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Multivariate dependence of implied volatilities from equity options as measure of systemic risk☆

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ABSTRACT

This paper presents a methodology to examine the multivariate tail dependence of the implied volatility of equity options as an early warning indicator of systemic risk within the financial sector. Using non-parametric methods of estimating changes in the dependence structure in response to common shocks affecting individual risk profiles, possible linkages during periods of stress are quantifiable while recognizing that large shocks are transmitted across financial markets differently than small shocks. Before and during the initial phase of the financial crisis, we find that systemic risk increased globally as early as February 2007 — months before the unraveling of the U.S. subprime mortgage crisis and long before the collapse of Lehman Brothers. The average (multivariate) dependence among a global sample of banks and insurance companies increased by almost 30% while joint tail risk declined by about the same order of magnitude, indicating that co-movements of *large* changes in equity volatility were more likely to occur and responses to extreme shocks became more differentiated as distress escalated. The key policy consideration flowing from our analysis is that complementary measures of joint tail risk at high data frequency are essential to the robust measurement of systemic risk, which could enhance market-based early warning mechanisms as part of macroprudential surveillance.

1. Introduction

The global financial crisis demonstrated the importance of establishing effective early warning systems for identifying system-wide vulnerabilities to sources of financial sector distress and adopting suitable defenses against the impact of systemic risk events. Such events can arise from shocks to individual or collective arrangements – both institutional and market-based – that could either lead directly to material financial distress and/or significantly amplify its consequences (with adverse effects on the real economy). Thus, any disruptions to the flow of financial services due to an impairment of all or parts of the financial system would be deemed material and systemically relevant if there were the potential of financial instability to trigger serious negative spillovers to the real economy.[1]

Systemic risk is also an integral element in the design and implementation of macroprudential surveillance. Macroprudential surveillance aims to limit, mitigate or reduce systemic risk, thereby minimizing the incidence and impact of disruptions in the provision of key financial services that can have adverse consequences for the real economy (and broader implications for economic growth). The traditional approach to financial stability analysis concentrates analytical efforts on vulnerabilities to individual failures, assuming that the financial system is in equilibrium and adjusts when it experiences a shock. As opposed to this conventional approach, the potential build-up of systemic

☆ This work was largely completed as part of a chapter in the Global Financial Stability Report (GFSR) on systemic risk methodologies (Gray & Jobst, 2011a, chap. 3) when the author was Economist at the International Monetary Fund (IMF). The views expressed in this paper are those of the author and should not be attributed to the BMA, the IMF, and their respective Boards of Directors.

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[1] Impairment to the flow of financial services occurs where certain financial services are temporarily unavailable, as well as situations where the cost of obtaining the financial services is sharply increased. It would include disruptions due to shocks originating outside the financial system that impact on it, as well as shocks originating from within the financial system.

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Table 1
Distinction between macro- and microprudential analysis.
Source: Borio (2003) and Jobst (2012).

	Macroprudential	Microprudential
Proximate objective	Limit system-wide distress	Limit distress of individual firm
Characterization of risk	"Endogenous" (dependent on collective behavior)	"Exogenous" (independent on firm behavior)
Consideration of interlinkages between firms and common exposures	Essential ("firm-to-firm" and "firm-to-aggregate" linkages)	Optional
Calibration of prudential controls	In terms of system-wide risk; top-down	In terms of individual risk; bottom–up

vulnerabilities warrants a comprehensive monitoring of on-going developments in areas where the impact of disruptions to financial stability is deemed most severe and wide-spread — and especially in areas of economic significance to both the financial sector and the real economy (Table 1).

Ideally, systemic risk measures should support, or be linked to, macroprudential surveillance by providing information on the build-up of system-wide vulnerabilities in both the time and cross-sectional dimensions with an acceptable level of accuracy and latency. Efforts aimed at preventing the propagation of individual or joint distress of firms and/or the failure markets that are deemed systemically important have resulted in a multi-faceted approach comprising complementary measures in areas of regulatory policies, supervisory scope, and resolution arrangements with a view towards enhancing the resilience of the financial sector while avoiding impairment to efficient activities that do not cause and/or amplify system-wide stress in any meaningful manner.[2]

