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Is it attractive to invest in alternative energy? Evidence from a five-factor Fama-French model for regional DJSI and renewable stock indexes

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Abstract

Purpose – This study aims to examine the attractiveness of the regional Dow Jones Sustainability Indexes (DJSI) and several renewable energy indexes during December 31, 2010 to December 31, 2019. This study uses a risk-return analysis and a set of explanatory factors. Lastly, this study conducts a comparative analysis of these indexes with conventional indexes.

Design/methodology/approach – This study uses data from Eikon, a Thomson Reuters database. To analyze the indexes' behavior, this study uses the indexes' annual return as of December 31 for each year. Next, this study estimates the Fama and French's five-factor model using an ordinary least squares regression for regional DJSI and renewable energy indexes.

Findings – The results show that regional DJSIs delivered returns both above and below conventional indexes. In contrast, renewable energy indexes had high betas and negative returns, making them unattractive to investors.

Practical implications – The results imply the need for public financing programs that support the transition to a sustainable economy and reduce risk and increase the return on private investment.

Social implications – This study provides insights for policymakers regarding the importance of sustainability indexes in the transition to a green economy.

Originality/value – This study contributes to the growing literature on Fama and French's five-factor model of sustainability indexes, especially in the current context characterized by intense green political changes. In particular, this study complements the few studies that have addressed the economic implications of renewable energy indexes in markets.

Keywords Renewable energy, Socially responsible investments, DJSI, Stock indexes, Risk return analysis

Paper type Research paper

1. Introduction

Socially responsible investments (SRIs) consist of incorporating a company's good practices regarding environmental, social and corporate governance into the asset selection process (Miralles-Quirós *et al.*, 2020). SRIs and renewable energy have become increasingly relevant in recent decades (Ivanisevic Hernaus, 2019; McCollum *et al.*, 2018). An increasing number of individual investors, institutional investors and portfolio managers are incorporating SRIs into their portfolios. The importance of investing in SRI is apparent as it accounted for US

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$30.683tn in investments in the top five markets (Europe, USA, Japan, Canada and Australia/New Zealand) at the beginning of 2018. All markets experienced growth, with Japan leading the way with a 300% increase since 2016; meanwhile, in Europe, sustainable investing assets have declined relative to total managed assets since 2014 (Global Sustainable Investment Alliance, 2018).

Public policies that promote a transition to a more sustainable and environmentally friendly economy may also be relevant (Jacobsson and Lauber, 2006; Martens and Rotmans, 2005; Wiser and Pickle, 2017). It is sometimes assumed that SRI, particularly environmentally sustainable investments, must be supported by public policies to be financially attractive (Egli, 2020; Polzin *et al.*, 2015; Yi and Feiock, 2014). The United Nations Principles for Responsible Investing (PRI) (United Nations, 2006) asks investors to align themselves with society's broader objectives through their investment decisions. An increasing number of forums adopt PRI principles in this vein, such as the Forum for Sustainable and Responsible Investment in the USA or the European Sustainable Investment Forum in Europe. In addition, the 2030 agenda requires investors to redirect their investment flows toward sustainable development investments, thereby contributing to the achievement of sustainable development goals (SDGs). This concern suggests interest in studying the relationship between a company's financial and sustainability behavior.

This study analyzes sustainability investments in economic, social and environmental terms. This study focuses on environmental factors through the analysis of renewable indexes. The study of renewable companies is of great importance in achieving public policies that incentivize this sector in regions where private investment is weaker (Aslani, 2014). However, this kind of research is underdeveloped. Most studies focus on the causal link between the price of oil, changes in technology and renewable companies (Henriques and Sadorsky, 2008; Inchauspe *et al.*, 2015; Kumar *et al.*, 2012; Sadorsky, 2012b). Furthermore, the relevant literature is incomplete in terms of companies' financial and environmental behavior and suffers from mixed results because of the samples used, the period chosen or the econometric models applied (Cedrick and Long, 2017; Mazzucato and Semieniuk, 2018). For example, Reboredo *et al.* (2017) found a lower return on renewable energy funds on SRI investments, whereas Rezec and Scholtens (2017) found otherwise. Therefore, some research questions remain unanswered, and there is still a field open to study.

