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Systemic risk spillovers in the European banking and sovereign network☆

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ABSTRACT

We propose a framework for estimating time-varying systemic risk contributions that is applicable to a high-dimensional and interconnected financial system. Tail risk dependencies and systemic risk contributions are estimated using a penalized two-stage fixed-effects quantile approach, which explicitly links time-varying interconnectedness to systemic risk contributions. For the purposes of surveillance and regulation of financial systems, network dependencies in extreme risks are more relevant than simple (mean) correlations. Thus, the framework provides a tool for supervisors, reflecting the market's view of tail dependences and systemic risk contributions. The model is applied to a system of 51 large European banks and 17 sovereigns during the period from 2006 through 2013, utilizing both equity and CDS prices. We provide new evidence on how banking sector fragmentation and sovereign-bank linkages evolved over the European sovereign debt crisis, and how they are reflected in estimated network statistics and systemic risk measures. Finally, our evidence provides an indication that the fragmentation of the European financial system has peaked.

1. Introduction

A lesson from the global financial crisis has been the propensity for company-specific risk to spill over to other firms. These spill-overs arise from contractual linkages in conjunction with heightened counterparty risk, but also from price effects generated, for instance, by fire sales. The result of these externalities and spill-overs has been the freezing of interbank markets observed at the height of the global financial crisis in October 2008. The market freeze was followed by a much longer period of interbank market fragmentation during the European sovereign debt crisis, with banks in core European countries no longer willing to finance banks in the periphery.

Another key feature, particularly salient during the European sovereign debt crisis, has been the interplay between fiscally strained sovereigns and stressed banks. An impaired banking sector has a limited ability to support economic activity, which in turn further strains public finances, eventually putting in question the ability of the sovereign to support the banking system in case of need. The ECB (2011, 2014) has continuously identified this adverse feedback loop as one of the key risks to financial stability in the euro area. A better ability to understand and monitor the fragmentation of European financial markets as well as the interdependence between banks and sovereigns is thus of utmost importance for central banks and policy makers.

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Quantifying these relationships empirically is challenging due to (i) the high dimensionality of the underlying financial and sovereign system, (ii) lack of public data on cross-linkages and detailed individual characteristics for a large cross-section of financial institutions and sovereigns, and (iii) the time-variability of network connections and systemic risk contributions. Moreover, for purposes of surveillance and regulation of financial systems, network dependencies in extreme risks are more relevant than simple (mean) correlations. This requires focusing on connections between (time-varying) tails, as, e.g., represented by conditional quantiles, expected shortfall or related tail measures of the underlying risk distributions. Finally, the empirical methodology should ideally produce measures and estimates that are empirically tractable and easily interpretable.

In this paper, we address these challenges and contribute to the literature both methodologically and empirically. In terms of methodology, we propose an econometric framework that allows for complex tail risk networks while producing sufficiently precise and robust estimates given the available data over relatively short (but rolling) time spans. Empirically, we provide new insights into the time-varying tail risk dependencies and spillovers between European banks and sovereigns, especially during the 2008 global financial crisis and the subsequent European sovereign debt crisis. We show how network interconnectedness, fragmentation and interactions between European financial institutions and sovereigns changed over this time period and how the state of the financial system is reflected in the topology of the underlying network.

Our methodology builds on the framework proposed by Hautsch et al. (2015) (henceforth HSS2015) and Hautsch et al. (2014). The underlying idea is to quantify the systemic impact of an individual company by the marginal effect of a firm's time-varying Value at Risk (VaR) on the VaR of the entire system. To statistically identify the relevant tail risk drivers of a specific company out of a high-dimensional set of potential characteristics (including the tail risk of other companies), HSS2015 propose using a statistical regularization and shrinkage method. The selection of individual-specific tail risk drivers gives rise to a risk network, determining to what extent the VaR of a company is driven by the tail risk of other companies. This information is then explicitly utilized in a second step, where the marginal systemic relevance of an individual firm is quantified using a quantile regression of the system VaR on the VaR of the respective company while controlling for the firm-specific risk drivers and additional economic state variables.

