WP/09/230

IMF Working Paper

Global Market Conditions and Systemic Risk

Brenda González-Hermosillo
and Heiko Hesse

INTERNATIONAL MONETARY FUND

 WP/09/230

IMF Working Paper

Monetary and Capital Markets Department

Global Market Conditions and Systemic Risk[1]

Prepared by Brenda González-Hermosillo and Heiko Hesse

Authorized for distribution by Laura Kodres

October 2009

Abstract

Abstract: This paper examines several key global market conditions, such as a proxy for market uncertainty and measures of interbank funding stress, to assess financial volatility and the likelihood of crisis. Using Markov regime-switching techniques, it shows that the Lehman Brothers failure was a watershed event in the crisis, although signs of heightened systemic risk could be detected as early as February 2007. In addition, we analyze the role of global market conditions to help determine when governments should begin to exit their extraordinary public support measures.

JEL Classification Numbers: C32, E44, G12

Keywords: Systemic Risk, Global Financial Crises, Emerging Markets, Subprime Crisis, Volatility, Solvency, Markov-Switching

Author's E-Mail Address: bgonzalez@imf.org and hhesse2@imf.org

[1] We would like to thank Laura Kodres and seminar participants at the Banco Central de Chile, Bank of England, Bundesbank, ECB, European Commission and IMF for useful comments and suggestions.

Contents Page

Figures

I. INTRODUCTION

The IMF has been recently called upon by the international community to deepen its work on systemic risk, on identification of systemically important institutions and markets, as well as on developing early warning signals of distress. An important element of anticipating and identifying systemic events are the role played by underlying "market conditions" and the ability for events to subsequently further alter fragile market conditions. At its most basic level, the value of the assets on the books of financial institutions are highly dependent on the underlying financial environment. When the level of market uncertainty (measured, for example, by the implicit volatility of asset prices) is high, then even a temporary shock can lead to defaults and generate significant negative aftershocks, including liquidity spirals (Brunnermeier and Pedersen, 2009). Similarly, when investors' risk appetite is low or global liquidity is tight, even relatively small shocks can have large effects on global financial markets.

The observation that general market conditions matter for the existence and propagation of risks through the financial system can be used to examine periods of high vulnerability to shocks that may become systemic. While most of the tools used to compute early warning indicators of crisis rely on an assessment of vulnerabilities (as measured, for example, by large current account deficits or high debt levels), often those vulnerabilities can persist for a long time, even years, before a crisis occurs. Abrupt changes in market conditions are often the "trigger" that sets off a financial crisis. Moreover, some of the measures of financial fragility that are widely used (including credit default swap spreads, but also some more sophisticated reduced-form models of financial instability) are typically unable to separate the idiosyncratic credit risk component associated with the potential default of an individual institution from the intrinsic premium that is attached to the overall distress in market conditions. Finally, it is also useful to identify when market conditions signal a regime change such that tranquil periods turn into medium or high volatility states, or when they reverse to more tranquil periods and the exit of supporting government interventions can be considered.

We adopt regime switching models using variables that proxy for several key global market conditions. In particular, the VIX is used as a proxy for market uncertainty,[2] the three-month TED spread as a measure for stress in the interbank market,[3] and the euro-U.S. dollar forex swap as an indicator of U.S. dollar funding pressures in international financial markets.[4]

---

[2] The VIX, the Chicago Board Options Exchange volatility index, is a measure of the implied volatility of the S&P 500 index options over the next 30 days and is calculated from a weighted average of option prices.

[3] The TED spread is the difference between the three-month LIBOR and the three-month treasury bill rate.

[4] The spillovers from the interbank market to the foreign exchange swap market has led to periods whereby foreign exchange swap prices deviated from that implied by covered interest parity conditions. This highlights

(continued)

We first look *qualitatively* at the behavior of some global market variables in advanced and emerging market economies during the financial crisis before presenting the formal findings of the regime switching models. The analysis presented is focused on two periods, with the first one concentrating on the events and market signals that led to the peak of the global crisis in the aftermath of the Lehman collapse on September 15, 2008. This marked a watershed event that led to rapid spillovers to emerging market economies, sharply increasing uncertainty across asset markets, a scramble for U.S. dollars with the breakdown of the carry trade, and the need for financial institutions to refinance their U.S. dollar positions. The regime switching models indicate a move towards a high volatility state before the Lehman episode, which are consistent with elevated systemic risks in the financial system.

The second period of analysis is that which followed massive government intervention in a number of countries in support of their financial systems. The examination of the most recent period is of interest because global market conditions and economic activity appear to have improved since mid-2009, potentially signaling that exit strategies can begin to be contemplated. The results suggest that, although market conditions have improved substantially since the spring 2009, the regime switching models examined still signal moderate pressures on certain market conditions. In particular, the VIX and the forex swap market both signal a high probability of a medium-volatility regime. In contrast, the TED spread strongly signals a high probability of being in a low-volatility state.

The paper is organized as follows: Section II provides on overview of systemic risk, while Section III discusses the role of global market conditions and systemic risk from a qualitative perspective. The methodology and results are presented in Section IV, and we offer some concluding remarks in Section V.

II. Overview of Systemic Risk

Before evaluating tools that can be useful to detect and measure "systemic risk," one needs to define it. "Systemic risk" is a term that is commonly and broadly used. However, it has so far resisted formal definition and quantification. Indeed, systemic risk typical reflects a sense of a "broad-based" breakdown in the financial system which is normally realized (ex-post) by a large number of failures of financial institutions (usually banks). Similarly, a systemic episode may be simply seen as a extremely acute financial crisis, even though the degree of severity of the financial stress has proven difficult, if not impossible, to measure.[5] Systemic

---

the international interconnectedness of banks' funding requirements through foreign exchange swap markets and the potential for banks' inability to obtain funding liquidity.

[5] Some recent attempts to measure the degree of severity of financial stress in a given country include Illing and Liu (2006). However, most empirical analyses of multi-country financial crises rely on a binomial notion

(continued)

risk is also viewed as a phenomenon not only measured by its intensity, but also by the breath of its reach across markets and countries.