Private investors need to know whether their positions in the markets will be moneymaking with respect to the risk they bear (Dilla *et al.*, 2016). Public subsidies will eventually become extinct to make way for private capital (Justice, 2009). In this sense, our research seeks to address this research gap by answering the following questions: Can investors in sustainable indexes and renewable energy expect a return according to their risk level? Is it more cost-effective to invest in sustainability and renewable energy than conventional indexes? This study's main objective is to respond to these two questions by adopting a financial risk investor stance.

We work with a broad global sample consisting of the leading sustainable and renewable international market indexes during 2010–2019. Most studies are based on investment funds. Funds are assets that may be affected by other issues such as fund size, age or assets on which they fluctuate. Authors such as Schröder (2007) and Statman (2006) try to avoid this problem through the use of socially responsible investment (SRI) indexes. Thus, the sample we work with consists of stock indexes to prevent the influence of these factors on profitability. We use the multifactorial model proposed by Fama and French (2015). In addition, complementarily, we carry out a comparative study between sustainable and renewable energy indexes and conventional benchmarks. Our main results indicate that

renewable energy investment is unattractive, with corresponding low returns and high betas (systematic risk).

Other studies focus on certain investment funds or types of energy (Cedrick and Long, 2017; Mazzucato and Semieniuk, 2018). However, here, we try to encompass many companies at an international level through the stock indexes. Thanks to a broad and global sample of stock indexes, this study contributes to broadening the knowledge in this research field. It allows us to know and compare the risk profitability ratio of these assets to make investors' decisions. Meanwhile, as we study stock indexes instead of specific companies, these indexes provide us with a more general vision as these are, in turn, made up of many companies.

As one of our objectives to know each index's profitability and its investment risk, our model can be of great help to the investor community. Therefore, investor attractiveness is understood as an investment in an asset that provides high returns and low risk. This relationship is the profitability-risk duality on which this study's analysis is based (McInerney and Bunn, 2019; Wüstenhagen and Teppo, 2006). This duality consists of comparing the index's performance concerning the beta factor of the investment (risk), a concept that we will analyze later.

The results suggest that this investment requires government institutions' support to ensure that the investor has enough confidence to be a part of long-term sustainable companies (Andersen *et al.*, 2019). Once the private sector is more focused on such investments, financial support from the public sector will decline rapidly.

The remainder of the paper is organized as follows. Section 2 provides a detailed literature review of the financial and environmental behavior of sustainable companies; Section 3 describes the data and methodology used; Section 4 presents the results; Section 5 undertakes the discussion; and Section 6 presents the conclusions and political implications.

2. Literature review

2.1 Sustainability as a responsibility investment

Recently, there has been an increase in SRI worldwide (Global Sustainable Investment Alliance, 2018) in accordance with investors' growing commitment to align their investments with broader societal objectives, as defined in the SDGs (United Nations, 2006). SRI strategies are of interest to practitioners and academics in finance, particularly with respect to performance measurement.

The relationship between a company's sustainable activity and its financial performance has attracted attention in recent years (Aboud and Diab, 2019; Ambec and Lanoie, 2008; Badía *et al.*, 2020; Becchetti and Ciciretti, 2009; Cunha *et al.*, 2020; Iwata and Okada, 2011). Studies have used various approaches to explain how and why the sustainability variable affects financial behavior and have found different results (Chan and Walter, 2014). For example, while Inchauspe *et al.* (2015) find poor financial performance for companies listed in the Wilderhill New Energy Global Innovation Index, others such as Fang *et al.* (2020) find that there is a premium green factor.

The return on investing in companies is manifested through the cash flows they are generating for their investors. A company with high cash flow improves its financial performance, and with it, the stock price is higher (Campbell and Shiller, 1988). In general, value-creating companies reflect a high return that is higher than the cost of capital.

On the one hand, studies on sustainable companies show that this overperformance does not occur (Geczy *et al.*, 2005). In their portfolio theory, Stuart and Markowitz (1959) mention the penalty of restricting investment in sustainable companies. Renewable energy companies are highly volatile and perform less well than expected owing to the nature of the

sector they are located in (Angelopoulos *et al.*, 2016; Gross *et al.*, 2010; Wüstenhagen and Teppo, 2006). Sadorsky (2012a) demonstrates that for a set of renewable companies listed in the North American market, the systematic market risk is higher than one (beta > 1) during 2001–2007. For a sample of 14 indexes around the world, Rezec and Scholtens (2017) find that sustainable indexes' behavior was unattractive from an investment approach. Moreover, the risk of these indexes was much higher than conventional indexes.

