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Stock market indices and sustainability: A comparison between them

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ABSTRACT

In this paper, we examine the issue of sustainability in the stock markets by comparing various statistical properties of the classical stock market indices against the recent sustainable ones. Weekly and monthly data from Dow Jones, Eurostoxx and Hang Seng indices were collected, and fractional integration methods were used to analyze differences in terms of persistence and mean reversion for both sustainable and common indices. The results indicate high levels of persistence in all cases, observing almost no differences across the markets. Long memory is also detected in the absolute and squared returns in both markets.

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1. Introduction

Corporate Social Responsibility (CSR) is a classical economic concept that was initially proposed by Bowen (1954), appealing to the social responsibility of corporations to produce not only goods, but also to return to society part of what it had provided them. Drucker (1984) indicated that ‘Social Responsibility of Business’ in the years to come will no longer mean ‘Doing Good’ or ‘Not Doing Harm’, it will have come to mean converting social problems into opportunities for profitable business.

Since the UN Assembly of 1979, the Brundtland (1987), and during the 1990s as a result of the Kyoto Protocol, environmental problems have also been included in the equation to define the concept of sustainability or sustainable development (SD). Van Marrewijk (2003) clarified the relationship between SD and CSR as being two sides of the same coin. CSR is associated with the everyday aspects of people such as transparency, stakeholder dialogue or sustainability reporting, while SD is focused more on value creation, environmental management and friendly production systems. Today, both concepts (CSR and SD) are seen as two of the main drivers for businesses over the past decade (Elmualim 2017) which support sustainable competitive advantages (Pistoni, Songini, and Perrone 2016). The need to advance in SD is gaining increasing importance due to the desire to counterbalance the threatening implications of global warming and the long-term perspective of corporate strategies.

Despite considerable academic development and the standardization of reporting requirements in large corporations, the role of sustainability in the real economy still appears unclear. Besides classical indices in which companies are included according to their size or market capitalization, some new stock indices including the term sustainability in their name have appeared, in which companies must meet a set of socially responsible practices in order to be listed. In this light, the present paper focuses on the study of the differential value of these SD companies, by comparing the performance of both sustainable and classical indices since the inception of these sustainable indices in the market. The aim of the analysis is to provide evidence regarding some of their statistical properties, in particular their degree of persistence and mean reversion, by applying fractional integration techniques to a set of long-term data from the U.S.A. (Dow Jones), Europe (Eurostoxx) and Asia (Hang Seng). This methodology is very appropriate to determine if shocks in the series have permanent or transitory effects depending on the value of the differencing parameter d , helping to identify investment opportunities. Thus, if the order of integration of the series is smaller than 1, shocks will have a transitory nature, disappearing faster the lower the degree of integration is, while orders of integration equal to or above 1 imply a lack of mean reversion and permanency of shocks. In the standard literature, these values are 0 for stationary series and 1 for nonstationary ones; however, allowing for fractional orders of integration we get a much higher degree of flexibility in the dynamic specification of the data.

The layout of the paper is the following: Section 2 reviews the relevant literature regarding sustainable stock market indices; Section 3 describes the data and the econometric framework; Section 4 discusses the empirical findings; finally, Section 5 offers some concluding remarks.

2. Sustainable stock market indices

2.1. A brief history of the Sustainability concept

The concept of Sustainability was first officially raised at the United Nations General Assembly in 1979. It was first taken on board by governments and multilateral organizations in 1987 with the UN Report on Environment and Development ‘Our Common Future’ or Brundtland with a definition that has already become classic: *‘sustainable is development that meets current needs, without compromising the ability of future generations to meet their own needs’*. However, this concept has a history of more than three centuries as it was initially used by Carlowitz (1713) with the expression *‘nachhaltendes wirtschaften’* or sustainable yield. The idea behind that concept was the perception of scarcity resulting from the industrial revolution, in which the need for wood was so great that the effects of deforestation began to be intuited.

Since its inception, the sustainability concept has been linked to the term CSR. This arose in the last century as a result of certain world conflicts that provoked the interest of citizens to determine the repercussions of certain economic practices which were being employed to maintain various objectionable political regimes. As a consequence, society began to ask for changes in the way businesses were managed and for a greater commitment of the business environment to social problems. These social implications of business activity became evident in the wake of the acceleration of economic activity

in a capitalist framework, with the arrival of globalization, and the development of new technologies against the backdrop of the emergence of strong ecological awareness worldwide.

After the Second World War a framework for action evolved to fight for social responsibility, which began with the adoption of the Universal Declaration of Human Rights Treaty in 1948, which would eventually become the instigator and driving force for multiple social changes. In 1976, the Organization for Economic Cooperation and Development (OECD), set out recommendations and defined the principles and standards characteristic of socially responsible conduct, in order to guarantee that organizational activities were carried out under the guidelines of public policy and therefore would contribute towards the relationship between companies and society becoming based on mutual trust. The OECD guidelines enable companies to create internal guidance and management systems, which help establish commitments with good intentions and following sound practices, in order to guarantee social dialogue regarding what constitutes responsible business conduct. Thus, they have become the institutional, political and legal frame of reference for the efforts of private organizations, aimed at defining and implementing SD and promoting positive contributions to economic, environmental and social progress.