While there is still no consistent theory of systemic risk measurement, existing approaches can be broadly distinguished based on several core principles underpinning two general approaches (see Box 1). The "contribution approach" defines the propensity of individual failure to pose a threat to financial stability in the absence of close substitutes due to the nature, scope, size, scale, concentration of its activities, or its connectedness with other financial institutions FSB (2010 and 2012). In contrast, the "participation approach" assumes that a firm experiences losses from a single (or multiple) large shock(s) to concentrated activity that represents a common exposure whose impact under adverse conditions exceeds the firm's loss bearing capacity. In the case of the former, firms contribute to systemic risk from individual failures that propagate material financial distress or activities via intra- and inter-sectoral linkages to other institutions and markets (especially within conglomerate structures). Moreover, the initial effect of direct and indirect exposures to a failing institution (e.g., defaults on liabilities and/or asset fire sales) can also escalate to cause spillover effects to previously unrelated institutions and markets as a result of greater uncertainty or the reassessment of financial risk (i.e., changes in general risk appetite and/or the market price of risk). Conversely, the participation in systemic risk occurs via an institution's credit and market risk exposures affected by the adverse impact of other financial institutions. Table 2 in Box 1 below shows the distinguishing features of both approaches.

The distinction of measurement approaches also reflects varying channels of risk transmission that influence assumptions on tail dependence. Most approaches thus far have focused on determining the contribution of financial institutions to systemic risk, including the assessment of spillover and contagion effects between institutions within and across different sectors and national boundaries. Among the main channels that facilitate the transmission of shocks, the combination of interconnectedness and asset liquidation has become most relevant for the modeling of dependence that takes into account measures of joint tail risk, i.e., multiple institutions and/or markets experience a high-severity but low-probability event. Claims by creditors, counterparties, investors, or other market participants ("direct linkages"), as well as common exposures to certain asset classes, industry sectors, and markets ("indirect linkages") establish relationships that can exacerbate contagion effects, especially when extreme shocks

Box 1
General concepts of systemic risk measurement.

In this paper, we present measurement approaches of nonlinear, time-varying-dependence based on the joint negative tail behavior of implied equity volatilities of selected firms in order to assess the potential for systemic risk. Even though our focus is on the connectedness rather than the identification of systemically important activity, a general conceptualization of systemic risk (see below) suggests that our approach would broadly support efforts aimed at quantifying the contribution to systemic risk conditional on how individual failure(s) are propagated by "firm-to-firm" linkages.

Despite many methodological and empirical approaches aimed at the identification of systemic risk, there is still no consistent theory of measuring systemically important activity in the financial sector. That being said, existing approaches can be broadly distinguished based on their conceptual underpinnings regarding the causality of systemic risk: (i) a particular activity causes a firm to fail, whose importance to the system imposes marginal distress on the system ("contribution approach"), or (ii) a firm experiences losses from a single (or multiple) large shock(s) due a significant exposure to the commonly affected sector, country and/or currency ("concentration of activity"), which are large relative to overall losses ("participation approach"). In the case of the former, the contribution to systemic risk results from direct and indirect exposures to the distressed institution whose actions (e.g., defaults on liabilities and/or fire sales of assets) cause spillover effects to previously unrelated institutions and markets amid greater uncertainty or the reassessment of financial risk (i.e., changes in risk appetite and/or the market price of risk). In contrast, the participation in systemic risk occurs via the institution's exposure to other financial institutions and markets, which could result in expected losses that can exceed the loss absorbing capacity of available capital. Table 2 below shows the distinguishing features of both approaches and how they are reflective of different policy objectives regarding the broader effect of systemic risk on financial stability.

[2] In a recent progress report to the G-20 (IMF, 2009b; FSB/BIS, 2011b), which followed an earlier update on macroprudential policies (IMF, 2009a; FSB/BIS, 2011a), the FSB takes stock of the development of governance structures that facilitate the identification and monitoring of systemic financial risk as well as the designation and calibration of instruments for macroprudential purposes aimed at limiting systemic risk. While the report acknowledges considerable progress in the conduct of macroprudential policy, the report finds that there is still much scope for systemic risk regulation and institutional arrangements for the conduct of policy. Note that similar efforts in the banking sector are more advanced. The CGFS (2012) recently published a report on operationalizing the selection and application of macroprudential policies, which provides guidance on the effectiveness and timing of banking sector-related instruments (affecting the treatment of capital, liquidity and assets for the purposes of mitigating the cyclical impact of shocks and enhancing system-wide resilience to joint distress events).