Although systemic events are intrinsically related to an aggregate measure of risk, it is ultimately built up by its components. In this sense, a natural starting point is to begin by examining the characteristics of individual financial institutions. Some financial institutions may be simply too-interconnected or large enough that are systemically important. However, the sum of the fragilities of individual financial institutions may not necessarily equate to the fragility of the global financial system. Indeed, a body of the literature has made the case that systemic events are often characterized by contagion, whereby financial crises in some markets spillover to others in ways that are not characteristic of non-crisis periods. In particular, channels over and above the market fundamental mechanisms that link countries and asset markets during non-crisis periods appear only during contagious episodes.[6] The classic example of contagion in the earlier literature is that of bank panics resulting from information asymmetries. In particular, depositors withdraw their funds simultaneously from banks, creating a "run" on bank assets that ultimately leads to multiple bank failures (even from banks that were considered to be sound prior to the run).[7] Since the establishment of deposit insurance schemes in the United States in 1934 and in other advanced economies several decades ago, and more recently in practically all developing countries following the Asian crisis in 1996, deposit "runs" have become less frequent than before. However, the recent financial crisis that began in mid-2007 has brought to the forefront other types of bank runs. These more recent "runs" have encompassed runs on wholesale funding (including the inability to roll roll over funding for banks' off-balance sheet special purpose vehicles), on interbank lending,[8] and on banks' market equity values.[9]

At the heart of most of these approaches is the notion that "systemic" events are somehow self-reinforcing and bring into play additional linkages across countries and markets that only

---

whereby the dependent variable takes the value of one during the known crisis period or zero otherwise (e.g., Kaminsky and Reinhart (1999); Hardy and Pazarbasioglu (1999); and Demirguç-Kunt and Detragiache (1998)) with no information about the actual severity of the crises.

[6] See, for example, Masson (1999); Dornbush, Park, and Claessens (2000); and Dungey, Fry, González-Hermosillo, and Martin (2005, 2006, 2007). Dungey, Fry, González-Hermosillo, and Martin (forthcoming) argue that the LTCM/Russian crisis in 1998 and the subprime crisis that began in mid-2007 have been the most contagious crises in the past decade, based on a sample of advanced and emerging economies whereby credit and equity market daily data are modeled jointly across countries.

[7] Deposit runs are formally modeled as a result of asymmetries of information by Diamond and Dybvig (1983). More recently, Laeven and Valencia (2008) suggest blanket deposit guarantees to address information asymmetries.

[8] Issues associated with banks' restricted interbank lending are examined in IMF (2008).

[9] These more recent types of "runs" are discussed by Gorton (2008).

exist during systemic episodes. For example, a liquidity shock which is temporary by nature, can metamorphose into a default event which further affects liquidity conditions.[10] This view intrinsically suggests that the degree of vulnerability of individual financial institutions may be related to the degree of stress in global market conditions. For example, when the level of market uncertainty (measured by the implicit volatility of assets) is high, then even a temporary liquidity shock can lead to defaults and have exponential aftershocks. Similarly, when investors' risk appetite is low or global liquidity is tight, then even relatively small shocks can have large effects on global financial markets—and vice-versa.[11]

From the risk managers' perspective, systemic risk is often viewed in the context of hedging positions, such that a diversified portfolio should be able to neutralize market risks. Systemic events in this context are often measured in practice by the degree of correlation of the various markets in a diversified portfolio; the higher the correlation among assets, the less ability that market participants have to hedge the odds. Market participants usually look at correlations during "normal" times as a gauge to compare correlations when asset markets become synchronized during periods of stress. Cluster analysis is a tool often used to rank events based on their degree of correlation. However, from a statistical perspective, observed high correlations could be simply a function of the non-constant volatility characteristic of the shocks.[12] Thus, basic measures of correlation need to control for the fact that the volatility of the shocks is typically autocorrelated (heteroskedasticity) during crises periods.

More generally, systemic financial risk is also connected to the notion that there is a regime shift such that normal periods, and even "contained" crises, become fundamentally different at some point. In addition to changes in correlations among assets, it may be that higher moments (including skewness and kurtosis) in the probability density function of the data generating process also change during systemic events. Complicating this analysis is the fact that policy actions (such as providing guarantees, capital injections, and various other crisis resolution schemes) can alter the outcome of events by reducing systemic risks. Some government actions (including lack of a comprehensive crisis resolution strategy) can also actually increase systemic risks.

Finally, systemic risk is some times reserved for events that trigger a loss of economic value or confidence in a substantial portion of the financial system that is serious enough to have significant potential effects on a country's real economy.[13] Similarly, the real sector effects can be extended to span not only a certain country or group of countries, but most of the

[10] Brunnermeier and Pedersen (2009) model this process for the current financial crisis.

[11] Different measures of risk appetite are discussed in González-Hermosillo (2008).

[12] As argued by Forbes and Rigobon (2002).

[13] Group of Ten (2001).

world through direct financial links (such as financial institutions' parent-subsidiary connections, cross-border financial flows, trade finance affecting global trade), or indirect links (rebalancing of investors' portfolios, deleveraging, and repricing of relative risks as some debt becomes guaranteed but other is not and therefore becomes less attractive). Even under confidence and lack of information can work as catalysts to spread systemic risks.

Clearly, it is difficult to ascertain when financial crises become "systemic," and how to measure the degree of systemic risk. Given the growing complexity and interconnectivity of the global financial system, it is a daunting task to expect to arrive at a single measure of systemic risk. Indeed, systemic financial risk may be best viewed as a collection of measures.[14] However difficult it is to measure financial systemic risks, and all the caveats associated with any such measures, knowing when the system switches into systemic gear is of critical importance for policymakers. In particular, it is unfeasible to expect to manage systemic risk if it cannot be gauged, even if imperfectly.

This paper examines financial "systemic" risk from one particular angle in search for indicators that would have been useful in anticipating systemic events during the current crisis. The approach chosen to assess systemic risk is to examine regime changes in global market conditions. This information can be also invaluable in determining when market conditions have improved sufficiently for policymakers to begin to "exit" the interventions that were previously introduced to provide support to the financial system in a systemic crisis.

III. Global Market Conditions and Systemic Risk: A Qualitative View

With interbank markets across various advanced economies becoming clogged in early August 2007, there was clear evidence towards a "*run for quality"* by investors. For example, the gold spot price, which is often used as a crude measure of storage of value, started its continuous increase in early August 2007 from $660 per ounce and reached its peak of $1002 around the Bear Stearns rescue by JP Morgan and the Fed's announcement of the Primary Credit Dealer Facility on March 16, 2008, after which time the gold spot price dropped 10 percent in a short time.[15] In addition, there was a strong demand for 10-year U.S. Treasuries as a "safe heaven," and yields almost halved between the onset of the crisis in August 2007 and the Bear Stearns and Lehman episodes. The bid-ask spread deviated frequently from its usual pattern.

---

[14] Lo (2009), for example, considers that "systemic" risk should be measured by leverage, liquidity, correlation, concentration, sensitivities, and connectedness.

[15] The bankruptcy of Lehman Brothers saw the price of gold soar over 20 percent within a few weeks, as global risk appetite dramatically deteriorated and precipitated a run for quality across asset classes and markets.