In 1992, the United Nations Conference on Environment and Development held in Rio de Janeiro set out an Action Plan to transform the current development model based on the exploitation of natural resources as unlimited goods, proposing a new model which would meet the needs of both current and future generations. This plan came to be represented by the term SD or, in other words, the efficient and rational use of resources with equitable benefits. During the year 2000, the UN member countries agreed on the Millennium Development Goals (MDGs) for 2015. At the end of the period for fulfilling these MDGs, the UN General Assembly established a new global agreement in which the 193 member states around the world pledged to adopt the 2030 Agenda, a program that sets out 17 Sustainable Development Goals (SDGs) and 169 targets.

2.2. Sustainable markets

In the field of economic investments, the concept of SD generated the Socially Responsible Investment (SRI) initiatives, based on a growing awareness among the population, investors, companies and governments of the effects of nonfinancial MSG risks (environmental, social and good governance). Chatzitheodorou et al. (2019) explain the different perspectives of SRI investments today, as the majority of the literature focuses on SRI performance versus traditional investments (TI), outlining these categories through the orientation of SRIs (social, environmental and financial) and the motivations of investors (socially-oriented, profit-seeking, risk averse).

Through the Stock Market, the monetary resources of investors are channeled to companies or governments to finance investment projects through investment funds. There are around 125 stock markets in the world with an estimated total of 3429 indices in 2017 (Canales 2017) that monitor changes in the value of traded assets. As the stock index refers to the weighted average of the market capitalization of a specific list of securities (Lo 2012), it is one of the statistical measures designed to study the evolution and

aggregate behaviour of asset value and for making decisions based on said value (Elbaum 2004).

Sustainable indices emerged in the 1990s, and since then have been used to record the added, weighted and adjusted value of stock performance (Searcy and Elkhawas 2012), providing thus a measurement of stock performance for those companies that meet SR requirements. The CSR approach used by these indices is rooted in the triple bottom line that proposes the generation of three types of results: economic, social and environmental or ESG (Elkington 1999). This focus is in line with the Brundtland (1987), which supports development that meets current needs without compromising the ability of future generations to meet theirs.

The first sustainable stock index traded was the Dow Jones Sustainability Index (DJSI) in New York, formed by more than 300 companies, with a business approach to creating long-term value for shareholders by taking advantage of economic, environmental and social development opportunities (Dow Jones Sustainability Index 2015). This index is managed by the company RobecoSAM applying its own method for evaluating the environmental, sustainability and good governance policies of each company. After ranking more than 1000 data points, each company receives a final score. Only those with the top 10% highest scores are reflected in the DJSI.

Among other sustainability indices, we find the Euro Stoxx Sustainability 40 Index that started in the early 2000s, providing consistent information on the main companies in terms of environmental, social and long-term governance in the Euro area, and the Hang Seng Corporate Sustainability Index that measures the performance of companies with outstanding sustainability practices in the Hong Kong and mainland China markets that started trading in 2008.

Regarding the different performance of these kinds of investments the hypothesis that SRIs outperform 'traditional' value driven investments is unclear. Costa-Lourenço et al. (2012) provide empirical evidence on how corporate sustainability performance as proxied by membership of the DJSI, is reflected in the market value of equity, penalizing large profitable firms with low levels of CSP. Cheung and Roca (2013) found that for the Asian stocks in DJSI that both stock indices experience a significant decline in returns, an increase in trading volume, and an increase in idiosyncratic risk. Belghitar, Clark, and Deshmukh (2014) found there was a financial price to be paid for socially responsible investing, as zero-cost portfolios created by shorting the SRI indices and using the proceeds to invest in the conventional indices generated higher average returns. Fogliano, De Souza Cunha, and Samanez (2013) analyzed the Brazilian market and found no evidence of superior performance of SD portfolios. Oberndorfer et al. (2013) analyzed the inclusion of German corporations in the Dow Jones STOXX Sustainability Index, finding that stock markets may penalize the inclusion of a firm in sustainability stock indices and suggesting that the inclusion in a more visible sustainability stock index may have larger negative impacts.

Other studies such as Dam and Scholtens (2015) analyzed the literature and did not establish a significant impact of SRI on stock market returns. In this line, Leite and Cortez (2015) analyzed some European SRI fund performances during the financial crisis, finding that French SRI funds underperform conventional funds during noncrisis periods and match the performance of their conventional peers during market downturns. Renneboog, Horst, and Zhang (2011) analyzed the money flows of SRI funds

around the world, finding that SD investments were less sensitive to past negative returns than Traditional Index conventional fund flows (TI), with no evidence of a smart money effect as the funds that receive more inflows neither outperform nor underperform their benchmarks or conventional funds. Other specific studies such as that of Schaeffer et al. (2012) for U.S.A. oil companies also mention that they did not detect any positive impact between the adoption of a proactive environmental posture of these companies reflected by their adhesion to the DJSI, and their stock prices.

On the other hand, Nakai, Yamaguchi, and Takeuchi (2016) compared SRI funds and conventional funds in the Japanese market, and concluded that SRI funds resisted the 2008 financial crisis better than conventional funds. Gjerde, Knivsflå, and Sættem (2010) found that SD investment has a superior local performance for the Oslo Stock Exchange. Joliet and Titova (2018) found that SRI funds have a higher economic impact for value rather than growth funds in U.S.A. markets. Patel and Kumari (2020) analyzed the Indian market, finding a similar performance between SD and TI markets but concluding that SD indices are a better performing tool with which to satisfy the surge of green investment needs.