The explicit quantification and utilization of network dependencies distinguishes HSS2015 from alternative methods for measuring and predicting systemic risk. Adrian and Brunnermeier (2011) propose the concept of CoVaR, corresponding to a company's conditional VaR, given that the return of some other company reaches a certain benchmark value (e.g., its individual VaR). As discussed in HSS2015, there is a major conceptual difference to our methodology. The CoVaR does *not* measure the direct *marginal* effect of an individual VaR on the VaR of the system, but rather corresponds to the system VaR conditionally on the return of the particular company *realizing* its (pre-estimated) VaR. Moreover, the CoVaR does not capture any network spillovers and can only vary over time through the effects of individual VaRs. Another complementary approach to quantify systemic risk builds on Acharya et al. (2010). Here, systemic risk is defined as the propensity of a financial institution being undercapitalized when the financial system is under stress. This idea is put forward by Brownlees and Engle (2012) by proposing an econometric approach to measure the so-called marginal expected shortfall (MES), mainly building on time series (GARCH) methodology for asset returns. In the same spirit, Engle et al. (2015) measure systemic risk by the expected capital shortfall of a financial institution in a financial crisis and quantify it for a wide range of non-U.S. equities. These approaches ultimately build on the conditional asset return distribution of an individual company given distress of the market and aim at determining the capital surcharges of systemically important banks. Löffler and Raupach (2013), however, argue that pure market-based measures' ability to identify systemically important banks is limited. On the one hand, this is due the fact that extreme risks are not easily assessed based on return data. On the other hand, concepts like the CoVaR or the MES ignore tail risk dependencies induced by the underlying financial network structure. An important advantage of our approach is to explicitly take these dependencies into account when constructing the measures for systemic risk contributions. This information provides valuable additional insights into underlying tail risk connections and risk channels as perceived by the market.

In this paper, we extend the methodology introduced by HSS2015 in two directions. First, we adapt the approach to make it feasible in situations where the density of the network is high and the underlying sample period is comparably short. In such a situation, individual companies may face tail risk spillovers from many others, making it necessary to account for large sets of individual-specific tail risk drivers when estimating companies' marginal systemic risk contribution in a quantile regression of the system VaR. The requirement to control for a large number of different risk factors, while having a comparably short estimation window, makes standard estimates inherently inefficient and unstable and – in the extreme case – even infeasible. Therefore, we propose an adaptive version of the standard shrinkage technique for determining the relevant risk drivers not only among other banks but also among sovereigns. The use of relatively short estimation windows is driven by the need to account for time-variations in companies' systemic riskiness and underlying network connections. Accounting for time variations via rolling window estimates, however, is crucial when the framework is used to surveil and monitor the system building the basis for macro-prudential regulation.

To address the trade-off between estimation robustness and the ability to capture the time-variability of the underlying relationships, we propose to combine the two-step quantile framework with a panel fixed effects approach. While controlling for company-specific fixed effects, we keep the model sufficiently parsimonious by imposing group-wise common parameters. In contrast to HSS2015, this reduces the dimensionality of the estimation problem and allows us to estimate the individual companies' marginal effect on the system VaR in one step. We show that this approach is empirically tractable and balances model flexibility and estimation robustness in the given context where the financial network is of high dimension and dense. Second, when estimating a company's systemic relevance, we explicitly account for the interconnectedness of an institution, measured by its network centrality. In particular, we allow an institution's marginal systemic relevance to be time-varying and depending – among other things – on its interconnectedness. We empirically show that the latter is a significant factor of the firm's systemic risk contribution.

Empirically, we contribute to the literature in two major directions. First, focusing on 51 large European banks allows us to cover a substantial fraction of the European banking system. Moreover, by analyzing data up to 2013, we are able to study the effects of the global financial crisis, its aftermath and the transition into the European sovereign debt crisis on the fragmentation and integration of the European financial system. Second, bringing together both banks and sovereigns in a network estimated based on CDS returns yields novel insights on the interplay between banks and sovereigns. We quantify and visualize time-varying tail dependencies, spillover directions and the density of networks, and show how banking sector fragmentation and sovereign-bank linkages evolved over the European sovereign debt crisis.