The "run for quality" was also accompanied by a "*run for liquidity.*" With liquidity evaporating in many asset-backed securities, liquidity spirals occurred with a lack of both market and funding liquidity interacting, significantly impairing funding and asset-backed markets (IMF, 2008 and Frank, González- Hermosillo, and Hesse, 2008). While the Libor-OIS spread, as a proxy for funding liquidity and general stress in the interbank markets, has been subject to various humps such as at the onset of the crisis and with end-year effects in December 2007, the Lehman collapse exposed the interbank market to heightened counterparty and liquidity risk concerns, with market participants across the world withdrawing from these market segments. Many central banks had to inject liquidity and, in effect, substituted for the interbank market. There was a shortage of high-quality collateral for posting with the central bank with haircuts increasing across Treasury securities and risky assets. After the Lehman collapse, the failure of counterparties to deliver U.S. Treasuries to other parties in repo transactions, due to inability or unwillingness drastically soared.[16]

Volatility in various asset classes was also affected, mirroring the humps of the Libor-OIS spreads. For instance, a structural break of the VIX since the Lehman collapse is apparent with other implied volatility equity indices also revealing similar patterns. Volatility also spilled over into the foreign currency markets with the carry trade starting to rapidly unwind at the end of September 2008. The implied volatilities of major emerging market (EM) currencies (based on option prices) were reflecting this breakdown in the carry trade. High-yielding and previous investment currencies saw large depreciations against the U.S. dollar, while funding currencies such as the Japanese yen benefited from a repatriation of funds. There was a scramble for U.S. dollars, which was reflected in the higher volatility of the euro-U.S. Dollar swap rates. Relatedly, the assumption of covered interest rate parity (CIRP) has been also violated during the crisis.[17] The daily deviations from the CIRP jumped at the time of the Bear Stearns rescue, and then completely broke down for various EM currencies after Lehman's bankruptcy.

EM countries were less affected in the initial stages of the subprime crisis than countries in the epicenter; for example, EM equity markets peaked in November 2007. But the persistency of the crisis, the deterioration of economic fundamentals in advanced economies and the rise of global risk aversion, hit EM countries with full force in late 2008 after the Lehman collapse (see also Frank and Hesse, 2009). In particular, flows to EM equity and debt mutual funds turned negative. Total foreign assets in EM equity mutual funds peaked in November 2007, but assets in the equivalent EM debt mutual funds only began to fall rapidly

---

[16] This indicated that despite the higher supply of U.S. Treasury bonds, market participants had very high demand for U.S. Treasury collateral and were concerned about counterparty risk, even though governments had announced plans to re-capitalize major financial institutions and guarantee bank liabilities.

[17] The CIRP postulates that the currency forward premium equals the interest rate differentials of the home and foreign interest rate covering the same time period. A violation would indicate possible arbitrage opportunities.

beginning in September 2008, driven by the sharp fall in global risk appetite after the Lehman collapse and fear that EM economies would be affected by the looming recession in advanced economies. While EM corporate spreads (over Treasuries) gradually began to increase following the onset of the subprime crisis, they escalated sharply across the various EM regions after the Lehman bankruptcy. Similar behavior can be observed for the cost of corporate credit, especially high-yielding, in the United States and Europe.

EM countries with large current account deficits and whose banks prior to the crisis have been most reliant on foreign wholesale funding have been affected the most by the ramifications of the financial crisis. Initial financial spillovers to EM countries quickly morphed into real sector problems, whereby economies reliant on declining demand and available trade finance saw their domestic industrial production and GDP growth rates plunging. In order to counteract the looming adverse real sector impacts as well as to provide liquidity and credit support to the domestic banking systems, large fiscal stimulus plans were implemented beginning in late-2008.

Interestingly, emerging market equity, fixed income, and currency markets saw a sharp sell-off in February 2007, a relatively short-lived episode, but it revealed how fast and broad-based a worldwide reappraisal of risk and flight to quality can occur. Starting in late-February 2007, there was a significant correction in the Shanghai stock market due to an unwinding of large long equity positions. This reverberated across emerging and mature markets. At the same time, the price of the ABX (BBB) index (based on CDS written on subprime mortgages, investment grade tranche) began to decline while the outlook on the U.S. housing market worsened further. In particular, carry trades in high-yielding currencies such as in Brazil, South Africa, and Turkey, were rapidly unwound, causing them to decline and the yen to appreciate. In addition, implied volatilities across a range of other asset markets, notably fixed-income and equity, sharply increased and stock markets in previously booming economies such as China, Malaysia, Philippines, or Turkey observed the largest declines. The fall in global risk appetite was broad-based without much differentiation across regions. Compared to equity markets, sovereign spreads across EM countries did move in tandem with the general market direction but were less affected.

Since the spring of 2009, bolstered by central bank interventions, fiscal stimulus packages and a nascent pick-up of economic activity in advanced and developing countries, global market conditions have improved. For instance, volatility across asset classes has significantly subsided (albeit still at higher levels than the pre-crisis), and especially emerging markets have benefited from an improvement in global risk appetite. While a qualitative analysis is a useful starting point to examine the role of key global market variables in systemic risks, a more formal systematic analysis follows below.

IV. Markov-Regime Switching Analysis

We use Markov-regime switching techniques to examine financial stress in a formal way. Given the intrinsic volatility of high-frequency financial data, especially during periods of stress, the ARCH Markov-Switching model (SWARCH) by Hamilton and Susmel (1994) is chosen here because it can differentiate between different volatility states, for example, low, medium, and high. In particular, univariate SWARCH models are adopted with variables in first differences to account for the non-stationarity of the variables.

In general, the parameters of the ARCH process can alter. Equation (1) below describes a Markov chain with y_t being a vector of observed variables and s_t denoting a unobserved random variable with values 1, 2, …, K that as a state variable governs the conditional distribution of y_t.

$$\text{Prob}\,(s_t = j \mid s_{t-1} = i, s_{t-2} = k, ..., y_{t-1}, y_{t-2}, ...) = \text{Prob}\,(s_t = j \mid s_{t-1} = i) = p_{ij} \tag{1}$$

It is possible to combine all the transition probabilities p_{ij} in a $K \times K$ transition matrix. In our SWARCH framework, the mean equation is an AR(1) process and the variance is time-varying with the ARCH parameters being state dependent. Formally, the AR(1) process follows

$$y_t = \alpha + \phi y_{t-1} + \varepsilon_t \tag{2}$$

The time varying variance h_t^2 with the error term ε_t is parameterized as

$$\begin{cases} \varepsilon_t = \sqrt{g_{S_t}} \times \tilde{\varepsilon}_t \\ \tilde{\varepsilon}_t = h_t \bullet \upsilon_t \\ h_t^2 = a_0 + a_1\tilde{\varepsilon}_{t-1}^2 + a_2\tilde{\varepsilon}_{t-2}^2 + ... + a_q\tilde{\varepsilon}_{t-q}^2 + \delta \bullet d_{t-1} \bullet \tilde{\varepsilon}_{t-1}^2, \end{cases} \tag{3}$$

where $\upsilon_t \sim N(0,1), S_t \in \{1,2,3\}$ and d_{t-1} is a dummy variable in which $d_{t-1} = 1$ if $\tilde{\varepsilon}_{t-1} \leq 0$ and $d_{t-1} = 0$ if $\tilde{\varepsilon}_{t-1} > 0.$ Hereby, it is assumed that υ_t follows a mean zero process with unit variance that is independently and identically distributed (i.i.d.). The ARCH parameters are thus state dependent due to multiplication with the scaling factor g_{S_t} which is normalized to unity for the low volatility regime.[18]

