined baseline scenario, a supervisory baseline scenario specified by the Federal Reserve, a BHC-defined adverse scenario, and a supervisory adverse stress scenario specified by the Federal Reserve. The Federal Reserve scenarios are defined over 25 variables, including measures of economic activity and prices (gross domestic product, unemployment, disposable income, and inflation), financial factors (two house price indexes, an equity index, and a market volatility index); interest rates (three-month Treasury bills, 10-year Treasury notes, 10-year BBB corporate bonds, and fixed-rate 30-year mortgages); and international measures, each provided for four country blocks (change in real GDP, change in inflation, and exchange rates) (Board of Governors, 2012).

7. The IMF's stability assessment for Iceland had stated prior to the crisis in that country: "The banking system's reported financial indicators are above minimum regulatory requirements and stress tests suggest that the system is resilient" (IMF, 2008). For evaluations of stress test practices, see Borio, Drehmann, and Tsatsaronis (2012) and Alfaro and Drehmann (2009).

8. Specifically, the Basel II document states that banks should perform "rigorous, forward-looking stress testing that identifies possible events or changes in market conditions that could adversely impact the bank" (BCBS, 2004).

9. The new disclosure regime based on Section 165(i) of Dodd-Frank began with CCAR 2012; the first CCAR exercise, in 2011, displayed a lower level of disclosure than the SCAP, with no bank level results

being published. The stress scenario disclosure for CCAR 2012 included results based on the projections made by the Federal Reserve of each bank holding company's losses, revenues, expenses, and capital ratios over the planning horizon.

10. See EBA (2011). In addition to the results of the stress test under the baseline and adverse scenarios, institution-specific disclosures contain information on credit exposures and exposure to sovereigns.

11. Recent research on liquidity risk includes papers published by the Bank of England (Aikman and others, 2009), the Hong Kong Monetary Authority (Wong and Hui, 2009), the Dutch National Bank (Van den End and Tabbae, 2009), and the IMF (Schmieder, Puhr, and Hasan, 2011). Systemic episodes emerging from credit risk and funding risk are provided in Gorton and Metrick (2009) and Afonso, Kovner, and Schoar (2011). Barnhill and Schumacher (2011) observe that a systemwide liquidity shock is more likely to happen in the presence of a shock to fundamentals that depresses asset values and makes the market reluctant to fund these assets and the institutions holding them.

12. Afonso, Kovner, and Schoar (2011) examine the connections between solvency and liquidity during the crisis and conclude that counterparty risk played a larger role than liquidity hoarding.

13. Brunnermeier and Pedersen (2009) and Diamond and Dybvig (1983), respectively, provide models of liquidity shocks and funding shocks.

14. "The stress scenario projections do not make explicit behavioral assumptions about the possible actions of a bank holding company's creditors and counterparties in the scenario, except through the Supervisory Stress Scenario's characterizations of financial asset prices and economic activity" (Board of Governors, 2012).

15. The credit-risk-adjusted German or Italian bond yield is defined as the yield offered to an investor purchasing a five-year German or Italian bond and five-year CDS protection on that bond. The credit-risk-adjusted spread is the spread between the credit-risk-adjusted Italian and German bond yields.

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