On the other hand, some studies find excellent financial performance of sustainable and renewable companies based on various assessments. Thus, sustainable companies receive aid and public funding, which improves their financial performance (Fang *et al.*, 2020). Continuous advancement in technology allows for cost savings and increased productivity. This explains sustainable companies' benefits (Narayan, 2018). Another factor that this approach considers is pollution. From an investor's perspective, companies with very high pollution rates may be unattractive. Rather, investment in the prevention of this problem can lead to economic benefits (Albertini, 2013). Investor attention to this type of asset may be another contributing factor to good behavior. In many cases, these types of companies are considered as very responsible at the social and environmental levels. This in turn contributes to the investor's overperformance (Ciarreta *et al.*, 2014; El Ghoul *et al.*, 2018).

A priori, sustainable and renewable energy indexes are riskier as they are nascent and highly volatile companies (Dutta, 2017). Because of the instability and early emergence of the sector, investors tend to look at the risk (beta coefficient) that comes with the investment, rather than other economic-financial factors of the company (Ng and Rezaee, 2015; Xiao *et al.*, 2013). Similar results were found by Becchetti *et al.* (2015), who reported a high-risk aversion to this type of investment during the US bubble. On the one hand, investment in technology has been shown to be a crucial aspect affecting investment in sustainability. This can explain the character of constant and volatile changes in the sector (Masini and Menichetti, 2012). On the other hand, authors such as Bauer and Hann (2012) argue that sustainable companies tend to be associated with low debt costs and high credit ratings, demonstrating attractive investors and low risk in such investments. In summary, the SRI empirical research is inconclusive and reveals the need for clear standard models that help us to unify whether investment in renewables is profitable.

2.2 Fama-French's five-factor model

When analyzing the efficiency of firms' SRIs, Brzeszczyński and McIntosh (2014) find that conventional factor analysis does not entirely explain profitability. Most studies have tried to relate environmental behavior to profitability (Inchauspe *et al.*, 2015; Sadorsky, 2012b; Sokolovska and Kešeljević, 2019). Rather, we argue that the question is whether the SRI satisfies the risk-return relationship; that is, the greater the risk, the greater the return. This is embodied in the general equilibrium of the capital asset pricing model (CAPM) (Koutmos, 2015).

As CAPM returns depend only on the beta factor (systematic risk), some authors have criticized its capacity to appreciate firm performance. These authors opt to use other models such as the three-factor model of Fama and French (1992), which posits that the expected return depends on the systematic risk, company size and the value effect. However, owing to its inconclusive results (Bowman, 1980; Fiegenbaum and Thomas, 1988; Henkel, 2009; Santacruz, 2019), the three-factor model has been improved with the addition of new variables. The result is Carhart's (1997) four-factor model which adds the momentum factor Winner minus Loser (WML), or Fama and French's (2015) five-factor model which incorporates the Robust minus Weak (RMW) and Conservatives minus Aggressive (CMA) factors.

Using the four-factor model, Marti-Ballester (2019) finds that there is a financial cost in renewable investments compared to conventional investments. Statman and Glushkov (2009) study the behavior of renewable indexes using the four-factor model and find that the returns were not significant. Novy-Marx (2013) and Titman *et al.* (2004) demonstrate that the three- and four-factor models are incomplete in capturing the effects on the profitability of factors such as investment or operating returns.

According to Fama and French (2015), the five-factor model better describes average return performance than the traditional three-factor model when applied to companies with high investment and strong operating returns. The literature has shown empirical evidence of model behavior. Fama and French (2017) test the three- and five-factor models for a portfolio set in 23 developed markets. They find that the model performed better in the North American and European regions and for companies with high capitalization levels. In contrast, Foye (2018) finds that the five-factor model behaved better for Eastern Europe and Latin America than the three-factor model but failed in Asia's case.

Studies that have used the five-factor model have shown that this model is suitable for analyzing the attractiveness of renewable for investors. Using the five-factor model, Martí-Ballester (2020) finds that health-care and biotechnology companies have better financial behavior than conventional funds. These sectors fall under the United Nations SDG 3 (United Nations, 2019). Joliet and Titova (2018) and Sokolovska and Kešeljević (2019) find that the factors that make up the five-factor model are considered by investors in socially responsible funds.