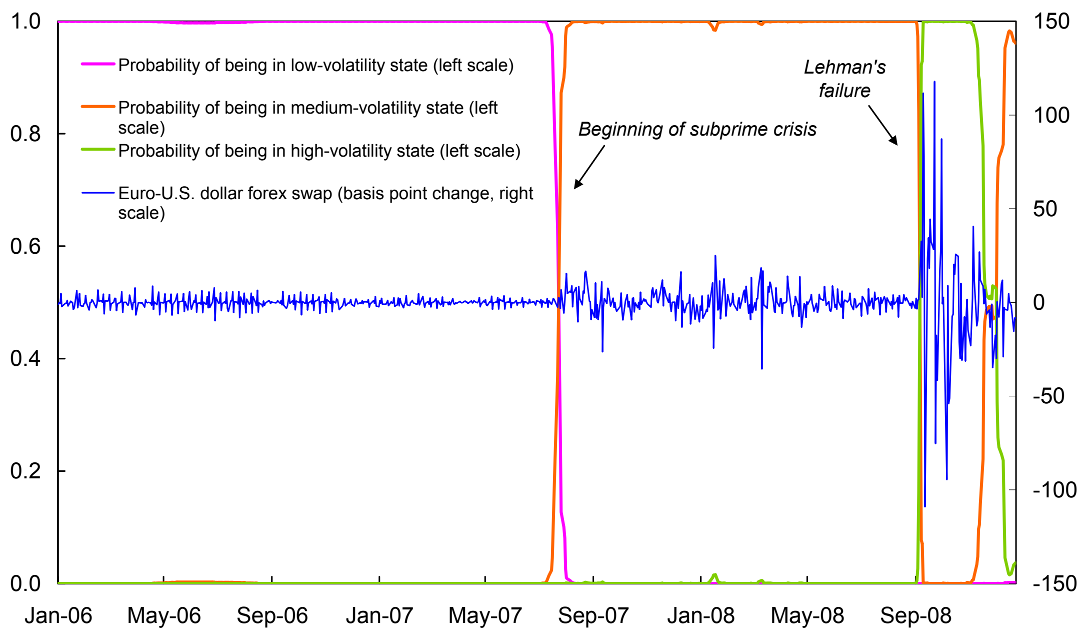
[18] In this paper, an ARCH specification is estimated, as the GARCH(p,q) is not nested within the SWARCH framework, due to its implicit infinite lag representation.

A. Results During the Peak of the Crisis

1. SWARCH Model based on Euro-Dollar Forex Swap

A regime switching model of the euro-U.S. Dollar Forex swap reveals that this variable moves from a low to a medium volatility regime in the beginning of August 2007, before entering the high volatility state right after the Lehman collapse in September 2008, remaining there until the end of November 2008 (Figure 1). Many non-U.S. banks, especially European ones, faced a shortage of U.S. dollar funding for their conduits and SIVs beginning in the summer of 2007. As the interbank market for dollar funding became squeezed due to counterparty and liquidity risks, these banks increasingly engaged in foreign currency (FX) swap arrangements as well as in the cross-currency swap market (see Baba et al, 2008). In particular, both the euro and sterling were used as the funding currencies for the dollar FX swaps. The spillovers from the interbank market to the FX swap market led to a situation whereby FX swap prices temporally deviated from their covered interest parity condition. With the turbulence becoming more persistent, many non-U.S. financial institutions also increasingly engaged in the longer-term cross-currency swap markets. This episode especially highlighted the international interconnectedness of banks' funding requirements through FX swap markets.

Figure 1. Euro-Dollar Forex Swap



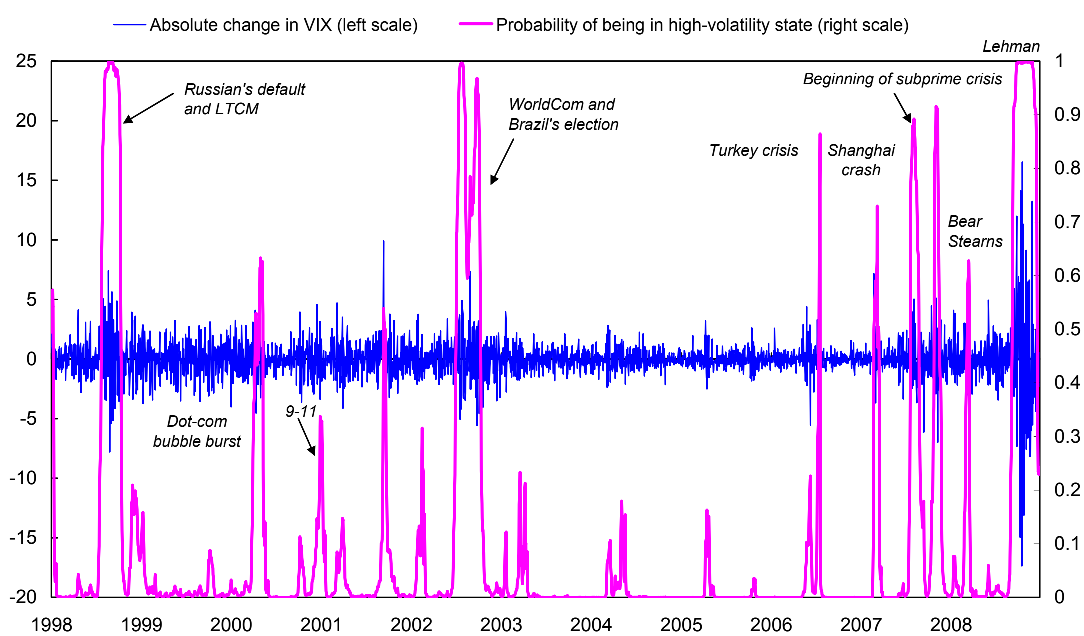
Sources: Bloomberg L.P.; and IMF staff estimates.

As shown in Figure 1, the move of the forex swap into the high volatility state on September 15, 2008, coincides with the sharp increase in counterparty risk resulting from Lehman's failure and a sizeable dollar shortage that occurred with margins and haircuts increasing on most dollar-denominated assets.