Due to the differing regional profitability reported across these works, this paper analyzes the different performances of the SRI investments compared with their TI counterparts in terms of persistence and mean reversion. Mynhardt, Makarenko, and Plastun (2017) observed more persistence in the SRI than in the standard markets. Similarly to our study, they compared the behaviour of the TI traditional indices and SR Indices (in particular, DJSI, Nasdaq CRD SI, FTSE 4Good, MSCI Global ESG and SP500 ESR), and using the Hurst exponent as a measure of their degree of persistence, they found that SR indices have lower efficiency than traditional ones, thus reducing fundamental predictability of prices and the possibility of arbitrage opportunities with financial assets. As Mynhardt, Makarenko, and Plastun (2017) noted, and despite the considerable amount of research on the differences between the TI and SR Indices, effectiveness and the nature of changes in the dynamics of indices appears not to have been reviewed. We also focus on this issue, looking for a better measurement of persistence with fractional integration techniques and different sampling periods.

3. Methodology

The techniques used in this work belong to the category of long range dependence, that means that the observations are strongly correlated across time. Within this group, we use a particular type of model known as fractionally integrated that basically means that the number of differences required to render a series stationary $I(0)$ is a fractional value. Given a second-order (or covariance) stationary process $\{u_t, t = 0, \pm 1, \dots\}$ with autocovariance function $\gamma_u = E(u_t - Eu_t)(u_{t+u} - Eu_t)$ we say that u_t is $I(0)$ or short memory if it satisfies the following property:

$$\sum_{u=-\infty}^{\infty} \gamma_u < \infty. \quad (1)$$

Within this context, we say that a process $\{x_t, t = 0, \pm 1, \dots\}$ is integrated of order d , and denoted as $I(d)$ if it requires d -differences to become $I(0)$, i.e. x_t is $I(d)$ if it can be

expressed as:

$$(1 - L)^d x_t = u_t, \quad t = 1, 2, \dots, \quad (2)$$

where L refers to the lag operator, that is, $L^k x_t = x_{t-k}$, and using a Binomial expansion on the polynomial in L above,

$$(1 - L)^d = \sum_{j=0}^{\infty} \binom{d}{j} (-1)^j L^j = 1 - dL + \frac{d(d-1)}{2} L^2 - \dots \quad (3)$$

Equation (2) can be expressed as

$$x_t = d x_{t-1} - \frac{d(d-1)}{2} x_{t-2} + \dots + u_t. \quad (4)$$

Thus, if d is a noninteger value, x_t will depend on all its past history and d can be taken as the relevant parameter to measure persistence in the data as the higher the value of d is, the higher the level of persistence or association between the data is.

In the context of stock market data, if $d = 1$ (and u_t is for example a white noise process), x_t follows a random walk, supporting thus a weak version of the efficiency market hypothesis and implying then that there is no possibility of obtaining systematic profits from the past history of the data. On the other hand, values significantly different from 1, either above or below, suggest the existence of inefficiencies in the markets.

We estimate the differencing parameter d by using an approximation to the likelihood function, named the Whittle function, expressed in the frequency domain as presented in Dahlhaus (1989), and using a simple version of the Lagrange Multiplier (LM) tests of Robinson (1994) which is very appropriate in the context of nonstationary data.¹

4. Data and results

We use data on weekly and monthly returns from the Reuters Eikon database for the DJSI (.WISGI) over the period 1 January 1994 to 31 January 2020; the Stoxx Sustainability 40 Index (.STOXX50E) from 15 October 2001 to 31 January 2020, and the Hang Seng Corporate Sustainability index (.HSSUS) from 2 January 2008 to 31 January 2020. Figures 1–2(a, b and c) summarize the dataset, while Figure 3 compares the performance of the different indices under study.

Figure 4 shows the differential returns between the performance of the sustainability index and its traditional counterpart. It can be seen that the U.S.A. indices have a negative relationship, while it is positive in the other two cases.

We estimate the following regression model,

$$\begin{aligned} y_t &= \beta_0 + \beta_1 t + x_t; & (1 - L)^d x_t &= u_t, & t \\ &= 0, 1, \dots, \end{aligned} \quad (5)$$

where y_t is each of the observed time series; β_0 and β_1 are unknown coefficients and x_t is supposed to be $I(d)$. We report the results in terms of the estimated values of d for the three standard cases in the unit root literature of: (i) no deterministic terms (i.e. $\beta_0 = \beta_1 = 0$ in (5)), (ii) an intercept ($\beta_1 = 0$ in (5)), and (iii) an intercept with a linear time trend (β_0

Types of investors	SRI focus			Investors' motivations			Potential Investors
	Social	Environmental	Financial	Social-oriented	Profit-seeking	Risk averse	
Social-based investments							
Idealistic investors,	x			x			Religious investors, charities
Socially Opportunistic	x		x		x		Social Investors
Prudent investors	x		x		x	x	Conventional Investors
Environmental-based investments							
Shareholder activist		x		x			NGOs
Environmentally Opportunistic		x			x		Conventional investors
Environmentally-risk avoider		x			x	x	Conventional Investors
Social-Environmental-based investment							
Collaborative investors	x	x			x		Conventional investors, NGOs
Socio-greener-oriented	x	x		x			Social investors
Crowd funders							
Eco-angels/ Philanthropic venture capitalists	x	x		x	x		NGOs, social investors
Sustainability Territory							
Sustainable investors	x	X	x	x	x		Institutional investors

Figure 1. Different types of SRI investors (Chatzitheodorou et al. 2019).

and β_1 unknown), marking in bold in the table the selected model for each series, based on the t -values of the estimated coefficients on the d -differenced series.

