Physica A 391 (2012) 4342–4349

Contents lists available at SciVerse ScienceDirect

Physica A

journal homepage: www.elsevier.com/locate/physa

On the efficiency of sovereign bond markets

Luciano Zunino [a,b,*], Aurelio Fernández Bariviera [c], M. Belén Guercio [c], Lisana B. Martinez [c], Osvaldo A. Rosso [d,e]

[a] Centro de Investigaciones Ópticas (CONICET La Plata - CIC), C.C. 3, 1897 Gonnet, Argentina

[b] Departamento de Ciencias Básicas, Facultad de Ingeniería, Universidad Nacional de La Plata (UNLP), 1900 La Plata, Argentina

[c] Department of Business, Universitat Rovira i Virgili, Av. Universitat 1, 43204 Reus, Spain

[d] LaCCAN/CPMAT - Instituto de Computação, Universidade Federal de Alagoas, BR 104 Norte km 97, 57072-970 Maceió, Alagoas, Brazil

[e] Laboratorio de Sistemas Complejos, Facultad de Ingeniería, Universidad de Buenos Aires. 1063 Av. Paseo Colón 840, Ciudad Autónoma de Buenos Aires, Argentina

ARTICLE INFO

Article history:
Received 29 January 2012
Available online 23 April 2012

Keywords:
Sovereign bond market efficiency
Complexity-entropy causality plane
Permutation entropy
Permutation statistical complexity
Bandt and Pompe method
Ordinal time series analysis

ABSTRACT

The existence of memory in financial time series has been extensively studied for several stock markets around the world by means of different approaches. However, fixed income markets, i.e. those where corporate and sovereign bonds are traded, have been much less studied. We believe that, given the relevance of these markets, not only from the investors', but also from the issuers' point of view (government and firms), it is necessary to fill this gap in the literature. In this paper, we study the sovereign market efficiency of thirty bond indices of both developed and emerging countries, using an innovative statistical tool in the financial literature: the *complexity-entropy causality plane*. This representation space allows us to establish an efficiency ranking of different markets and distinguish different bond market dynamics. We conclude that the classification derived from the complexity-entropy causality plane is consistent with the qualifications assigned by major rating companies to the sovereign instruments. Additionally, we find a correlation between permutation entropy, economic development and market size that could be of interest for policy makers and investors.

1. Introduction

The study of the informational efficiency is maybe one of the most elusive issues in financial economics. In spite of the fact that the first model of an informational efficient market was based on the price changes of French government bonds [1], the literature focused its efforts on the study of stock markets rather than bond markets. The reason for this bias is probably twofold. On the one hand, stock markets trading figures are much larger than bond markets. On the other hand, sovereign bonds[1] began to be traded in exchange markets much more recently in time for many countries, specially for emerging ones. More details about the development of fixed income markets for emerging countries can be found in Refs. [3,4]. Among the studies on the fixed income markets we can cite Ref. [5] in which the January effect in returns of corporate bonds of the Dow Jones Composite Bond Average is found, Ref. [6] in which patterns of daily seasonality in high yield corporate bonds are observed, and Ref. [7] where it is shown the existence of daily seasonalities in the Spanish sovereign bonds for

* Corresponding author at: Centro de Investigaciones Ópticas (CONICET La Plata - CIC), C.C. 3, 1897 Gonnet, Argentina.
E-mail addresses: lucianoz@ciop.unlp.edu.ar (L. Zunino), aurelio.fernandez@urv.net (A. Fernández Bariviera), mariabelen.guercio@urv.net (M.B. Guercio), lisanabelen.martinez@urv.net (L.B. Martinez), oarosso@fibertel.com.ar, oarosso@gmail.com (O.A. Rosso).

[1] "A bond is an instrument in which the issuer (debtor/borrower) promises to repay to the lender/investor the amount borrowed plus interest over some specified period of time". Definition extracted from Ref. [2, p. 213]. "Bonds issued by autonomous nation states are included in sovereign debt". Definition extracted from Ref. [2, p. 223].

0378-4371/$ – see front matter
doi:10.1016/j.physa.2012.04.009

different maturities. Also the patterns of comovements in government bond market yields have been recently analyzed by implementing the minimum spanning tree approach [8,9]. Useful conclusions are obtained by examining the dynamic evolution of market linkages.