For these reasons, we use Fama and French's (2015) five-factor model to study the convenience of investing in SRI. Specifically, the methodology used is not based on the asset's expected returns but on the alpha that the five-factor model reports for the set of proposed indexes. This is because this model behavior is better than other asset valuation models (Miralles-Quirós *et al.*, 2020).

As we will see in more detail in Section 3, the Fama-French five-factor model illustrates the duality relationship between profitability and the risk of an investment. Profitability is measured through the well-known Jensen alpha. This is a tool that allows us to analyze profitability adjusted to risk (Jensen, 1968). This risk is measured using the investment beta factor. If we find an asset with a high Jensen's alpha (in the eyes of the investor) and a low beta factor (below 1), we can affirm that the investment is attractive.

Following previous work on measuring investment funds (Hürlimann *et al.*, 2019a; López *et al.*, 2007a, 2007b; Searcy and Elkhawas, 2012), we use returns as a representative variable of financial behavior. Considering the performance–risk pair as an indicator of the attractiveness of investing in sustainability, the results are mixed. Consequently, our null and alternative hypotheses are as follows:

H1$_0$. Sustainability and renewable energy indexes are attractive to the investor.

H1a. Sustainability and renewable energy indexes are not attractive to the investor.

Concerning the comparison between sustainable and conventional indexes, authors such as Rezec and Scholtens (2017) show that a set of renewable and sustainable indexes has a poorer investor attractiveness than conventional indexes. Using a sample of sustainable funds for the USA, UK, Continental Europe and the Asia Pacific, Renneboog *et al.* (2008) demonstrate that the return was −2.2% to −6.5% below conventional funds' returns. Other authors, such as Hamilton *et al.* (1993), find no statistical significance in the return of sustainable funds compared to conventional funds. Concerning the comparison between renewable and conventional investments, according to Marti-Ballester (2020), investors in

renewable energy funds go beyond their financial utility when making their portfolio decisions than investors in non-renewable energy and other conventional companies.

On the contrary, some studies indicate a higher sustainable return than conventional indexes (Ortas and Moneva, 2013). The so-called green premium, the expected return on green investments compared to conventional investments (Pineda *et al.*, 2018), is one of the newest approaches within the research. Fang *et al.* (2020) find a green premium for a set of sustainable companies. Their five-factor model shows that there is a higher average monthly return on sustainable than conventional companies. Chia *et al.* (2009) find that average profitability was above the benchmark for a group of renewable companies. Miralles-Quirós and Miralles-Quirós (2019) show that for a VAR asymmetric dynamic conditional correlation approach, alternative energy exchange traded funds (ETF) outperform conventional energy funds. Therefore, renewable energy fund investments are attractive.

Other authors argue that environmentally irresponsible companies can be perceived as risk assets (Albuquerque *et al.*, 2019; Hong and Kacperczyk, 2009). Risk may lead to reduced financial performance (El Ghoul *et al.*, 2018). For example, Chava (2014) finds that banks charge a higher interest rate to companies with environmental problems (high pollution rates or toxic waste). The latest study scenario calls for a more reduced financial performance in renewable indexes compared to conventional indexes.

Because the results for the comparison between sustainable and conventional indexes are mixed, we establish our null hypothesis as follows:

H2$_0$. Sustainable and renewable indexes outperform conventional indexes.

The alternative hypothesis is as follows:

H2a. Sustainable and renewable indexes either underperform or perform similar to conventional indexes.

3. Sample and methodology

3.1 Data and method

This study uses the five-factor model of Fama and French (2015) applied to a set of sustainable and renewable energy indexes. This model allows us to contrast the starting assumptions optimally because it is the most up-to-date multifactor model in asset valuation. For example, in Fama and French's (2015) seminal article, the five-factor model provided a 71% and 94% variance in expected profitability. The three-factor model was expanded by including the profitability and investment factors owing to this model's low efficiency to explain the variation in expected returns in portfolios with high levels of investment or profitability (Novy-Marx, 2013; Titman *et al.*, 2004).

The indexes' daily returns as of December 31 of each year are used to analyze index behavior. Following previous studies, the daily return of both the indexes and the Fama-French factors was annualized (Nadeem *et al.*, 2020; Searcy and Elkhawas, 2012; Sokolovska and Kešeljević, 2019). This treatment of the sample limits the influence of outliers and improves the results obtained (Uyar *et al.*, 2020). The study period spanned from December 31, 2010 to December 31, 2019. Data were extracted on May 4, 2020 from *Eikon*, a database by Thomson Reuters (Nadeem *et al.*, 2020; Uyar *et al.*, 2020). Data not available in this database were queried in the databases of the respective index developers.

