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Q1 Monitoring the informational efficiency of European corporate bond markets with dynamical permutation min-entropy

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HIGHLIGHTS

- Informational efficiency of corporate bond markets is studied.
- Permutation min-entropy is implemented to unveil hidden temporal structures.
- Effects of the 2008 credit crisis are addressed.
- Heterogeneous impact of the crisis on different economic sectors is confirmed.
- Sectors related to the financial economy are more vulnerable to the crisis impact.

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ABSTRACT

In this paper the permutation min-entropy has been implemented to unveil the presence of temporal structures in the daily values of European corporate bond indices from April 2001 to August 2015. More precisely, the informational efficiency evolution of the prices of fifteen sectorial indices has been carefully studied by estimating this information-theory-derived symbolic tool over a sliding time window. Such a dynamical analysis makes possible to obtain relevant conclusions about the effect that the 2008 credit crisis has had on the different European corporate bond sectors. It is found that the informational efficiency of some sectors, namely banks, financial services, insurance, and basic resources, has been strongly reduced due to the financial crisis whereas another set of sectors, integrated by chemicals, automobiles, media, energy, construction, industrial goods & services, technology, and telecommunications has only suffered a transitory loss of efficiency. Last but not least, the food & beverage, healthcare, and utilities sectors show

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a behavior close to a random walk practically along all the period of analysis, confirming a remarkable immunity against the 2008 financial crisis.

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1. Introduction

One of the richest fields for the application of econophysics methods is Finance. Financial markets produce a large amount of ready-to-use time series, which could be examined via concepts and methods of statistical physics [1]. Particularly, informational efficiency and long-range dependence have been recurrent topics in the finance literature. Over a century ago the French mathematician Bachelier developed the first rational expectation model proposing a random walk model for the bond prices on the Paris Bourse [2]. Such a walk is a random process whose increments are uncorrelated (fair game pattern). Lately, Samuelson [3] gave a formal proof about the random character of speculative prices, and Fama [4] introduced the celebrated Efficient Market Hypothesis (EMH). This efficiency hypothesis was then subdivided into three categories, *i.e.* weak, semi-strong and strong, according to the information set reflected in prices [5]. In empirical studies the weak-form of the EMH has been mainly considered. It requires that today price reflects the information of the sequence of past prices, excluding the possibility of finding profitable trading strategies systematically. Despite all these seminal contributions, the quest for a stochastic model that reflects asset prices remains as an open and controversial issue [6].

Nowadays, it is widely recognized that the random walk model of prices can be considered only as a first approximation of price behavior. Within this avenue of research, most of researchers concentrated on testing the efficiency of different financial markets by estimating the Hurst exponent H ($H \in (0, 1)$) as a way to characterize long-range dependence phenomena (*e.g.*, Refs. [7–22], among many others). The interested reader may refer to Ref. [23] for a comprehensive survey about different Hurst exponent estimators. A Hurst exponent $H \neq 0.5$ is, in principle, an evidence of the presence of memory effects in the time series under analysis. For $H > 0.5$ persistence or positive long-term memory is found whereas $H < 0.5$ indicates anti-persistence or negative long-term memory. The deviation from the uncorrelated, ideal state ($H = 0.5$) is considered as a signature of inefficiency since price fluctuations could be predicted, allowing for risk-free profitable trading strategies. Indeed, it has been shown that large profits can be obtained from persistent than anti-persistent markets, both with exactly the same deviation from the memoryless case, *i.e.* $|H - 1/2|$ [24]. However, Hurst exponent estimators are usually biased by the presence of heavy tails [25], finite-size effects [26], and/or short-range dependence [27,28] generating doubts about the reliability of their results. These drawbacks can lead to the erroneous identification of memory effects, $H \neq 0.5$, in true uncorrelated financial records [29]. On the other hand, the inappropriate application of the estimation methods can also lead to the spurious identification of anti-persistent behavior in financial time series [23,30]. Furthermore, Bassler et al. [31] have shown that the estimation of the Hurst exponent alone cannot be used to determine either the existence of long-term memory or the efficiency of markets since a Hurst exponent $H \neq 1/2$ might be perfectly consistent with Markov processes with nonstationary increments. Consequently, several researchers have focused on looking for alternative or complementary approaches to quantify the underlying temporal correlation structures of financial time series. Particularly, descriptors derived from information theory, especially entropy measures, have been proposed for such a goal. These measures are of more general applicability since they are model-independent, *i.e.* not linked to a specific stochastic model. Additionally, entropy approaches have the salient ability to account for nonlinear dependences. Gulko [32], Zhang [33] and Darbellay and Wuertz [34] were probably the first to demonstrate the usefulness of entropy concepts to characterize financial time series. Later, Pincus and Kalman [35] confirmed that approximate entropy can be used as a marker of market stability. In the last decade, other entropy-related methodologies have been introduced to quantify market efficiency in foreign exchange [36], stock [37–42], commodity [43–45], and bond [46–48] market indices. Interest rate time series have been also characterized using an information theory approach [49,50]. We need to emphasize here the starring role played by the permutation entropy in some of the above-mentioned studies. It is also worth mentioning the Efficiency Index (EI), introduced by Kristoufek and Vosvrda, that incorporates long-term memory, fractal dimension and entropy in a single measure [51–53]. Actually, it has been observed that the entropy measure has a stronger effect in the final efficiency ranking when the EI is applied to different stock market indices across the world [52]. In the present study, a very recently introduced entropy measure, namely the permutation min-entropy, is implemented for quantifying the market efficiency. This fast and simple symbolic tool has been shown particularly suitable for dealing with the identification of intricate temporal structures from time series data [54].

Despite the importance of fixed income markets in the composition of investment portfolios and in company and government financing, there are very few empirical studies about their informational efficiency. The fixed income markets are divided into two categories, depending on the legal status of the issuer. Corporate bond markets refer to debt instruments issued by private and public corporations whereas sovereign bond markets include debt instruments whose borrowers are autonomous nation states. Estimating the Hurst exponent through a rolling window approach, Bariviera et al. [55] have detected that the 2008 financial crisis affects more the informational efficiency of the corporate than the sovereign bond indices of seven European Union countries. Later, following a similar analysis, the same authors have observed that the financial turmoil has a uneven effect on the informational efficiency of fifteen sectorial indices of European corporate

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