2. SWARCH Model based on the VIX

After the Lehman episode, the VIX increased to historical heights, and it is of interest to put the S&P 500 stock market volatility during the current financial crisis into a historical perspective. Figure 2 shows a daily SWARCH model for VIX from 1998 to the end of 2008. The model has the highest probability of being in the high volatility state during the Russian Crisis and LTCM default in 1998, the period surrounding the WorldCom scandal and Brazil's election in 2002, as well as the beginning of the subprime crisis in the fall of 2007 and the period following the Lehman collapse. In particular, the model also enters the high volatility state briefly at the time of the Shanghai stock market crash and the first abrupt ABX (BBB) price decline of investment grade asset-backed subprime mortgages in late-February 2007. During the Bear Stearns rescue, the VIX was more likely to be in the high rather than medium volatility state. The Lehman failure then triggered a very fast movement of the VIX into the high volatility regime where it remained until the end of the sample period ending December 31, 2008. After the start of the subprime crisis, the VIX only oscillated between the medium and high regime, in contrast to the predominantly low volatility regime during 2003–2007.

Figure 2. Markov-Switching ARCH Model of VIX



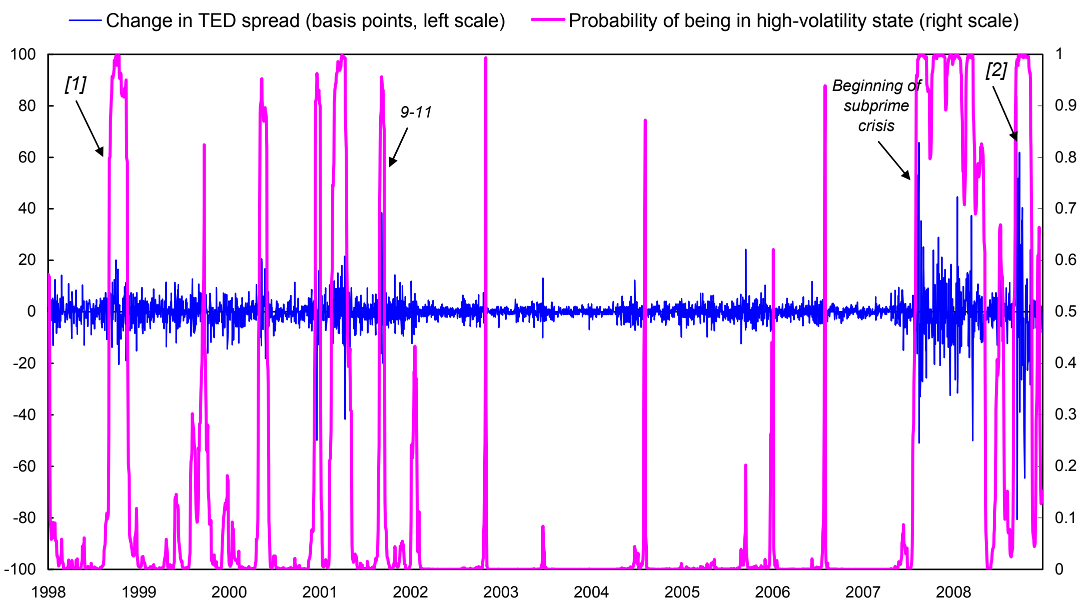
Sources: Bloomberg L.P.; and IMF staff estimates.

3. SWARCH Model based on TED Spreads

A similar SWARCH model is estimated for the three-month TED spread (the difference between Libor and Treasuries). Figure 3 suggests that this indicator of short-term bank credit risk moved decidedly into a high volatility regime in the beginning of August 2007 and remained in it until the Bear Stearns' rescue. The Lehman collapse again triggered a high volatility regime. As in the VIX model, the SWARCH framework for the TED spread picks up the Russia and LTCM default in 1998 as well as the September 11 shock. The findings also imply a role for the sharp Shanghai stock market correction and the first round of ABX (BBB) price declines in late February 2007, which could be seen as a potential warning signal about the impending fragilities in the global financial system.

Overall, while the recent persistence of the high-volatility period for the TED spread is unprecedented over the past decade, that for the VIX is not, suggesting a greater relative stress in interbank markets during this crisis episode.

Figure 3. Markov-Switching ARCH Model of TED Spread



Sources: Bloomberg L.P.; and IMF staff estimates.
Note: [1] = Russian default and LTCM crisis; [2] = Lehman Brothers failure.

B. Results After Massive Government Programs in 2009 to Address the Global Crisis

Since the peak of the global crisis following the bankruptcy of Lehman Brothers in September 15, 2008, and particularly in the early part of 2009, a number of countries introduced measures in support of their financial systems which ranged from implicit and explicit guarantees to capital injections and outright nationalization of banks. In this regard, Aït-Sahalia et al (2009) find that, for a number of advanced economies and using an event study methodology, government interventions had a significant impact on the easing stress in the interbanking market but that this effect was smaller the more prolonged the crisis became.[19] The examination of this most recent period may help policymakers decide whether indeed market conditions have sufficiently stabilized so that they can start to exit their massive support provided to the financial system. Casual observation would suggest that global market conditions and economic activity have improved significantly in 2009. The regime switching models examined still provide a mixed picture and signal moderate pressures on certain market conditions through the summer of 2009.[20] For example, while the TED spread strongly signals a high probability of being in a low-volatility state, the VIX and the forex swap market both signal a high probability of a medium-volatility regime.

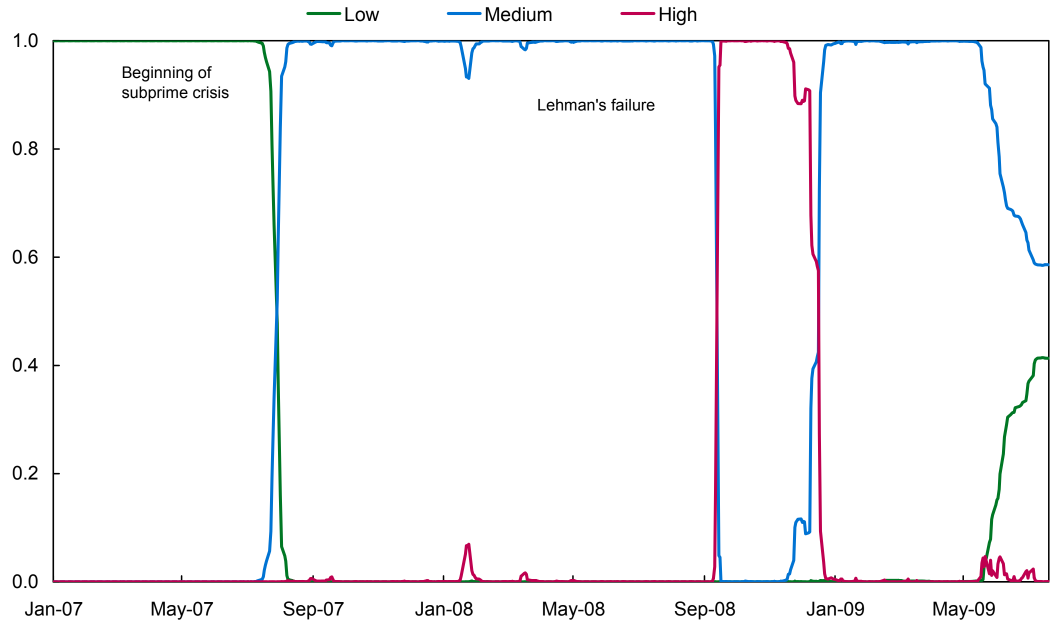
1. SWARCH Model based on Euro-Dollar Forex Swap