Following Rezec and Scholtens (2017), we conducted a brief initial study on these returns' behavior using descriptive statistics such as mean, standard deviation and Sharpe ratio. The Sharpe ratio is an index widely used in the literature to compare the risk-adjusted returns of

two or more investments. Return is adjusted to the asset's volatility by measuring the overperformance per unit of the asset's standard deviation (Sharpe, 1994). The Sharpe ratio was configured using the following formula:

$$SR_i = \frac{R_i - R_f}{\sigma_i}, \tag{1}$$

where R_i is the average annual return of asset i, R_f is the risk-free yearly return of the US Treasury at one month and σ_i is the standard deviation of the asset's returns i. A positive (negative) value denotes that the risk-adjusted returns are above (below) the risk-free return.

Regarding the base data used to analyze the explanatory factors, the data repository published by French (2020) was used with the same data frequency and extracted period as the return variable. This data repository is distributed by geographic regions, namely, Developed Markets, North America, Europe and Asia-Pacific. Regarding the dependency analysis for the analyzed indexes' returns, depending on each index's constituent companies, one geographic region or another has been used. For example, the NASDAQ Renewable Edge US Liquid Index has been analyzed with the Fama-French factor sample for North America.

The underlying factor model for investment analysis was the CAPM (Lintner, 1965; Sharpe, 1964). The central argument of this model is that the market portfolio is efficient in relation to its variance (Stuart and Markowitz, 1959). Market efficiency implies that asset return is a positive linear function of the market beta and that beta is sufficient to explain the variance in expected returns. It specifies that investors are compensated only for undiversified risk (systematic risk). CAPM had certain contradictions, the most significant being the size effect found by Banz (1981). The author shows how a company's size explains some of the variances of its return. Therefore, only considering the market's performance is insufficient. The coefficients α_i and β_i were obtained from the regression of asset return on the market's return as follows:

$$R_{it} - R_{ft} = \alpha_i + \beta_i\left(R_{mt} - R_{ft}\right) + \varepsilon_{it}, \tag{2}$$

where R_{it} is the return of the asset at time t, R_{ft} is the return of the risk-free asset at time t, R_{mt} is the return of the reference index, α_i represents Jensen's (1968) alpha, β_i is the systematic risk of the asset and ε_{it} is the error.

Jensen's alpha, also known simply as alpha, is a measure based on risk-adjusted performance and represents the average return on a portfolio or investment. In our case, the return is for a stock market index. This performance is above or below the minimum return required by the CAPM, given a specific beta and average market return. When alpha is positive (negative), we say that the asset's return is higher (lower) relative to the market. Thus, Jensen's alpha measures the difference between the asset's return and the return reported by the reference market.

Therefore, the methodology used is based on the alpha generated by the five-factor model owing to its superior performance compared to other models (Miralles-Quirós *et al.*, 2020). Authors such as Schröder (2007) and Sokolovska and Kešeljević (2019) have used Jensen's alpha to assess the attractiveness of sustainable indexes.

Systematic risk (β_i) affects the difference between market returns and risk-free asset returns. This difference is what Fama and French (2015) call the market risk premium (MRP):

$$R_{mt} - R_{ft} \tag{3}$$

We try to relate Jensen's alpha and beta, or systematic risk, through the five-factor model. Jensen's alpha reflects the performance of risk-adjusted assets, whereas beta tells us the asset's volatility compared to its benchmark market. In this way, we can assess the return-to-risk ratio of each index. An alpha factor above zero denotes a higher positive return on the asset relative to its reference market. A beta value above one indicates that an asset is more volatile than its reference market. For example, a beta of 1.10 indicates that the asset rises ten percent more than the market when the market rises.

In short, the five-factor model is as follows:

$$R_{it} - R_{ft} = \alpha + \beta_1 MRP_t + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 CMA_4 + \beta_5 RMW_5 + \varepsilon_t \tag{4}$$

Here, SMB stands for Small minus Big and HML for High minus Low. Equation (4) allows us to identify the factors that influence asset returns. Here, the five-factor model's choice allows us to identify a more significant number of factors with possible influences on expected returns. Fama and French's five-factor model was estimated using the ordinary least square regression Dow Jones Sustainability Index (DJSI) regional indexes and for renewable energy indexes.

