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Structural changes in cross-border liabilities: A multidimensional approach

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HIGHLIGHTS

- Time series of interbank liabilities by country are used to develop geometrical spaces.
- The systematic information of the interbank market is shown to populate a 3D ellipsoid.
- The shape of the ellipsoid is shrunk and distorted in periods of financial turbulence.
- Multivariate skewness and kurtosis quantify the shape deviations from normality.
- These coefficients and a measure of the space volume characterize systemic risk.

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ABSTRACT

We study the international interbank market through a geometric analysis of empirical data. The geometric analysis of the time series of cross-country liabilities shows that the systematic information of the interbank international market is contained in a space of small dimension. Geometric spaces of financial relations across countries are developed, for which the space volume, multivariate skewness and multivariate kurtosis are computed. The behavior of these coefficients reveals an important modification acting in the financial linkages since 1997 and allows us to relate the shape of the geometric space that emerges in recent years to the globally turbulent period that has characterized financial systems since the late 1990s. Here we show that, besides a persistent decrease in the volume of the geometric space since 1997, the observation of a generalized increase in the values of the multivariate skewness and kurtosis sheds some light on the behavior of cross-border interdependencies during periods of financial crises. This was found to occur in such a systematic fashion, that these coefficients may be used as a proxy for systemic risk.

1. Introduction

Globalization of economies leads to an ever-increasing interdependence of countries. The late 2000s financial crisis – considered by many economists to be the worst financial crisis since the Great Depression – resulted in the collapse of large financial institutions, the bailout of banks by national governments and downturns in stock markets around the world.

The recent turmoil in the international banking system has stressed the need for understanding financial systems as sets of countries where cross-border financial relations play the fundamental role. While some authors have investigated the role globalization plays in shaping the spread of financial crisis [1,2], studies on the consequences of financial crises to the international banking system are less prominent. As we recently argued [3], the adoption of a topological approach is

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recommended not only because of the proper emphasis on the financial interdependencies but also due to the possibility of describing how the structure of these interdependencies evolves in time. In so doing, we are able to address the role that the existing structure plays in the spread of shocks and conversely, the effectiveness of stress events and their impact on the structure of the cross-border interdependencies.

The high level of interdependency that characterizes financial institutions makes banking and financial crises different from other economic crises. It is mostly due to the associated fear of spreading or contagion, which is technically called systemic risk. Systemic risk refers to the risk (in probabilistic terms) of breakdowns affecting the system as a whole, in contrast to the idea of partial or isolated breakdowns, which are restricted to individual parts or to specific components.

Researchers have recently applied network tools to model systemic risk in financial systems [4–7]. The authors in Ref. [4] found that hedge funds and insurance companies have become highly interrelated over the past decade, likely increasing the level of systemic risk through a complex and time-varying network of relationships. Battiston and co-authors [5] introduced a novel measure of systemic impact (DebtRank) which was inspired by feedback-centrality. They analyzed a new and unique dataset on the USD 1.2 trillion FED emergency loans program to global financial institutions during 2008–2010. They found evidence that systemic default could have been triggered even by small dispersed shocks, suggesting that the debate on *too-big-to-fail* institutions should include the *too-central-to-fail* epithet [5].

Whenever risk has to be measured, the resource to the concept of standard deviation is the most common practice in the financial community. However, the fact that financial returns do not follow normal distributions raises many criticisms against, for instance, portfolio strategies based on the use of variance as a proxy for risk.

A step forward in the statistical setting in understanding how data differ from normality leads to the computation of higher moments of the distributions throughout the application of measures of skewness and kurtosis. The calculation of univariate measures in order to evaluate deviations of statistical indexes from normality is a common procedure. A certainly less common procedure is the evaluation of deviation from normality from a multidimensional perspective.

Here we address the impact of the recent financial crises in the international banking system from a geometric point of view. In so doing, we are able to evaluate systemic risk by a technique similar to classical multidimensional scaling. The resulting multivariate geometric spaces provide the basis for the computation of multivariate skewness and kurtosis in different time periods. These coefficients, while indicating deviations from multinormality allow for the characterization of systemic risk.

Geometric analysis of time series of stock returns was performed in the past for the characterization of stock market crises. It revealed that most of the systematic information of financial markets was contained in a space of small dimension [8–10] where one finds noticeable differences between *business-as-usual* and critical periods. During market crisis there is a contraction of volume in the reduced geometric space, corresponding to a greater synchronization of the market fluctuations. In addition, whereas the geometric "market cloud" of points in *business-as-usual* periods looks like a smooth ellipsoid, during some crises it displays distortions, which may be detected by computing higher moments of the distribution. Here we apply the same geometric analysis to flows of financial capital between countries.

During the last years, several authors have approached financial systems through a topological approach. Some papers have favored the study of interdependencies between credit banks [11], or focused on the analysis of shocks storming the financial systems of several countries [12]. The topological properties of some national interbank markets have been studied by Soramaki and co-authors [13], who analyzed the topology of a network of commercial banks. Another example is the work of Fujiwara [14] exploring the credit relationships that exist between commercial banks and large companies in Japan.

Empirical studies have also been carried out on some European national interbank markets [15,16] throughout the analysis of the topological properties of the networks of Italian and Austrian banks.

Using the Bank for International Settlements (BIS) dataset, some papers have addressed the evolution of networks of bank transfers [16,17,14,11,18]. It is evident from the work of McGuire [18] that the international banking system has become an important conduit for the transfer of capital across countries. The work of Minoiu and Reyes [19] also explored the proprieties of the global banking networks; for several networked systems, they found evidence of important structural changes following the occurrence of stress events.

In this paper, from series of interbank liabilities over different time periods we have developed geometric spaces where each country is uniquely identified by a set of coordinates. For this purpose, a geometric approach is used, with a metric constructed from time series of amounts of liabilities by country. By a technique similar to classical multidimensional scaling, each country is mapped onto a point in Euclidean space and then the shape of the resulting "cloud of points" is analyzed. It turns out that, up to very small deviations, the market of cross-border liabilities is mostly concentrated in a low dimensional subspace. Furthermore, in this reduced subspace, the countries populate an elongated ellipsoid with faster decreasing axis.

Empirical results allow us to relate the shape of the geometric spaces to the characteristics of some relevant periods of financial turbulence, during which the shape of the ellipsoid is distorted, acquiring prominences in some particular directions. Measures of multivariate skewness and kurtosis are applied in order to quantify how far that shape deviates from multinormality. These statistical coefficients together with a measure of the space volume allow for the characterization of systemic risk.

The paper is organized as follows: Section 2 briefly presents the set of empirical data and the methodology. Section 3 presents the first results obtained from the application of a stochastic geometry technique. The main contributions of the paper are presented in Section 4, where measures of multivariate skewness and kurtosis are applied in order to test deviations from multinormality. The paper ends with appropriate conclusions.