U.S. dollar funding pressures have declined dramatically since end-2008, largely as a result of a number of facilities and swap arrangements between the Fed and several central banks. However, while the probability of a low-volatility regime has increased to over 0.4 since early-July 2009, the probability of a medium-volatility state (though declining) still remains at around 0.6 (Figure 4).

[19] Frank and Hesse (2009) also find that central banks' action led to a reduction in Libor spreads in the first phase of the global financial crisis, even though economic magnitudes were rather small.

[20] The last observation in the estimation of the model is July 23, 2009.

Figure 4. Euro-Dollar Forex Swap
(Probability of being in low-, medium-, and high-volatility state)



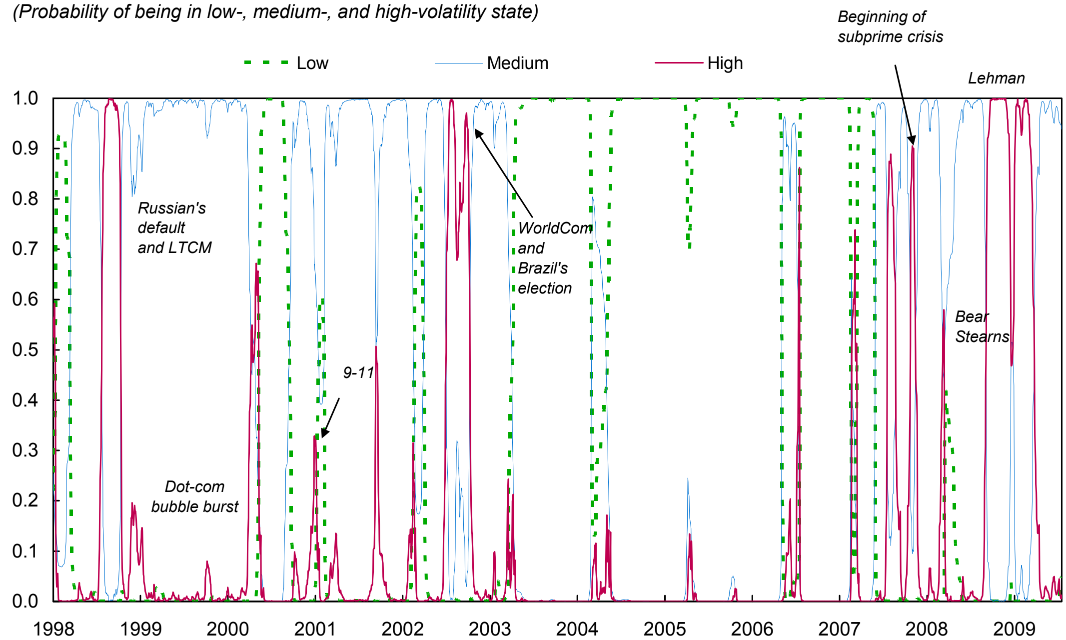
Sources: Bloomberg L.P.; and IMF staff estimates.

2. SWARCH Model based on the VIX

As discussed, the most recent peak of a probability of being in a high-volatility state was reached at end-September 2008 and lasted until mid-March 2009, at close to 1 (Figure 5a). Thereafter, the probability of being in a high-volatility state declined rapidly to reach less than 0.05 by end-April 2009. Since then, the probability of being in a high-volatility state has remained at around the same low level.

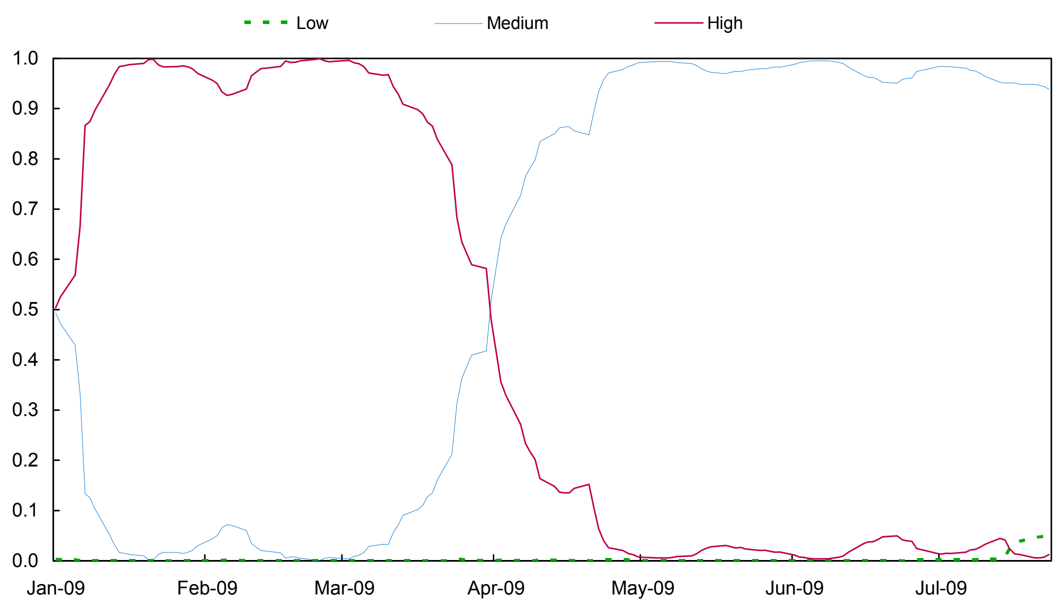
Despite the sharp decline in the probability of being in a high-volatility regime, market conditions (based on the VIX as a proxy for market uncertainty) have not yet returned to a low-volatility state and instead have remained at a high probability (nearly 1) of a medium-volatility state since early-May 2009 (Figure 5b). The probability of a low-volatility regime is nearly zero, indicating that market conditions based on the VIX have not yet returned to a tranquil period.

Figure 5a. Markov-Switching ARCH Model of VIX
(Probability of being in low-, medium-, and high-volatility state)



Sources: Bloomberg L.P.; and IMF staff estimates.
Note: ARCH = autoregressive conditional heteroskedasticy; LTCM = Long-Term Capital Management; VIX = Chicago Board Options Exchange volatility index.

