Financial Contagion: Evolutionary Optimisation of Multinational Agent-Based Model

Abstract

Over the past two decades, financial market crises with similar features have occurred in different regions of the world. Unstable cross-market linkages during financial crises are referred to as financial contagion. We simulate the transmission of financial crises in the context of a model of market participants adopting various strategies; this allows testing for financial contagion under alternative scenarios. Using a minority game approach, we develop an agent-based multinational model and investigate the reasons for contagion. Although contagion has been extensively investigated in the financial literature, it has not been studied yet through computational intelligence techniques. Our simulations shed light on parameter values and characteristics which can be exploited to detect contagion at an earlier stage, hence recognising financial crises with the potential to destabilise cross-market linkages. In the real world, such information would be extremely valuable to develop appropriate risk management strategies.

Introduction

Emerging markets have experienced a variety of financial crises over the past twenty years (e.g. Mexico in 1987, Asia in 1997, Russia in 1998, etc.), with shocks originating from one country being transmitted to its neighbours. This has been modelled as contagion or interdependence (K. Forbes and R. Rigobon, 2002; G.M.
Caporale et al., 2005). The basis distinguishes contagion and interdependence is to compare linkages between markets in stability period and crisis period. We adopt the definition of contagion introduced by K. Forbes and R. Rigobon (2002), a ‘significant’ increasing in cross markets linkages after a shock to a group of countries; otherwise synchronous tumble during the crisis is rather referred to as “interdependence”. Detecting contagion at an early stage would contribute to crisis management. If shocks are spread through stable cross-market linkages, then countries experiencing them can take measures to improve economic fundamentals; if the shocks are propagated even though the fundamentals are sound, then IMF intervention might be appropriate (G.M. Caporale et al., 2005).

Recently, some of traditional economic theories and approaches are doubted, such as efficient market hypothesis, although numerous researches attempt to demonstrate this theory, the authenticity of this hypothesis remains uncertain. Agent-based models as an alternative approach for financial markets have become increasingly popular in recent years. An artificial markets built by agent-based model populated with heterogeneous agents with learning optimisation capabilities. It stresses interactions, and learning dynamics in groups of traders learning about the relations between various factors. It is easily point out many artificial financial markets model. For example, Kirman (1991) as early artificial financial markets focuses on analysing strategies that are used to trade a risky asset. With increasingly computer technologies development, agent-based model can endow traders very diverse set of types and behaviours to simulate more complex situation, also the behaviours themselves, are allowed to evolve over time in response to past performance. GA (Genetic Algorithm) is involved in to optimal parameter in various
specifications for the portfolio policy. Generally speaking, these artificial markets with heterogeneous behaviours close to real world markets.

Studies of financial crisis studies, however usually focus on forecasting the outset of crises, rather than contagion, when developing early warning systems (G. Kaminsky, 1999). Most early warning systems for financial crisis developed so far have been designed to monitor long-term or macroeconomic fundamental variables, and predict potential financial crisis on a long-term basis (G. Kaminsky, 1999). However, recent financial crises show that the crisis may arise suddenly from a chaotic financial market without a significant long-term deterioration in economic fundamentals (Oh et al., 2006), and one financial crisis may impact to neighbouring markets, although affected financial markets may have relative stable fundamental situation, such as the Asian crisis in 1997, unstable Thai currency markets first suffered the tumble, then the crisis quickly spread to Hong Kong, South Korean and other Asian countries, although based on normal view, those countries have stable fundamental situation. Thus, there are also other researches attempted to establish the pattern to predict unstable states of financial market through monitoring and analysing dynamic daily movements of the financial markets (Oh et al., 2006). In this paper, we simulate the transmission of financial crises modelling the behaviour of market participants and their various strategies using a mixed-game agent-based approach, as a first step in developing an early warning system for financial contagion.

Our model is a multinational framework which is suitable for the analysis of financial contagion. Existing studies have shown that irrational choices by noise traders lead to the emergence of herding behaviour and other risk factor (J. De Long et al., 1990). Herd behaviour has been identified as a major factor behind contagion. This arises because of irrational investment choices made by noise traders (J. De Long
et al., 1990). Agent-based models are an effective tool to describe and simulate such behaviour. Experiments show that the presence of noise traders increases price fluctuations. Agent-based models may be further employed to simulate linked markets rather than a single market. For example, international financial crises are studied in Kaizoji (2001) investigating correlated markets. Each market has a certain number of participants, where the proportion of participants with an attitude to buy/sell in each market is determined by the average domestic attitudes, average foreign attitudes and global fundamentals. Thus the model is able to simulate interdependence, when a shock to one of the markets is followed by a fall in the related market. By introducing noise traders as well, it is possible to simulate contagion during a financial crisis (A. Serguieva, 2007; G.M. Caporale et al., 2008).

