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A game theoretic model of economic crises

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ABSTRACT

Global financial crises have revealed the systemic risk posed by economic contagion as the increasing interconnectedness of the global economy has allowed adverse events to spread across countries more easily. These adverse economic events can be attributed to contagion through either credit or trade channels, or to common macroeconomic conditions that cause adverse events in multiple countries even without contagion. We model this system as a game between five types of players: countries; central banks; banks; firms; and households. In this framework, we model strategic choices, conduct sensitivity analysis, and analyze the impacts of random shocks in two examples. Our results demonstrate that each of the three causes discussed above (contagion through credit channels, contagion through trade channels, or common macroeconomic conditions with no contagion) can lead to crises even if all agents in the model behave rationally.

1. Introduction

We seek to add to the understanding of global economic risks that contribute to economic crises, at both an academic and a policy level. Global markets are imperfect and experience shocks from time to time. Shocks are adverse economic events that diminish the credit standing of countries, banks, as well as other borrowers. Such shocks can occur locally and subsequently spread globally. The propagation of shocks is referred to as contagion, and its potential is a key source of systemic risk. We distinguish between market risk, which is systematic, and idiosyncratic risk, which is specific to a single player and unsystematic. This risk is exacerbated by the problems of adverse selection[1] and moral hazard[2] that lead to country risk. We address these concerns through a proposed game-theoretic model with key themes of debt, capital, and trade.

The 2007–2008 financial crises revealed the global economy's vulnerability to economic risks marking a key departure from previous notions of country risk. Financial globalization and innovation have led to substantial growth in the derivatives market. This in turn led to an abundance of global credit, with resulting global risk exposures. Consequently, country risks were exacerbated. Increased derivative securities usage along with increased diversification led to increased information asymmetries and amplified contagion and common cause effects, by allowing adverse economic events to spread across countries. Additionally, abundant credit established an implicit promise of foreign lending, creating moral hazard. This structural shift in the global economy increased both country risk exposure and impact. The 2009–2012 Eurozone crisis underscored global economic risks'

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[1] For example, the poor choice in borrower that leads to less than full repayment of debts.
[2] For example, fiscal irresponsibility driven by an implicit promise of future credit or aid.

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importance as a systemic risk while exemplifying the debate between contagion and common cause failures as it is unclear whether the crises can be attributed to contagion or common cause failure.

Various approaches have been applied to understand the crises and their spread. In their seminal work, Eaton and Gersovitz [1] discuss crises through a model of sovereign debt, default, and repudiation. The spread of crises defined as contagion is discussed by many in the literature; Allen and Gale [2] and Kaminsky and Reinhart [3] discuss contagion through financial sectors and common creditors; Hernández and Valdés [4] and Kaminsky et al. [5] highlight the fact that contagion can come from trade or credit channels; Forbes and Rigobon [6,7] discuss the plausibility that the perceived problem of contagion is only a problem of interdependence.

Recent advances in game theory and applications demonstrate its importance in tackling large social problems. On the topic of evolutionary dynamics, Nowak [8] stresses the value of interpreting natural phenomena through the tools of evolutionary dynamics. Nowak [8] presents a strong case for the use of dynamic models and game theory in solving real world problems. Cressman and Tao [9] demonstrate the stability of Nash equilibria for dynamics and evolutionary game theory, extending them to symmetric, asymmetric, multiplayer, and population games.

The importance of both network structure and strategy on optimal solutions to social problems is explored by Wang et al. [10–13], Wang and Perc [14], and Wang et al. [15]. Discussing coevolution of network structure and strategy, Wang et al. [10] conclude that using interdependence in networks can lead to cooperative advantages in solving social problems. In what Wang et al. [10] describe as two classes of players resulting within the network structure, Wang et al. [11] find that in interconnected networks, "distinguished players" emerge with strong influence on cooperation. Furthermore, Huang et al. [16] discuss the importance of heterogeneity in players finding that under simple assumptions heterogeneity of investments has a positive effect on cooperation. Kokubo et al. [17] extend theory in the direction of realism from the discrete modeling choices of cooperative vs defective strategy. As solutions to social dilemma games Kokubo et al. [17] offer discrete, continuous, and mixed strategies. Gao et al. [18] show how the payoffs from mutualistic cooperation are differently impacted by faster evolving and slower evolving species.

The literature exploring the use of game theory in economic crises is, however, small. Morris and Shin [19,20] model contagion in a coordination game of investors to currency crises, bank runs, and debt pricing to assess adverse selection. Arellano and Bai [21] include Nash bargaining for debt renegotiation in a model of linkages in sovereign debt markets. Hausken and Plumper [22] propose a contagion game for how a crisis spreads and can be contained through intervention by the IMF and collective action. Most similarly to our objectives, Baral [23] proposes a network formulation game between U.S. borrower banks, lender banks, and the Federal Reserve to model contagion. Similarly, Acemoglu et al. [24] compute Nash equilibria in a network formulation of the interbank market to describe contagion and counterparty risk. However, most of the literature applying game-theoretic approaches to economic contagion is limited in either its use of game-theoretic and decision-theoretic tools, or its ability to address the multiple-channel problems discussed by Hernández and Valdés [4] and Kaminsky et al. [5].

We develop a game-theoretic model consisting of five types of players; countries, central banks, banks, firms, and households. Countries produce, consume, trade, invest, borrow, and lend. Central banks lend and borrow. Banks, firms and households borrow and lend capital. A country's debts and assets are endogenously determined. By determining strategic behavior and the outcome of adverse shocks, we endogenize financial frictions.

We model contagion dynamically in a way that explains how the propagation of adverse economic events occurs. Additionally, we find equilibrium strategies which implicitly suggest how policy can be adapted to stem the spread of contagion. At the heart of contagion is lending by one player to another, exposing the lender to the risks of the borrower. Both borrowers and lenders have specified strategy sets. Moral hazard and adverse selection arise in such games when information asymmetries keep borrowers and lenders from knowing each other's true characteristics (e.g., when the lender cannot easily or accurately assess the credit-worthiness of a borrower). The players' strategy sets are quite large enabling extensive endogenization. Large strategy sets means that there are many strategic variables. The model can either be used with all strategic variables as strategic variables. Alternatively, the model can be used interpreting some of the strategic variables as exogenous parameters.

In Section 2 we present a model with five types of players; households, firms, banks, countries, and central banks. We define player strategy sets and player interactions through goods and debt including endogenous default. We conclude by defining the Nash Equilibrium. In Section 3 we present a two country numerical example over ten periods. In Section 3.1 we conduct a numerical analysis of and solution to a game with one country, a set of households, and a set of firms. We explain how shocks change behavior and how under certain conditions, this can lead to default. In Section 3.2 we conduct a numerical analysis of and solution to a game with two countries, each with a set of households, and a set of firms. We explain how a shock in one country impacts the behavior of the other. In Section 4 we conclude and describe the model implications to global economic stability.

2. The model

2.1. Players, variables, and parameters

We consider a complete information, non-cooperative, T period game where $T \in [1, \infty]$, with five types of fully rational players which can make simultaneous or sequential moves. The players are interlinked as in Fig. 1 and defined in Table 1. Black dashed arrows represent the debt market and red dash-dotted arrows represent the market for goods and services. All parameters are common knowledge for all players. The strategic choice variables of the five players are shown in Table 2, the parameters in Table 3, and the dependent variables in Table 4.