Figure 5b. Markov-Switching ARCH Model of VIX
(Probability of being in low-, medium-, and high-volatility state)



Sources: Bloomberg L.P.; and IMF staff estimates.
Note: ARCH = autoregressive conditional heteroskedasticy; LTCM = Long-Term Capital Management; VIX = Chicago Board Options Exchange volatility index.

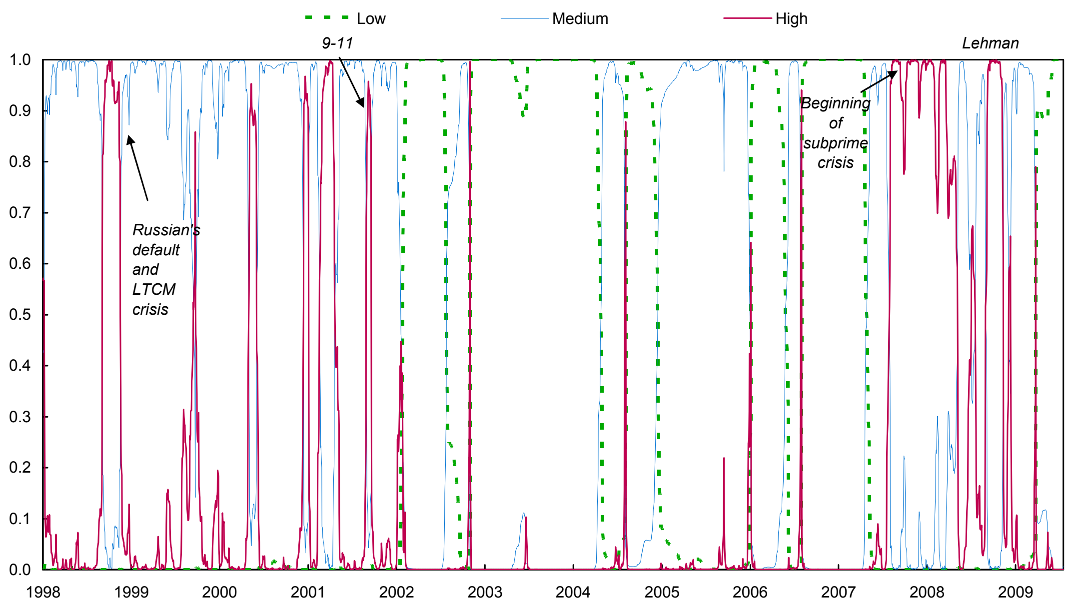
3. SWARCH Model based on TED Spreads

Similarly, after reaching a peak late in 2008, the probability of being in a high-volatility state based on TED spreads has declined dramatically since early-April 2009 where it has remained since then (Figure 6a).

However, in contrast with the VIX, the probability of being in medium-volatility regime is quite low (less than 0.1) while the probability of being in a low-volatility state has been higher than 0.9 since late May 2009, where it has remained since then (Figure 6b).[21]

Thus, while the VIX still signals moderate uncertainty in financial markets, the TED spread suggests that pressures in interbank markets have subsided dramatically since the spring of 2009.

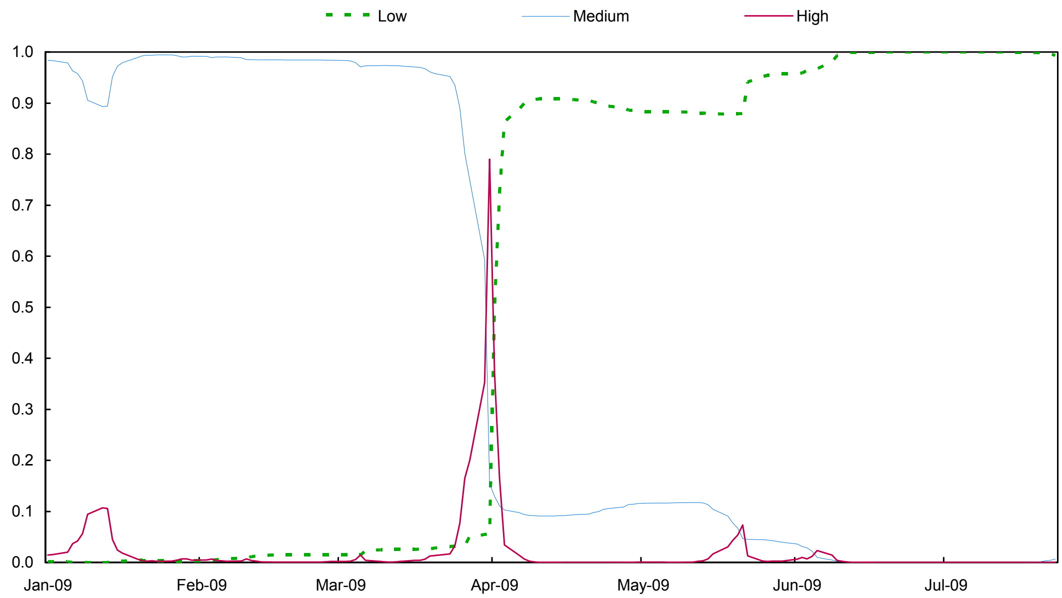
Figure 6a. Markov-Switching ARCH Model of TED Spread
(Probability of being in low-, medium-, and high-volatility state)



Sources: Bloomberg L.P.; and IMF staff estimates.
Note: ARCH = autogressive conditional heteroskedasticity; LTCM = Long-Term Capital Management; TED = the spread between the three-month LIBOR and treasury bill rates.

[21] The temporary spike in the probability of a high-volatility state for the TED spread observed in late-March 2009 was likely related to the announcement that the Federal Reserve would start a program of directly buying U.S. Treasury bonds in the market. Yields on U.S. Treasury bonds dropped significantly following the announcement, but began to creep up in the days that followed.

Figure 6b. Markov-Switching ARCH Model of TED Spread
(Probability of being in low-, medium-, and high-volatility state)



Sources: Bloomberg L.P.; and IMF staff estimates.
Note: ARCH = autogressive conditional heteroskedasticity; LTCM = Long-Term Capital Management; TED = the spread between the three-month LIBOR and treasury bill rates.

V. Conclusion

To summarize, this paper presents a Markov-regime switching technique to examine when key global market conditions variables such as the VIX, forex swap or the TED spread moved into a high volatility regime. The findings support the view that the Lehman failure was a key watershed event in the crisis, but periods of a high volatility state were also present before Lehman's failure. In particular, based on the VIX SWARCH model, these earlier episodes of distress include the Shanghai stock exchange crash and the ABX (BBB) price decline in February 2007, the beginning of the subprime crisis in August 2007, and the Bear Stearns rescue in March 2008. The results suggest that the bankruptcy of Lehman Brothers aggravated what it appeared to be already a crisis characterized by persistent (albeit at times noisy) signs of a high volatility state. High volatility states can be viewed as a potential manifestation of systemic risk.