Table 1 displays the estimates of d (and their associated 95% confidence intervals) under the assumption that u_t in (5) is a white noise process. The first thing we observe is that the time trend is only required for the Dow Jones indices, the intercept being sufficient to describe the deterministic part in the remaining cases. While focusing on the estimated values of d , it can be seen that the values are very close to 1 in all cases, with slightly superior numbers for the sustainable indices results and also higher for monthly sampling compared with weekly data. Starting with the Dow Jones, it is observed that the estimated value of d is 1.00 for the DJI and 1.07 for the DJSI market on a monthly sampling, and the values are 0.95 and 0.99 for the weekly sampling. In the case of Eurostoxx, the differences are narrower, ranging between 1.04 for TI and 1.03 for SI on a monthly basis, and 0.94 and 0.95 for a weekly basis sampling. Finally, in the case of Hang Seng, the performance is very similar for both indices, ranging from 1.03 for monthly data and 1.01 for weekly data. As a conclusion from this table, we can say that all series display high levels of persistence; the $I(1)$ null hypothesis is almost never rejected, the only two exceptions being Dow Jones and Eurostoxx for a weekly basis for the unsustainable indices.

In Table 2, we allow the error term to be autocorrelated. However, instead of imposing a specific modelling assumption for u_t in (5), we use here a nonparametric method due to Bloomfield (1973). It is called nonparametric in the sense that no functional form is explicitly presented for u_t in (5). The model is exclusively defined in terms of its spectral density function through an expression that approximates fairly well a highly parameterized ARMA process. Moreover, this approach fits extremely well in $I(d)$ models (see Gil-Alana 2004). The results, displayed in Table 2, are very similar to those given in Table 1 in

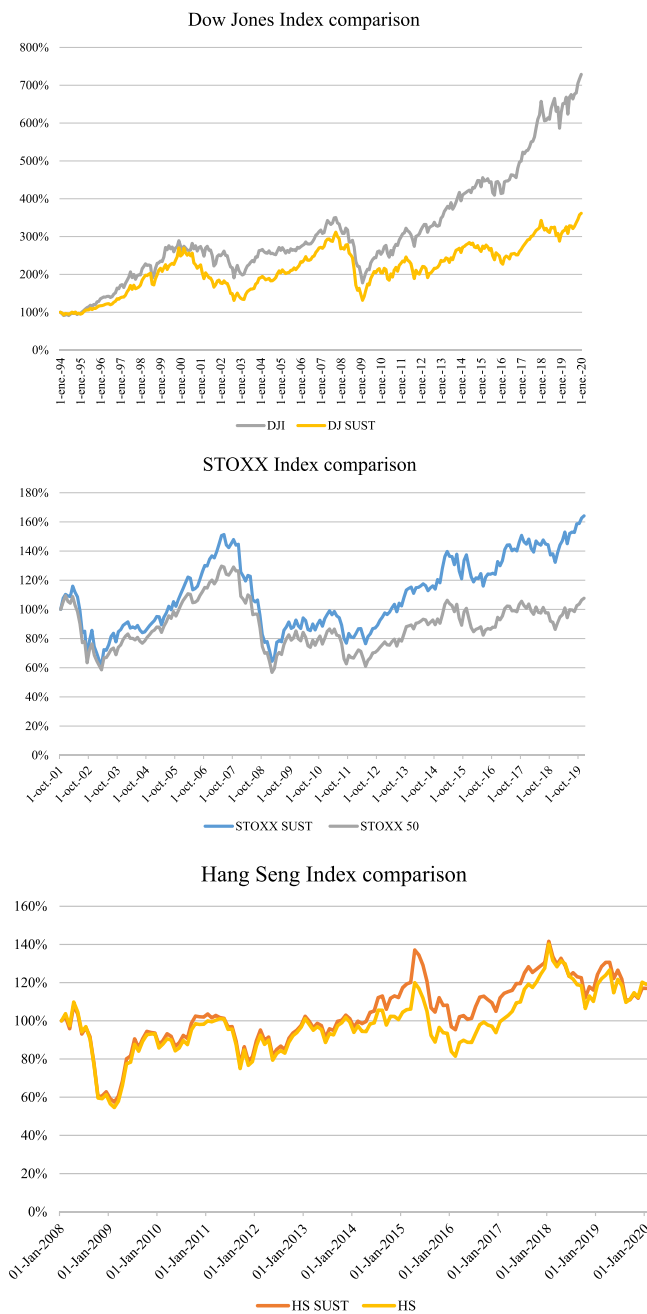


Figure 2. Performance of different indices [Figure 2\(a\)](#). Dow Jones Industrial Average and Dow Jones Sustainability Index [Figure 2\(b\)](#). Eurostoxx 50 and Eurostoxx Sustainability 40 index [Figure 2\(c\)](#). Hang Seng and Hang Seng Sustainability index.

the sense that all values are close to 1, but with lower values of d for monthly sampling instead of weekly sampling. It is important to notice that the Hang Seng index displays lower values of d regarding the other cases, as does the weekly sampling case which is 0.85

