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Symbolic hierarchical analysis in currency markets: An application to contagion in currency crises ☆

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ABSTRACT

In this paper we introduce a new method to describe dynamical patterns of the real exchange rate co-movements time series and to analyze contagion in currency crisis. The method combines the tools of symbolic time series analysis with the nearest neighbor single linkage clustering algorithm. Data symbolization allows us obtaining a metric distance between two different time series that is used to construct an ultrametric distance. By analyzing the data of various countries, we derive a hierarchical organization, constructing minimal-spanning and hierarchical trees. From these trees we detect different clusters of countries according to their proximity. We show that this methodology permits us to construct a structural and dynamic topology that is useful to study interdependence and contagion effects among financial time series.

1. Introduction

There is no doubt that currency markets are extremely important. As highlighted by McDonald, Suleman, Williams, Howison, and Johnson (2005) they represent the largest market in the world, having daily transactions totaling trillions of dollars, exceeding the yearly GDP of most countries. This global integration of capital markets has accelerated since the early 1990s, as illustrated, for example, by the rapid simultaneous increase in foreign assets and liabilities. The trend toward larger external assets and liabilities has been particularly relevant for industrial countries, where, relative to output, both average external assets and liabilities about tripled between 1990 and 2003. In emerging markets global trend has been similar, unless much smaller than in industrial countries (IMF, 2005).

During the 90s there has been a great amount of important turbulences, labeled currency crisis, in the world exchange markets. The European Monetary System (EMS) speculative attacks in 1992; the "Tequila crisis" originated in Mexico in December 1994; the collapse of southern Asian currencies from mid 1997 to first months 1998; the Brazilian currency devaluation on January 1999 and the Argentine currency board collapse and external debt default on January 2002 are the most relevant episodes of currency crisis in the 1990s generating interest in both academic and policy circles in the potential causes on symptoms of currency crisis and contagion.

Precisely the objective of this work is to understand the structure and dynamics of cross-country exchange rate liaisons to inquiry on the contagion phenomenon in currency markets. Ortega and Matesanz (2006) use Minimal Spanning Tree (MST) methodology in order to detect clusters of countries which could be affected when a crisis occurs.[3]

Constructing a cross-country hierarchical structure they detect three groups of countries which are clearly divided in regional dimension (EU, Asian countries, and Latin-American). In this paper we will study the same problem, but applying a different methodology and including cross-country analysis of the structures and linkages when countries are swimming into more volatile periods and currency crises events. We will combine the Symbolic Time Series tools with the nearest neighbor single linkage clustering algorithm in order to construct different MST that can be used to represent the evolution of the phenomena. The theoretical setup

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3 Recently, the correlations between economic data have been studied by using techniques and tools formerly used by physicists. See, among others Bonanno, Lillo, and Mantegna (2001a, 2001b) and Mantegna (1999).

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of Symbolic Time Series Analysis is based on Daw, Finney, and Tracy (2003) and Brida and Punzo (2003). In the first stage we introduce a partition of the space of states. Using this partition, all the values of the time series data are transformed into a finite string of symbols. This converts the original signal into a symbolic sequence, from where symbolic sequence statistics can be computed. In particular we apply concepts from information theory and symbolic dynamics to process the symbolic sequence.

The paper is organized as follows. In the next section we briefly review the theoretical literature in currency crisis and contagion and we state some possible causes of contagion during currency crisis. In Section 3 we introduce the minimal spanning tree, the ultrametric distance and the hierarchical tree, constructed from the Pearson correlation coefficient. Section 4 describes the data, introduces a criteria for data symbolization and the Symbolic Time Series tools. Next, by analyzing the data of various countries, we derive a hierarchical organization, constructing minimal-spanning and hierarchical trees constructed from different distances. From these trees we detect different clusters of countries according to their proximity. In the last section we draw our conclusions and present some future lines of studying.

2. Currency crisis and contagion. Some notes on the literature

Nowadays theoretical literature in currency crisis continues to grow but it is accepted that we can recognize three generation of models explaining the reasons of crises to occur. The first generation-models have flourished following seminal Krugman's paper (Krugman, 1979). This literature establishes that crises were caused by weak "economic fundamentals". These kind of models only worked explaining few cases of countries with histories of high inflation (Mexico and Chile in 1970s; France and Italy in the early 1980s) but they did not work in more recent currency crises episodes, such as 1990s European currency storms (Eichengreen & Wyplosz, 1993). In the 1990s appeared a second generation of models based on Obstfeld's model (see Obstfeld, 1997). These generation of models concentrate on non-linearities in government decisions. They highlight a trade-off between macroeconomic targets and monetary policy, including the maintaining of fix currency parity. Speculative attacks occur because markets feel that the cost of maintaining the parity by the authority become high related to their macroeconomic objectives (for instance, Ozkan & Sutherland, 1995 and Masson, 1995).

