Financial Cartography

2019

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Kimmo Sormäki is the Founder and CEO of FNA and the author of "Network Theory and Financial Risk". He has over 25 years of experience working with Central Banks and Financial Market Infrastructures. In 1997 Kimmo developed the world's first simulation model for interbank payment systems - and since then has been regularly invited to lead and contribute to simulation and payment system innovation projects with organisations like Bank of England, CLS, Payments Canada or SWIFT. He is a frequent speaker at industry events and has written over 50 articles cited in more than 2000 academic publications. Kimmo has an MSc in Finance and a DSc in Operations Research, both from Aalto University (Finland).

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Abstract

Geographic maps have been of military and economic importance throughout the ages. Rulers have commissioned maps to control the financial, economic, political, and military aspects of their sovereign entities. Large scale projects like the Ordnance Survey in the UK in the late 18th century, and the Lewis and Clark Expedition a few decades later to map the American West, are early examples of trailblazing efforts to create accurate modern maps of high strategic importance.

Digitalization, globalization, and a larger urban and educated workforce necessitate a new understanding of the world, beyond traditional maps based on geographic features. Many of today's most critical threats know no geographic borders. For instance, cyber attacks can be orchestrated through globally distributed bot networks; just-in-time manufacturing relies on the free flow of goods across jurisdictions; global markets and the infrastructures that support them relay information and price signals globally within seconds. A lack of understanding financial interdependencies was clearly demonstrated by the freezing of credit markets in the last financial crisis and the uncertainty created by Brexit. Ten years after the financial crisis we are still only beginning to map, model and visualise these critical maps of the financial world.

We call for attention to work on a large scale project of "Financial Cartography" to address this gap. In financial cartography, we replace geographic proximity with logical proximity, such as financial interdependence, similarity (e.g., of portfolio or income streams), a flow of transactions or a magnitude of exposures. Similar to geographic maps, financial maps will find many important uses across business, government and military domains. Critically, they are needed for protection and projection of state power, for optimizing and managing risks in business, and in making policy decisions related to the major challenges of climate change, mass migration and geopolitical instability.

Fundamentally, cartography is a way that reality can be modeled to communicate information on “big data” sets. Cartography allows one to simplify and reduce the complexity of the data to highlight salient features of the data, and to filter out noise. This makes maps ideal devices to increase the bandwidth by which information can be communicated to its users, for making quick decision based on complex data.

In the following pages, we make a case and provide starting points for a research agenda around "Financial Cartography" in three interrelated parts:

- Maps of Trade Networks
- Maps of Financial Markets,
- Maps of Financial Market Infrastructures

The work draws on experience from R&D and client projects carried out at FNA.
Vision

Modern countries’ economies can not be considered in isolation. Countless datasets containing input-output relations among economic sectors of all the countries of the world show, at various granularity level, that the whole world's economy can be considered a tangled interacting system. The availability of these datasets (trade between sectors and economies, shipping data, and SWIFT financial transactions), and advances in network modeling and visualization put us on track to be able to measure, model and visualize complex interactions in global trade networks. The vision is to operationalize this information to create a database of global trade network maps and relevant modeling and visualization techniques to enable a wide range of outcomes.

Research Challenges

Data
The data can broadly be categorized as sectoral level (e.g. MRO), company level (supply chains could be induced from payments data, e.g., SWIFT or in interbank payment systems) and product level (where companies collect product component supply chains). Many challenges exist around the confidentiality of the data, and the estimation of full networks based on partial data. Moreover, a task of major importance is to aggregate all the available dataset in order to be able to fully understand the deeply tangled nature of the system.

Models
Several models have been developed over the years. Starting from a single input-output network, computational and analytical techniques have been put forward to model single types of shock (natural disaster, climate change events, financial crisis, sudden political changes, etc.) able to trigger a sudden change to the nexus of economic relations. However, given the interconnected nature of the system, shocks can naturally trigger other shocks that can have different implications for different levels of granularity of the data we are looking at. The need for a unified modelling (and data acquisition) framework is a clear priority.

Enabled Outcomes

The resulting information will enable policy and decision makers to better measure, understand and maintain financial stability, identify choke points, identify the rise and decline of dominant countries,
measure power, identify trade blocs, and understand the effect of sanctions, natural catastrophes, and global warming. It also enables better targeting of economic and technical sanctions to targeted geographies & sectors, while minimizing the effect on friendly ones. All in all, the development of a unified modelling framework will enable better monitoring, forecasting and prevention of large scale events that can potentially have world-scale implications.