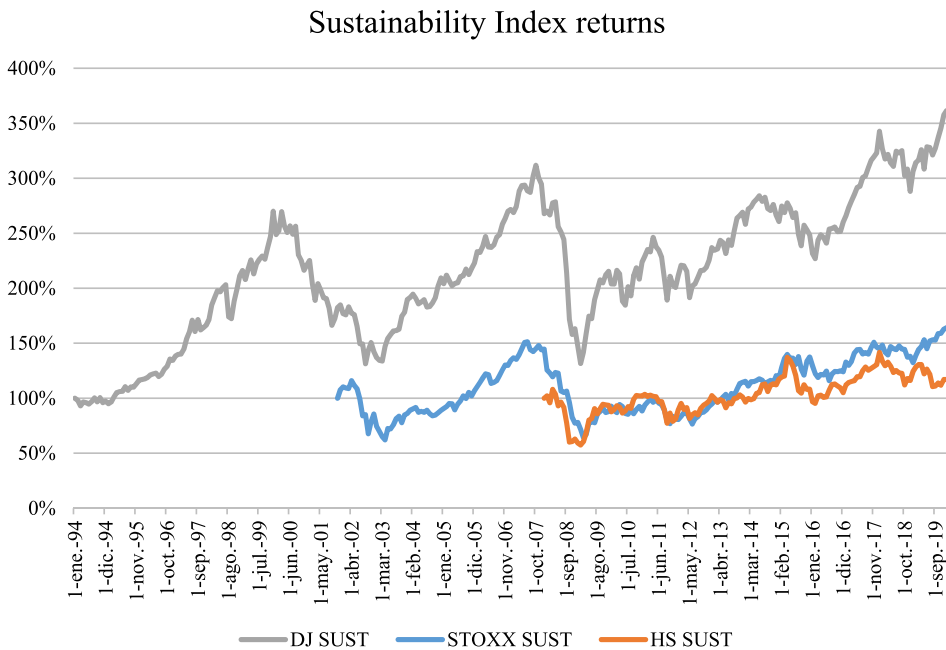


Figure 3. Performance of sustainability indices.

while for the rest of results range between 0.92 and 1.04. Nevertheless, the unit root null hypothesis cannot be rejected in any single case. From these two tables, we can conclude that there is almost no difference between the sustainable and nonsustainable indices in regard to their degree of persistence, finding evidence supporting the $I(1)$ hypothesis in all except a couple of cases with the sustainable indices.

Next, we focus on the volatility issue by proxying it through the absolute and squared returns, these being obtained by taking first differences on the logged prices. Tables 3 and 4 report the results (once more in terms of d and the confidence bands) under the assumption of white noise errors. Though not reported, almost identical results were obtained when the errors were autocorrelated. The first thing we observe across these two tables is that the time trend is required in a number of cases, and the estimates of d are positive (and thus showing long memory, i.e. $d > 0$) in all except one single case (Hang Seng, with monthly data and sustainable index). In general, the values are very similar in the sustainable and nonsustainable indices, the only significant difference being observed in the Dow Jones index, on a monthly basis with a substantial increase in the estimated value of d in the sustainable index under both monthly and weekly data.

Some authors might argue that the long memory property found in the absolute and squared returns may be a spurious phenomenon caused by the presence of breaks and nonlinearities in the data that have not been taken into account. In order to deal with this issue, we have implemented the nonlinear approach developed in Cuestas and Gil-Alana (2016) that substitutes the linear trend in (5) for a nonlinear trend based on the Chebyshev polynomials in time, approximating then the potential breaks in a

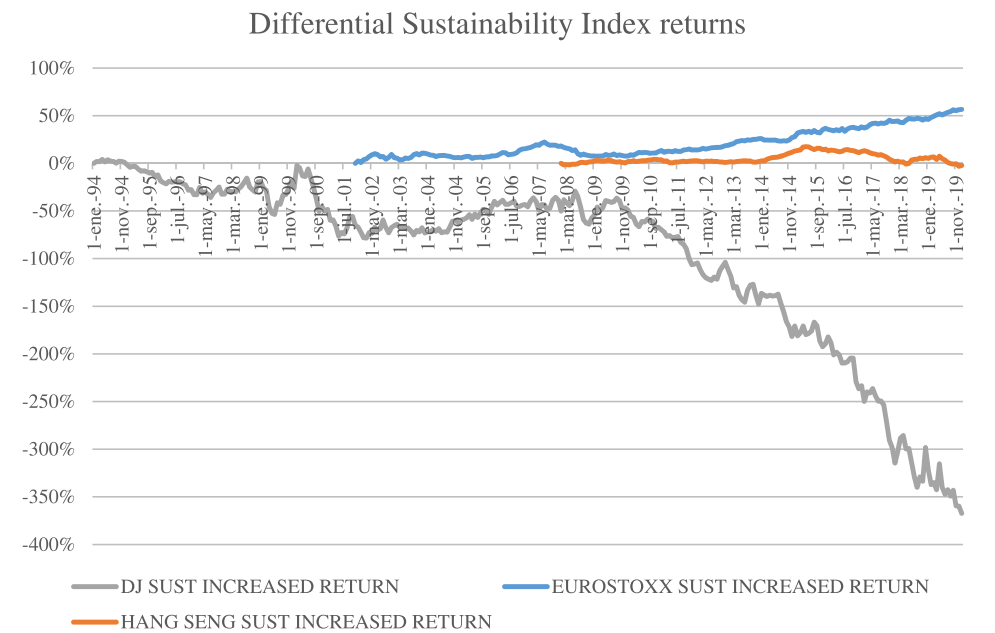


Figure 4. Differential performance of sustainability indices and traditional indices.