In the aftermath of the Lehman collapse in the fall of 2008, which corresponded to the peak of the global crisis, a number of countries introduced massive government interventions in support of their financial systems. The examination of this most recent period is of interest because global market conditions and economic activity appear to have improved since mid-2009, potentially signaling that exit strategies can begin to be implemented. However, the regime switching models examined still signal moderate pressures on certain market conditions as of end-July 2009. For example, while the TED spread strongly signals a high probability of being in a low-volatility state, the VIX and the forex swap market both signal a high probability of a medium-volatility regime.

Overall, the results show that the global market indicators examined here sometimes do not stay in the high-volatility state for long, with some exceptions such as the TED spread or the VIX. This suggests they should be used in combination with other tools to help policymakers detect systemic crises and when those are receding.

The approach presented in this paper can be a helpful tool for policymakers to evaluate when market conditions are such that even a relatively small shock can lead to systemic events, or when financial institutions and markets can become distressed as a result of unstable market conditions, or when conditions have improved sufficiently to begin to withdraw government support to financial institutions and markets that had been previously embroiled in a systemic crisis.

A caveat of the methodology used in this paper is that it has been applied univariately to global market conditions, and future research should attempt to adopt multivariate SWARCH models that can combine various factors in a coherent and forward-looking manner. In addition, the states are determined by the existing dataset so once the high volatility periods exit the dataset, a high volatility state would signify less actual volatility compared to the crisis period.

References:

Aït-Sahalia, Y., J. Andritzky, A. Jobst, S. Nowak, and N. Tamirisa, 2009, "How to Stop a Herd of Running Bears? Market Response to Policy Initiatives during the Global Financial Crisis," Working Paper 09/2004 (International Monetary Fund, Washington, D.C.).

Baba, Naohiko, Frank Packer, and Teppei Nagano, 2008, "The spillover of money market turbulence to FX swap and cross-currency swap markets," *BIS Quarterly Review*, pp.73–86.

Brunnermeier, Markus, and Lasse H. Pedersen, 2009, "Market Liquidity and Funding Liquidity," *Review of Financial Studies* 22(6), pp. 2201–2238.

Demirguç-Kunt, A., and Enrica Detragiache, 1998, "The Determinants of Banking Crises in Developing and Developed Countries," *IMF Staff Papers* 45, No. 1, pp. 81–109.

Diamond, Douglas W., and Philip H. Dybvig, 1983, "Bank Runs, Deposit Insurance, and Liquidity, "*Journal of Political Economy*," 91(3), pp. 401-419.

Dornbush, R., Y.C. Park, and S. Claessens, 2000, "Contagion: Understanding How It Spreads," *The World Bank Research Observer*, 15(2), pp. 177–97.

Dungey, Mardi, Renee Fry, Brenda González-Hermosillo, and Vance Martin, 2005, "Empirical Modeling of Contagion: A Review of Methodologies," *Quantitative Finance*, 5, pp. 9–24.

———, 2006, "Contagion in International Bond Markets during the Russian and LTCM Crises," *Journal of Financial Stability*, 2, pp. 1–27.

———, 2007, "Unanticipated Shocks and Systemic Influences: The Impact of Contagion in Global Equity Markets in 1998," *North American Journal of Finance and Economics*, 18, pp. 155–174.

———, forthcoming, "Are Financial Crises Alike?—From the 1998 Russian/LTCM Crisis to the 2007 Subprime Debacle and Liquidity Crisis," IMF Working Paper (Washington: International Monetary Fund).

Forbes, K., and Rigobon, R., 2002, "No Contagion, Only Interdependence: Measuring Stock Market Co-movements," *Journal of Finance*, 57(5), pp. 2223–61.

Frank, Nathaniel, Brenda Gonzalez-Hermosillo, and Heiko Hesse, 2008, "Transmission of Liquidity Shocks: Evidence from the 2007 Subprime Crisis," IMF Working Paper 08/200 (Washington: International Monetary Fund).

Frank, Nathaniel, and Heiko Hesse, 2009, "Financial Spillovers to Emerging Markets during the Global Financial Crisis," IMF Working Paper 09/104 (Washington: International Monetary Fund).

———, 2009, "The Effectiveness of Central Bank Interventions during the First Phase of the Subprime Crisis," IMF Working Paper 09/206 (Washington: International Monetary Fund).

González-Hermosillo, Brenda, 2008, "The Role of International Investors' Risk Appetite in Global Financial Crises: 1998–2007," IMF Working Paper 08/85 (Washington: International Monetary Fund).

Gorton, Gary, 2008, "The Panic of 2007," Prepared for the Federal Reserve Bank of Kansas City, Jackson Hole Conference, August.

Group of Ten, 2001, *Consolidation in the Financial Sector* (Basel: Bank for International Settlements).

Hamilton, James D., and Raul Susmel, 1994, "Autoregressive Conditional Heteroskedasticity and Changes in Regime," *Journal of Econometrics,* Vol. 64 (September-October), pp. 307–33.

Hardy, D. C., and Ceyla Pazarbasiouglu, 1999, "Determinants and Leading Indicators of Banking Crises: Further Evidence," *IMF Staff Papers* 46 (3), pp. 247–258.

Illing, Mark, and Ying Liu, 2006, "Measuring Financial Stress in a Developed Country: An Application to Canada," *Journal of Financial Stability*, pp. 243–65.

International Monetary Fund, 2008, *Global Financial Stability Report,* "Market and Funding Illiquidity: When Private Risk Becomes Public," Chapter 3. World Economic and Financial Surveys (Washington, April).

———, 2009, *Global Financial Stability Report,* "Detecting Systemic Risk," Chapter 3. World Economic and Financial Surveys (Washington, April).

Kaminsky, G.L., and Reinhart, C.M., 1999, "The Twin Crises: The Causes of Banking and Balance of Payments Problems," *American Economic Review* 89 (3), pp. 473–500.

Laeven, L. and F. Valenci, 2008, "The Use of Blanket Guarantees in Banking Crises," IMF Working Paper 08/250 (Washington: International Monetary Fund).

Lo, Andrew, 2008, "Hedge Funds, Systemic Risk, and the Financial Crisis of 2007–2008," Written testimony to the U.S. House of Representatives Committee on Oversight and Government Reform, November 13, 2008.

Masson, Paul, 1999, "Contagion: Monsoonal Effects, Spillovers, and Jumps Between Multiple Equilibria" in Agenor, P.R., Miller, M. Vines, D. and Weber, A. (eds.), *The Asian Financial Crisis: Causes, Contagion and Consequences*. Cambridge University Press, Cambridge.