Examples:

Figure 1: ‘The global network of payment flows’ showing key trade hubs and major trade communities (Cook and Soramäki, 2014)
Figure 2: A network of US industries more likely to be affected by tariffs set by China (FNA Research)
Maps of Financial Markets

Vision

Global financial markets relay information and price signals globally within seconds. The vision is to give systematics views to these markets by creating stable and time-varying maps of global financial markets. The maps necessitate a system for describing financial instruments in the market (e.g. if it is moving along the market, against the market, diversifying or getting more concentrated, what other instruments are similar), akin to ‘latitudes’ and ‘longitudes’ in geographical maps.

Research & Computational Challenges

Visualization & Complexity reduction
Visualization of large networks is challenging and unless the amount of data is reduced, the networks look like ‘hairballs’. To filter signal from noise, we need to develop new visual ways of displaying complex multidimensional information using complexity reduction (spanning trees, filtered graphs, eigenvector maps, clustering and other unsupervised learning methods, etc.).

Large-scale & real-time
The maps can be updated in a real-time environment where we need to account for differences in timing of price information due to varying degrees of liquidity and time zone/opening hour differences of the global markets. To give an indication on the size of the problem, Bloomberg has quotes for 35 million financial instruments, although perhaps fewer than 100k are continually traded. New methods and/or large computing resources are needed for matrix inversion (which is needed for many analysis methods) and other computations on large data sets.

Scenario modeling
Ability to rapidly create and run scenarios and measure information cascades. For example, scenarios might consist of shocks to certain aspects of the markets such as prices or correlations between specific assets’ returns, and running the scenarios may yield results related to other aspects of the market. Big challenges lie in methods to develop scenarios and estimate their impact when no historical data on such scenarios exist.

Enabled Outcomes

Like real-world maps, these maps will have a plethora of uses. For instance, they can be used to systematically monitor global markets, detect anomalies/fraud/market manipulation, understand
slow-moving drifts, systemic fault lines and early warning for a financial crisis, and to devise more efficient asset allocation strategies.

Examples:

Figure 3: Global asset clusters based on correlations of daily returns pre- (top) and post -(bottom) the UK’s Brexit vote. Green = positive move; red = negative move; size = magnitude of move; close assets correlate with each other; assets on the right move strongly with the market, assets on the left against it (FNA research).
Maps of Financial Market Infrastructures

Vision

Our financial and economic systems are highly dependent on critical Financial Market Infrastructures (FMIs): payments systems, equity and derivatives exchanges, securities depositories, etc. These FMIs are interconnected via common members, service providers and IT systems. A disruption in one, has the capability to escalate into a world wide crisis (see eg Bank of England). Financial interconnections, especially around liquidity are a key concern for central banks, especially after the failure of Einar Aas in Nasdaq Nordic. FMIs are also increasingly targeted by state sponsored cyber attacks for profit purposes (eg. $81M Bangladesh Bank Robbery at FRBNY and $5M loss SPEI attack in Mexico) or ransom schemes (e.g. WannaCry). It is also a priority for certain industry groups around the world - e.g., the Financial Systemic Analysis & Resilience Center (FSARC) in the U.S. The vision is to map the interconnections and to develop methods for anomaly detection and simulation of failure scenarios.

Research Challenges

Data
Varying datasets exist publicly but need to be compiled together, such as CCP quantitative disclosures, GSIB (Global Systemically Important Banks) disclosures and various filings to regulatory databases (like Edgar in the US). Cyberterrorism regulators are beginning to compile data sets of IT infrastructure components and architectures. However, the level of granularity of details is uncertain.

Models
In order to model the interaction of FMIs, we need simulation models that incorporate the main technical details of their implementation. Such simulators (or agent based models) exist already in FNA Platform for several FMIs but not for all, and linking them with models of markets and with each other is a great challenge.

Enabled Outcomes

Combining IT infrastructure data and financial data will enable policy advisors and regulators to understand the systemic risk of financial failures, operational incidents and cyber attacks and begin to model failure scenarios and understand the potential financial impacts. They will be critical to protect national infrastructures from state sponsored attacks.
Figure 4: Interconnections of global FMIs through common global banks (FNA research).

Figure 5: Simulating the impact of CLS (in the center) on liquidity in global payment systems, in Soramäki and Cook: "Network Theory and Financial Risk" 2016.
Financial Cartography- Making Sense of a Hyperconnected World

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