Table 1. Estimates of d under the assumption of white noise errors.

Panel (i) No sustainable indices				
	Series	No regressors	An intercept	A time trend
Monthly data	Dow Jones	0.99 (0.92, 1.07)	1.00 (0.93, 1.08)	1.00 (0.93, 1.08)
	Hang Seng	0.97 (0.87, 1.11)	1.03 (0.90, 1.18)	1.03 (0.90, 1.18)
	Eurostoxx	0.99 (0.90, 1.10)	1.04 (0.95, 1.15)	1.04 (0.94, 1.15)
Weekly data	Dow Jones	1.00 (0.96, 1.04)	0.95 (0.91, 0.99)	0.95 (0.91, 0.99)
	Hang Seng	0.99 (0.93, 1.05)	1.01 (0.95, 1.06)	1.01 (0.95, 1.06)
	Eurostoxx	1.00 (0.96, 1.05)	0.94 (0.90, 0.99)	0.94 (0.90, 0.99)
Panel (ii) Sustainable indices				
	Series	No regressors	An intercept	A time trend
Monthly data	Dow Jones	0.99 (0.92, 1.08)	1.07 (0.99, 1.16) 9	1.07 (0.99, 1.16) 9
	Hang Seng	0.97 (0.87, 1.12)	1.03 (0.90, 1.19)	1.03 (0.90, 1.19)
	Eurostoxx	0.99 (0.90, 1.10)	1.03 (0.94, 1.14)	1.03 (0.94, 1.14)
Weekly data	Dow Jones	1.00 (0.96, 1.04)	0.99 (0.95, 1.03)	0.99 (0.95, 1.03)
	Hang Seng	0.99 (0.93, 1.05)	1.01 (0.96, 1.07)	1.01 (0.96, 1.07)
	Eurostoxx	1.00 (0.96, 1.05)	0.95 (0.91, 1.00)	0.95 (0.91, 1.00)

Table 2. Estimates of d under the assumption of autocorrelated noise errors.

Panel (i) No sustainable indices				
	Series	No regressors	An intercept	A time trend
Monthly data	Dow Jones	0.98 (0.87, 1.12)	1.00 (0.88, 1.13)	1.00 (0.89, 1.12)
	Hang Seng	0.93 (0.75, 1.18)	0.92 (0.62, 1.28)	0.92 (0.51, 1.28)
	Eurostoxx	0.96 (0.83, 1.14)	0.96 (0.81, 1.17)	0.96 (0.81, 1.17)
Weekly data	Dow Jones	0.99 (0.94, 1.06)	0.99 (0.94, 1.05)	0.99 (0.94, 1.05)
	Hang Seng	0.98 (0.88, 1.08)	1.04 (0.95, 1.14)	1.04 (0.95, 1.14)
	Eurostoxx	1.00 (0.91, 1.06)	1.00 (0.93, 1.06)	1.00 (0.93, 1.06)
Panel (ii) Sustainable indices				
	Series	No regressors	An intercept	A time trend
Monthly data	Dow Jones	0.97 (0.86, 1.13)	1.02 (0.88, 1.19)9	1.02 (0.89, 1.19)9
	Hang Seng	0.93 (0.74, 1.17)	0.85 (0.60, 1.22)	0.84 (0.40, 1.22)
	Eurostoxx	0.95 (0.82, 1.15)	1.00 (0.85, 1.22)	1.00 (0.85, 1.22)
Weekly data	Dow Jones	1.00 (0.94, 1.07)	1.02 (0.92, 1.09)	1.02 (0.97, 1.09)
	Hang Seng	0.98 (0.90, 1.08)	1.04 (0.95, 1.15)	1.04 (0.95, 1.15)
	Eurostoxx	1.00 (0.91, 1.07)	0.99 (0.92, 1.05)	0.99 (0.91, 1.05)

Table 3. Estimates of d under the assumption of white noise errors (Absolute rtns.).

Panel (i) No sustainable indices				
	Series	No regressors	An intercept	A time trend
Monthly data	Dow Jones	0.15 (0.09, 0.23)	0.13 (0.07, 0.20)	0.12 (0.05, 0.19)
	Hang Seng	0.21 (0.10, 0.34)	0.14 (0.06, 0.26)	0.11 (0.02, 0.24)
	Eurostoxx	0.20 (0.13, 0.30)	0.16 (0.10, 0.25)	0.16 (0.09, 0.24)
Weekly data	Dow Jones	0.22 (0.19, 0.25)	0.21 (0.18, 0.25)	0.21 (0.18, 0.25)
	Hang Seng	0.22 (0.18, 0.26)	0.17 (0.13, 0.20)	0.13 (0.09, 0.17)
	Eurostoxx	0.23 (0.20, 0.27)	0.21 (0.18, 0.25)	0.21 (0.18, 0.24)
Panel (ii) Sustainable indices				
	Series	No regressors	An intercept	A time trend
Monthly data	Dow Jones	0.20 (0.14, 0.28)	0.20 (0.13, 0.27)	0.19 (0.13, 0.27)
	Hang Seng	0.21 (0.10, 0.34)	0.14 (0.06, 0.26)	0.09 (−0.01, 0.23)
	Eurostoxx	0.22 (0.15, 0.30)	0.17 (0.11, 0.25)	0.15 (0.08, 0.23)
Weekly data	Dow Jones	0.22 (0.19, 0.25)	0.22 (0.19, 0.25)	0.22 (0.19, 0.25)
	Hang Seng	0.23 (0.19, 0.27)	0.17 (0.13, 0.21)	0.12 (0.09, 0.17)
	Eurostoxx	0.23 (0.20, 0.27)	0.21 (0.18, 0.24)	0.20 (0.17, 0.23)