The traditional definition of informational efficiency corresponds to a market where prices fully reflect all available information [10]. Therefore, the key element in assessing efficiency is to determine the information set against which prices should be tested. Informational efficiency is classified into three categories, depending on this information set [11,12]. The first category is the weak efficiency, where stock prices reflect all the information contained in the history of past prices. The second category is semi-strong efficiency, where the information set is all public known information. Finally, the third category is strong efficiency, where prices reflect all kinds of information, public and private. Although it may seem at first sight a sign of irrationality, random changes in stock prices reflect the quest of rational investors to catch mispriced securities in the market. The Efficient Market Hypothesis (EMH) is a necessary condition for the existence of equilibrium in a competitive market, in which arbitrage opportunities cannot exist. Ross [13] indicates that this definition evokes the idea that prices are the result of decisions made by individual agents and, therefore, they depend on the underlying information. As a corollary, with the same information set it is not possible to obtain superior returns. It implies, also, that future returns depend to a great extent not only on historic information but also on the new information that arrives at the market. Therefore, an investor, whose information set is the same or inferior to the market information set, cannot beat the market. In addition, investors cannot control the flow of their informative endowment towards the market, since their own transactions (according to its direction and volume) act as signals to the market, tending, thus, to an equalization of the informative sets of the different participants in the market. This produces that, in average, participants cannot beat the market on a regular basis. In an attempt to relax such strict assumptions, Grossman and Stiglitz [14] expand the concept of efficiency, arguing that when information is costly, prices will reflect the information of informed individuals, but only partially, so that information gathering is rewarded.

The aim of this paper is to analyze the sovereign bond market efficiency. More precisely, we want to: (i) classify bond indices, giving a rationale for the bond qualifications of the main rating agencies such as Standard & Poor's (S&P) and Moody's and (ii) analyze the link between sovereign bond market efficiency, economic development and market size. The relationship between economic growth and financial system development has been extensively studied in the economic literature [15–21]. Nevertheless, these studies consider the financial system only composed by the banking sector and the stock market. There is a scarce literature that includes the bond market and their results are contradictory [22–25]. The present paper extends the coverage of the empirical literature, considering a potential relationship between economic growth and the development of sovereign bond markets, as an important part of the financial system.

In order to quantify the efficiency related to government bond market indices we use the *complexity-entropy causality plane*, i.e. the representation space with the permutation entropy of the system in the horizontal axis and an appropriate permutation statistical complexity measure in the vertical one. This novel information-theory-tool was recently shown to be a practical and robust way to discriminate the linear and nonlinear correlations present in stock and commodity markets [26,27]. The location in the complexity-entropy causality plane allows to quantify the inefficiency of the system under analysis because the presence of temporal patterns derives in deviations from the ideal position associated to a totally random process. Consequently, the distance to this random ideal location can be used to define a ranking of efficiency. As will be shown in detail below, we have found that this permutation information-theory-tool is also useful for detecting and quantifying the presence of correlations and hidden structures in the temporal evolution of government bond markets.

This article contributes in several ways to the research field. First, to the best of our knowledge, this is the most comprehensive study of efficiency in the sovereign bond markets covering a total of thirty bond indices of both developed and emerging countries. Second, we detect a coherence of agencies' ratings with the time series efficiency endowment. Third, we find a statistically significant link between bond market randomness and economic development and market size. Fourth, we prove the practical utility of the complexity-entropy causality plane for quantifying efficiency in a financial context.

The remainder of the paper is organized as follows. In the next section, in order to keep our description as self-contained as possible, we introduce the complexity-entropy causality plane. In Section 3 we present the data and results. Finally, in Section 4, the main conclusions of this paper are summarized.

2. Complexity-entropy causality plane

Black box time series, given by the discrete set $\{x_t, t = 1, \ldots, N\}$, recorded from observable quantities associated to a system are very often the starting point to study the underlying dynamical phenomenon. They should be carefully analyzed in order to extract relevant information for simulation and forecasting purposes. Information-theory-derived quantifiers can be good candidates for this task because they are able to characterize some properties of the probability distribution associated with the observable or measurable quantity. Shannon entropy is the most paradigmatic example. Its usefulness as a measure of the volatility phenomenon in the financial domain has been proved [28]. Given any arbitrary discrete probability distribution $P = \{p_i : i = 1, \ldots, M\}$, Shannon's logarithmic information measure is given by $S[P] = -\sum_{i=1}^{M} p_i \ln p_i$. It is equal to zero when we are able to predict with full certainty which of the possible outcomes i whose probabilities are given by p_i will actually take place. Our knowledge of the underlying process described by the probability distribution is maximal