

Summary of the doctoral dissertation titled "Modeling Systemic Risk through Reduced-Form Dynamics of Bonds in Financial Networks"

author of the dissertation: Kamil Fortuna

How is a state likely to fail? The state is a cultural construct inherently tied to the very definition of civilization, and consequently to the concept of humanity itself. It represents a somewhat nebulous abstract notion, lacking a universally accepted academic definition, yet it significantly shapes the real lives of both societies and individuals. Thus, it is not surprising that the question of state survival has sparked considerable academic interest across time and space, from ancient Greece to pre-Columbian America and into contemporary Greece. An even more interesting problem lies in the sequences of failures experienced by multiple states, such as Ireland, Portugal, and Greece. The underlying causes of these phenomena stem from relational structures that are much older and more fundamental than the state itself, defined by the concept of money. Understanding how the activities of private institutions in America can trigger a wave of public institutional failures across the ocean can be achieved by examining these structures. Identifying the primary sources of risk enables the assessment of threats on a global scale.

These issues, both qualitatively and quantitatively, form the core of the discipline of systemic risk. It is defined as the threat of failure of the entire financial system or a significant part of it. Two main characteristics distinguish this discipline within the realm of financial mathematics: the endogeneity of risk and amplification mechanisms. The first characteristic indicates that the sources of failure are an integral part of the architecture of the systems themselves, allowing for the examination of these systems in terms of the likelihood and scale of the threats they pose. Amplification mechanisms describe the process of spreading and intensifying shocks when deteriorating institutional conditions mutually influence each other in a potentially infinite cycle of financial decay. However, the emphasis on these two characteristics has led to a widespread neglect of key factors shaping the price dynamics of financial instruments traded on global markets.

The aim of this dissertation is to develop new models of systemic risk that incorporate these factors, enabling a more realistic assessment of actual risk. Mathematically, this is achieved by integrating a rich class of reduced-form models used for pricing financial instruments with methods for calculating systemic risk. At the beginning of the thesis, it is demonstrated that even a simple interest rate model can capture the fundamental mechanisms of amplification and the transition of the system into a crisis state. This model, derived from fundamental processes in the credit market, is further enhanced by transitioning to continuous time and adding random noise to represent unpredictable fluctuations. The resulting paths of interest rate evolution can exhibit calm behavior for a time, followed by turbulence in the long run, which presents an intriguing property in the context of market modeling and the challenges of recognizing risk of collapse.

Subsequently, a general framework for the pricing process of instruments in financial networks is presented. It facilitates the creation of a class of reduced-form network models, allowing for the construction of specific models that account for key factors in the pricing of debt instruments, such as creditworthiness and the dynamics of interest rates in the banking market. Notably, the latter played a fundamental role in the development of the 2008 crisis and its subsequent spread to the Eurozone. Its significance is confirmed by a wave of bankruptcies on a scale impossible to replicate without its inclusion in the model, in the case of simulations performed on American banks data from 2023.

Current network-based risk assessment methods primarily rely on subjecting the system to an initial shock and examining its evolution, which is then completely determined by amplification mechanisms. However, in reality, the market may experience random fluctuations alongside the effects of systemic propagation at any given moment. A class of stochastic network models is constructed to capture this behavior. The analysis conducted using rigorous mathematical formalism yields highly useful results, enabling the calculation of key risk indicators used in determining reserve levels and investment strategies.

The culmination of this doctoral thesis is a model synthesizing the most important findings obtained throughout the dissertation. This model is built upon the class of stochastic network models from chapter five, integrating the deterministic, comprehensive network model from chapter four with the stochastic process of unstable dynamics in the credit market developed in chapters one and two. The combination of these components significantly impacts the calculations of fundamental risk indicators. This approach allows for a broad examination of risk aspects crucial to the dynamics of various crises, particularly the American banking crisis of 2023. The significance of research on detecting the vulnerabilities of financial systems is felt far beyond the circle of entities directly interested in market dynamics, as vividly illustrated by the example of Russia exploiting Europe's financial weaknesses and excessive energy exposure during its invasion of Ukraine.