fairly smooth way. The implemented model is the following one,

$$y_t = \sum_{i=0}^m \theta_i P_{i,T}(t) + x_t, \quad (1 - L)^d x_t = u_t, \quad t = 1, 2, \dots, \quad (6)$$

where m indicates the order of the Chebyshev polynomial, defined as:

$$P_{0,T}(t) = 1, \quad (7)$$

and

$$P_{i,T}(t) = \sqrt{2} \cos(i \pi(t - 0.5) / T), \quad t = 1, 2, \dots, T; \quad i = 1, 2, \dots \quad (8)$$

Table 4. Estimates of d under the assumption of white noise errors (Squared rtns.).

Panel (i) No sustainable indices				
	Series	No regressors	An intercept	A time trend
Monthly data	Dow Jones	0.14 (0.07, 0.22)	0.13 (0.07, 0.21)	0.13 (0.06, 0.21)
	Hang Seng	0.21 (0.10, 0.36)	0.18 (0.08, 0.32)	0.14 (0.02, 0.29)
	Eurostoxx	0.19 (0.12, 0.28)	0.18 (0.11, 0.27)	0.16 (0.09, 0.26)
Weekly data	Dow Jones	0.18 (0.14, 0.21)	0.18 (0.14, 0.21)	0.17 (0.14, 0.21)
	Hang Seng	0.18 (0.14, 0.22)	0.16 (0.13, 0.20)	0.14 (0.09, 0.18)
	Eurostoxx	0.15 (0.11, 0.19)	0.15 (0.11, 0.18)	0.14 (0.11, 0.18)
Panel (ii) Sustainable indices				
	Series	No regressors	An intercept	A time trend
Monthly data	Dow Jones	0.21 (0.14, 0.29)	0.21 (0.14, 0.29)	0.21 (0.14, 0.29)
	Hang Seng	0.20 (0.09, 0.35)	0.17 (0.07, 0.31)	0.12 (0.01, 0.23)
	Eurostoxx	0.21 (0.15, 0.30)	0.20 (0.14, 0.28)	0.17 (0.10, 0.23)
Weekly data	Dow Jones	0.20 (0.17, 0.24)	0.20 (0.17, 0.24)	0.20 (0.17, 0.24)
	Hang Seng	0.18 (0.14, 0.22)	0.16 (0.12, 0.20)	0.12 (0.09, 0.17)
	Eurostoxx	0.16 (0.13, 0.20)	0.16 (0.12, 0.19)	0.15 (0.12, 0.19)

In this context, if $m = 0$ in (6), the model contains only an intercept; if $m = 1$, it contains an intercept and a linear trend; and if $m > 1$, it becomes nonlinear, where the higher the value of m is, the higher the nonlinear structure is. We choose $m = 3$, and thus, θ_2 and θ_3 refer to the nonlinear coefficients.

Tables 5 and 6 report the estimated coefficients for the absolute and squared returns, respectively. The results are similar in both cases and evidence of long memory is found

Table 5. Estimates of d under the assumption of white noise errors (Absolute rtns.).

Panel (i) No sustainable indices						
	Series	d	θ_1	θ_2	θ_3	θ_4
Monthly data	Dow Jones	0.11 (0.04, 0.20)	0.0318 (11.92)	0.0033 (1.43)	−0.0008 (−0.36)	0.0001 (0.06)
	Hang Seng	0.08 (−0.03, 0.22)	0.0446 (9.58)	0.0086 (2.03)	0.0063 (1.54)	0.0037 (0.94)
	Eurostoxx	0.15 (0.08, 0.24)	0.0400 (8.83)	0.0048 (1.28)	−0.0018 (−0.53)	0.0030 (0.90)
Weekly data	Dow Jones	0.40 (0.32, 0.49)	0.0248 (0.45)	0.0044 (0.12)	−0.0084 (−0.28)	−0.0029 (−0.11)
	Hang Seng	0.08 (0.03, 0.12)	0.0226 (19.21)	0.0055 (5.16)	0.0043 (4.37)	0.0027 (2.81)
	Eurostoxx	0.20 (0.17, 0.24)	0.0219 (10.26)	0.0028 (1.67)	−0.0024 (−1.58)	0.0016 (1.12)
Panel (ii) Sustainable indices						
	Series	d	θ_1	θ_2	θ_3	θ_4
Monthly data	Dow Jones	0.18 (0.11, 0.26)	0.0347 (8.28)	0.0008 (0.23)	−0.0045 (−1.46)	0.0015 (0.54)
	Hang Seng	0.06 (−0.06, 0.20)	0.0419 (10.27)	0.0097 (2.57)	0.0050 (1.35)	0.0042 (1.17)
	Eurostoxx	0.15 (0.07, 0.23)	0.0388 (8.36)	0.0077 (2.00)	0.0002 (0.05)	0.0036 (1.05)
Weekly data	Dow Jones	0.42 (0.34, 0.51)	0.0241 (0.22)	0.0090 (0.13)	−0.0058 (−0.10)	−0.0106 (−0.21)
	Hang Seng	0.06 (0.01, 0.11)	0.212 (21.74)	0.0060 (6.60)	0.0038 (4.35)	0.0028 (3.31)
	Eurostoxx	0.20 (0.17, 0.23)	0.0211 (10.15)	0.0035 (2.17)	−0.0018 (−1.21)	0.0012 (0.90)

Table 6. Estimates of d under the assumption of white noise errors (Squared rtns.).