3.2 Sample

Following previous literature, we focus on the use of sustainable stock indexes and renewable energy indexes for investments globally (Hürlimann *et al.*, 2019b; López *et al.*, 2007a, 2007b). Studying the stock index allows us to determine the behavior of many companies and makes our analysis more efficient.

The study sample was divided into two blocks. To analyze investment in sustainability in global terms, the DJSI regional indexes were selected. Created by S&P Dow Jones Indices and RobecoSAM, the DJSI family of indexes comprises of leading sustainability companies, in line with environmental, social and governance criteria. Companies are selected each year according to the corporate sustainability ranking developed by RobercoSAM. The DJSI index family consists of four regional indexes: the DJSI World Sustainability Composite, DJSI Europe, DJSI North America and DJSI Asia-Pacific. For detailed information, refer to Table 1.

The second block of our sample comprises renewable energy indexes. Following previous literature (Rezec and Scholtens, 2017; Sokolovska and Keščeljević, 2019), we identified a set of stock indexes that fluctuate according to companies whose activity, directly or indirectly, is related to renewable energy. Finally, a total of 12 indexes were analyzed to extract their attractive investors. We accessed data from the suppliers of benchmark stock indexes such as the Financial Times Stock Exchange (FTSE), S&P Dow Jones Indices, NASDAQ or Wilderhill.

We also used the conventional indexes to conduct a comparative study of investor behavior (Table 1). Following Rezec and Scholtens (2017), a conventional index for comparison was identified for each sustainable and renewable energy index. Two criteria were adopted to relate the indexes to their conventional indexes: that they both fluctuated according to companies in the same region and that the developers of the index were the same.

Table 1 presents a schematic of the index samples used.

Sustained/renewable energy indexes	Reference indexes
DJSI World Sustainability Composite	S&P Global 1200
DJSI Europe	S&P Europe 350
DJSI North America	S&P 500
DJSI Asia Pacific	S&P Asia Pacific BMI
Ardour Global Alternative Energy	MSCI World
Ardour Global Alternative Energy Extra Liquid	
FTSE Environmental Opportunities Renewable and Alternative Energy 50 Index	FTSE All World
Ardour Global Alternative Energy Solar	MSCI World
World Renewable Energy	
S&P Global Alternative Energy	S&P Global 1200
S&P Asia Pacific LargeMidCap Carbon Efficient Index	S&P Asia Pacific BMI
BNP Paribas Global Renewable Energies Price Return Index	MSCI World
NASDAQ Renewable Edge U.S. Liquid	NASDAQ Composite Index
S&P Global Clean Energy	S&P Global 1200
European Renewable Energy	DJ Eurostoxx
Wilderhill New Energy Global Innovation	MSCI World

Source: Own elaboration

Table 1.
Study sample

4. Results

The results are structured in three blocks: a study of regional DJSI index and comparison with conventional index, a study of renewable and relative energy indexes with conventional index and cost-effectiveness risk ratio for sustainable and renewable energy indexes.

As we will see, the results presented below allow the investor to know in a summarized and concise way those indices that are more optimal for investment. This statement is contrasted with the risk–return relationship that we extract from the five-factor model of Fama-French.

Following Rezec and Scholtens (2017) and Fang *et al.* (2020), we report a summary of the descriptive statistics generated by Fama-French's five factors and studied indexes in Table 2.

We observe that all the factors except SMB have a direct relationship with the profitability of the indexes. With this, we can say that the factors influence the behavior of said profitability.

Factors	Mean	Median	Max	Min	Standard deviation
MRP	8.8553	9.2950	32.4700	−16.0800	14.5196
SMB	−0.3503	−1.5800	15.8500	−10.5800	7.1745
HML	−1.3053	−3.1050	21.9000	−20.2400	9.6870
RMW	8.7208	7.0050	37.8500	−17.9700	10.3110
CMA	2.8643	2.2700	17.4200	−6.8000	5.9900
WML (Momentum)	2.8798	2.9100	21.1000	−13.7400	7.5374

Source: Own elaboration

Table 2.
Descriptive statistics for Fama-French factors

The MRP, SMB and HML are the factors in Fama and French's (1992) three-factor model. WML is the momentum factor given by Carhart (1997). RMW and CMA are the profitability and investment factors given in Fama and French (2015), respectively.