An effective framework for studying more realistic and complex markets is provided by Game Theory. The game approach we implemented in the model is a mixed-game approach, which is based on minority game model (D. Challet and Y. –C. Zhang), and extends by Gou (2006). Minority game was developed by D. Challet and Y. –C. Zhang (1997), and is an effective framework for studying more realistic and complex market. Evolutionary Programming (EP) is also adopted to optimise the estimation of model parameters, and has been applied with success to many combinational optimisation problems (X. Yao et al., 1999). Our multinational model is estimated using time series data from the stock markets of Thailand, South Korea and Hong Kong up to the Asian crisis of 1997. Analysing simulation parameters and characteristics enables one to detect contagion at an earlier stage. Therefore, it is possible to recognise early financial crises with the potential to destabilise cross-market linkages. In the real world, such information would be extremely valuable for
taking appropriate risk management decision. Thus our analysis will contribute to developing a framework for the management of financial crises.

**Mixed-game Multinational Model**

Minority Game is developed by D. Challet and Y. –C. Zhang in 1997. Initially, it was used to solve the El-Farol bar problem, and then extended the application to modelling market behaviours of heterogeneous agents. The basic minority game structure involves an odd number of players $N$ in a market, each of whom has to choose an action out of two, buy or sell, in every time period. Two possible actions are denoted by $\{+1, -1\}$. In each turn, the players who have made the minority choice win the game. The action has won the game is the public information available to all the players. Each player decides $+1$ or $-1$ following the strategy with the highest score in their strategy table. Each Strategy is a choice of $+1$ or $-1$ corresponding to the $M$ size history. Each player has a capacity of having $S$ strategies in this strategy table. All the agents have the same $S$ and $M$. An example of a strategy table is shown in Table 1 for case of $M=3, S=2$.

<table>
<thead>
<tr>
<th>$\mu_t$</th>
<th>$S_{1,\mu}$</th>
<th>$S_{2,\mu}$</th>
</tr>
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<tbody>
<tr>
<td>-1, -1, -1</td>
<td>-1</td>
<td>+1</td>
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<tr>
<td>-1, -1, +1</td>
<td>+1</td>
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Gou (2006) extended Minority game by adding another type player, who plays majority game, the new game model is called mixed-game model. In the mixed-game model, odd numbers of players are divided into two groups playing a minority game and a majority game, respectively. A player in the majority game has approaches to
taking actions analogous to a player in the minority game. However, a majority player wins if his action is on the majority side. For the purpose to simulate the linkage between two markets, the mixed-game model extended by allowing players make investment decision based on information from domestic market and foreign market, but player only invests in domestic market, not in foreign market markets (G.M. Caporale et al., 2008). Therefore, each player has to face different possible actions depending on information from corresponding different markets. A proportion of noise traders are also introduced into the multinational mixed-game model. The behavior of noise traders are described as they have a tendency to follow the sign of the last price change on the markets (G.M. Caporale et al., 2008).

In order to modelling the movement of the target financial market, we need to search for proper parameter configurations. Evolutionary Programming (EP), inspired by biological evolution, is one of a class of paradigms for simulating evolution which utilizes the concepts of Darwinian evolution to iteratively generate increasingly appropriate solutions. Today EP has been applied with success to many numerical and combinatorial optimization problems. The EP procedure can be described by two major steps:

1. Populations as parents generate respective offspring via mutation.
2. Better individuals from the parents and offspring populations are selected as parents of the next generation.

Following the EP procedure, we first randomly initialize values of population consisting of a number of individuals. This random population are regarded as parents of the first generation. For each parent, creates a single offspring by mutation operator. Then, evaluate the fitness score for each individual from parents and offspring based on the fitness function. The tournament selection is applied to parents and offspring.
The same number with the first generation parents of individual can survive and be parents to the next generation, and repeats mutation and selection steps. Repetition stops if the halting criterion is satisfied.

We plan to apply EP parameter configuration optimization procedure outlined above for the mixed-game multinational model then used to simulate the Asian financial crisis from 1997. The crisis originated in Thailand (TH), and affected markets in South Korea, Hong Kong, Indonesia, Malaysia and other Asian countries. We simulate the markets in South Korea (SK) and Hong Kong (HK) as target real markets over 222 trading days, 25/02/1997–31/12/1997, in relation to the movement of Thailand’s stock market (See Figure 1 and 2).

![Figure 1](image-url). Real index movement in the contagion-origin market of TH (top), real SK market (middle), and a simulated SK market (bottom). Period is 25/02/1997-31/12/1997.
Figure 2. Real index movement in the contagion-origin market of TH (top), real HK market (middle), and a simulated HK market (bottom). Period is 25/02/1997-31/12/1997.
Reference


Serguieva, A. Wu, H. (2007) “Computational intelligence in financial contagion analysis”, Presented at the *Seventh International Conference on Complex Systems*, Boston, Massachusetts, Available in the online proceedings and submitted to the proceedings in print