Because second generation models were not successful explaining the East Asia Crisis, a third generation model surged also known as "twin crisis", these models propose that a weak bank sector can precipitate the beginning of both currency and financial crises (Kaminsky & Reinhart, 1999).

Finally (and maybe more relevant in the present work), some papers have focused on the existence, or not, of contagion effects during the currency crises. In general, explanation theories of contagion have been divided in two groups by Forbes and Rigobon (2001, 2002): crises-contingent and non-crises-contingent theories. In crises-contingent models it is assume that the transmission mechanisms change after a shock or, to put it another way, the behavior of investors is different after a crises and therefore cross-market linkages increases after a shock among countries. This can occur due to changes in investors' sentiment or herding behavior. In non-crises-contingent models it is assume that any increase in cross-market correlations after a shock is a continuation of previous and stable links among countries and, so, the transmission mechanism is the same during both crises and non-crises periods. These linkages are commercial, financial and/or institutional liaisons among countries.

Related to this division, there is an ongoing empirical debate around crises and non-crises contingent explanations of contagion. The stress of debate is focused on the difference between interdependence (non-crises-contingent models) and contagion, or pure contagion, (crises-contingent models). Many other works have tried to make progress on the debate but at the moment results are mixed and non-conclusive; for instance Hatemi and Hacker (2005) find evidence of contagion between Thailand and Indonesia equity markets. Gravelle, Kichian, and Morley (2006) discover evidence of contagion in developed countries and find evidence of interdependence in Latin American countries. Caporale, Cipollini, and Spagnolo (2005) find evidence of contagion for most pair of countries during the Asian crises; moreover they find strong evidence of interdependence among Asian countries during tranquil times. Corsetti, Pericoli, and Sbracia (2005) find some contagion effects and some interdependence effects on the Hong Kong stock market crisis of October 1997 as a case study. Candelon, Hecq, and Verschoor (2005) find no evidence of contagion in Mexican and Asian crises but long term interdependence among involved countries. In Dungey, Fry, Martín, and González-Hermosillo (2005) a review of the methodologies in the contagion empirical literature can be found.

3. Minimal spanning tree and hierarchical tree construction

Methodology proposed by Mantegna (1999) uses Pearson correlation coefficient as fundamental input which quantifies the degree of similarity between the synchronous time evolution of a pair of variables

$$\rho_{ij} = \frac{\langle Y_i Y_j\rangle - \langle Y_i\rangle\langle Y_j\rangle}{\sqrt{(\langle Y_i^2\rangle - \langle Y_i\rangle^2)(\langle Y_j^2\rangle - \langle Y_j\rangle^2)}} \tag{1}$$

where Y_i and Y_j are the real exchange rate of countries i and j. This coefficient is a temporal average performed on all the trading days of the investigated time period. By definition ρ_{ij} can vary from -1 (completely anti-correlation) to 1 (completely correlation). Taking all possible combination of countries it is possible to form the correlation matrix. This is clearly a symmetric matrix with a diagonal of 1 ($\rho_{ij} = 1$). To construct an appropriate taxonomy of currency countries we need a metric distance; i.e., a function d defined for each pair of countries that takes values in R such that:

(1) $d(i,j) \geqslant 0 \quad \forall i,j$
(2) $d(i,j) = 0$ if and only if i=j,
(3) $d(i,j) = d(j,i) \quad \forall i,j$
(4) $d(i,j) \leqslant d(i,k) + d(k,j)$

As it is well known, function (1) does not verify all these properties. As in Gower (1966), distances between countries can be constructed using the correlation coefficient

$$d(i,j) = \sqrt{2(1-\rho_{ij})} \tag{2}$$

This distance is used to determine the minimal spanning tree (MST) connecting the n countries. The MST is progressively constructed by linking all the countries together in a graph characterized by a minimal distance between time series, starting with the shortest distance. This method is the Kruskal's algorithm and consists of the following steps: in the first step we choose a pair of countries with the nearest distance and connect them with a line proportional to the distance. In the second step we also connect a pair with the 2nd nearest distance. In the third step we also connect the nearest pair that is not connected by the same tree. We repeat the third step until all the given countries are connected in a unique tree. The attractive of the MST is that provides an arrangement of currencies which selects the most relevant connections of each element of the set.