Panel (i) No sustainable indices						
	Series	d	θ_1	θ_2	θ_3	θ_4
Monthly data	Dow Jones	0.12 (0.05, 0.20)	0.0017 (5.38)	0.0002 (1.04)	−0.0001 (−0.65)	−0.00005 (−0.15)
	Hang Seng	0.08 (−0.05, 0.26)	0.0036 (4.44)	0.0016 (2.21)	0.0011 (1.62)	0.0008 (1.19)
	Eurostoxx	0.16 (0.09, 0.26)	0.0027 (3.78)	0.0002 (1.40)	−0.0001 (−0.21)	0.0031 (0.62)
Weekly data	Dow Jones	0.41 (0.33, 0.50)	0.0211 (0.16)	0.0084 (0.10)	0.0149 (−0.21)	−0.0062 (−0.10)
	Hang Seng	0.10 (0.05, 0.15)	0.0009 (6.39)	0.0004 (3.68)	0.0003 (3.24)	0.0002 (2.21)
	Eurostoxx	0.14 (0.10, 0.18)	0.0008 (4.47)	0.0002 (1.29)	−0.0002 (−1.52)	−0.00001 (−0.07)
Panel (ii) Sustainable indices						
	Series	d	θ_1	θ_2	θ_3	θ_4
Monthly data	Dow Jones	0.19 (0.12, 0.27)	0.0021 (3.42)	0.0002 (0.06)	−0.0006 (−1.53)	0.0002 (0.62)
	Hang Seng	0.07 (−0.07, 0.25)	0.033 (4.32)	0.0016 (2.36)	0.0010 (1.51)	0.0009 (1.40)
	Eurostoxx	0.17 (0.10, 0.26)	0.0027 (3.29)	0.0012 (1.91)	0.0003 (0.52)	0.0005 (0.89)
Weekly data	Dow Jones	0.42 (0.33, 0.51)	0.0545 (0.07)	0.0651 (0.13)	−0.0168 (−0.04)	0.0803 (−0.23)
	Hang Seng	0.08 (0.03, 0.13)	0.0008 (7.07)	0.0004 (4.48)	0.0003 (3.43)	0.0002 (2.55)
	Eurostoxx	0.15 (0.11, 0.19)	0.0008 (4.43)	0.0002 (1.68)	−0.0001 (−1.20)	−0.0001 (−0.12)

in all the series except for the Hang Seng monthly data where the $I(0)$ or short memory hypothesis cannot be rejected. Focusing on the nonlinear coefficients, all are statistically insignificant except for the Hang Seng weekly data although in this case long memory is also observed. Thus, there is no evidence of spurious long memory behaviour in the data and the results are once more very similar for the nonsustainable and sustainable indices.

5. Conclusions

In this article, we have examined the degree of persistence in stock market prices and their associated volatility (measured in terms of absolute and squared returns) under both sustainable and nonsustainable indices. In particular, we have examined the Dow Jones, Hang Seng and Eurostoxx stock indices on a monthly and weekly basis.

The results indicate almost no difference in the degree of persistence under both scenarios. Thus, the order of integration is very close to 1 in practically all cases, implying high levels of persistence and efficiency in the markets at least in the weak form (if the errors are uncorrelated). Long memory is also observed in the absolute and squared returns, this last result being consistent with previous works conducted on nonsustainable markets by authors such as Ding, Granger, and Engle (1993), Granger and Ding (1996), Anouro and Gil-Alana (2011), Bhattacharya and Bhattacharya (2012), Gil-Alana, Yaya, and Adepoju (2015) and others. However, it contradicts the findings in Mynhardt, Makarenko, and Plastun (2017) that find different behaviour in the two (sustainable and nonsustainable) markets. Note, however, that Mynhardt, Makarenko, and Plastun (2017) use a nonparametric approach based on the H-exponent, while we

have used a parametric approach based on fractional integration. Other methods for measuring the degree of persistence can also be implemented and more research in this line should be conducted in future papers.

The results presented in this work may be of interest for both academics and practitioners in spite of the fact that there are no substantial differences in the sustainable and nonsustainable markets, and the fact that long memory is found in the volatility series may indicate that there is some degree of predictability in their behaviour. More research should be conducted comparing the two markets. Thus, for example, the analysis of the long run co-movements between the indices, using fractional cointegration methods can be an interesting line of future research, investigating also if both sustainable and nonsustainable indices present long run equilibrium relationships. Work in this direction is now in progress.

Note

1. The estimation of the differencing parameter d is usually conducted on the stationary range ($0.5 < d < 0.5$). Robinson's (1994) tests, however, allows the examination of d for any real value, including thus those values in the nonstationary range (i.e. $d \geq 0.5$).

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