In Table 3, we see the mean annual returns on the DJSI World Sustainability Composite and DJSI Asia Pacific indexes are higher than the conventional index. As for standard deviations (index volatility), the sustainable index is less volatile than the conventional index. The Sharpe ratio exhibits a very similar behavior to that reported by the average yield. We note the value of the Sharpe ratio approaches zero but is not negative. We interpret this as a higher return on the risk-free asset.

Table 4 shows that returns are below the selected benchmark index for renewable energy indexes, with three exceptions: World Renewable Energy, S&P Asia Pacific LargeMidCap carbon Efficient Index and European renewable energy (Table 4). In terms of standard deviations, and unlike the sustainable index, volatility for renewable indexes is considerable. In all cases above the benchmark index, except for the S&P Asia Pacific LargeMidCap carbon Efficient Index. The Sharpe ratio is negative in some indexes, noting that the index in question (the benchmark index) reported less profitability than the risk-free asset (Sharpe, 1994). The Sharpe ratio of benchmarks is higher than that of the renewable index, except for the three indexes listed above.

4.1 Regional Dow Jones Sustainability Indexes and frame of reference

First, we report the results for the sustainability index obtained through the five-factor model (Table 5).

The most statistically significant variable is MRP. Thus, there is supporting evidence that the most influential factor, out of those proposed by Fama and French (2015), is the beta coefficient or systematic risk. Indexes such as the DJSI World Sustainability Composite, DJSI North America and DJSI Asia Pacific report betas lower than their benchmarks but are still close to one. In contrast, alpha coefficients are negative or close to zero and non-significant. Therefore, there is no positive relationship between the asset's risk and return. DJSI Europe and DJSI North America have negative returns. In contrast, the DJSI Asia-Pacific index reports a positive and significant alpha coefficient.

Concerning the size factor (SMB), only DJSI Europe has a statistically significant result at the 1% level. These values are disparate in their directions. The sustainable index has a positive direction for expected profitability, except DJSI Europe. This shows that the companies are low-capitalized. In contrast, benchmarks are made up of highly capitalized companies.

Regarding the value factor (HML), investors do not consider this feature in sustainable companies, except for DJSI Europe (negative and significant at 5%). This result for DJSI Europe means that in the European sustainable indexes, the companies are growth companies with a low book-to-market ratio. If we find positive values of HML, this says that sustainable companies are "value companies," that is, companies that trade with a market value below the value of their assets.

Next, we discuss the remaining two factors the five-factor model. For the RMW, or operational profitability factor, a positive coefficient value indicates that the index is made up of profitable companies. For the DJSI World Sustainability Composite and DJSI North America, the coefficient values are positive. For the remaining two indexes, the coefficient values are negative. For reference indexes, the value is positive in all regions. Apart from the management, this factor is not considered by investors, except for DJSI Europe (significant at 10%). This result for the DJSI Europe index indicates that we faced a lack of member companies' operating returns. Another factor is the investment factor or CMA. A positive

DJSI	Reference	Mean	Standard deviation	Mean (reference)	Standard deviation (reference)	Ratio Sharpe	Ratio Sharpe (reference)
DJSI World Sustainability Composite	S&P Global 1200	11.0797	10.9574	10.6850	12.9869	0.9634	0.7825
DJSI Europe	S&P Europe 350	3.7115	15.1856	6.2430	15.7737	0.2100	0.3626
DJSI North America	S&P 500	9.8260	12.0414	1.1530	12.2611	0.7726	1.1116
DJSI Asia Pacific	S&P Asia Pacific BMI	8.5600	11.8508	7.4970	14.0408	0.6782	0.4967

Source: Own elaboration

Table 3.
Descriptive statistics for the annual return of regional DJSI and reference

Table 4.
Descriptive statistics for the annual return of renewable indexes and reference

Renewable indexes	Reference	Mean	Standard Deviation	Mean (Reference)	Standard Deviation (Reference)	Ratio Sharpe	Ratio Sharpe (Reference)
Ardour Global Alternative Energy		5.1663	29.6214			0.1568	
Ardour Global Alternative Energy Extra Liquid	MSCI World	5.1427	31.5790	7.9580	12.7490	0.1463	0.5832
FTSE Environmental Opportunities Renewable and Alternative Energy 50 Index	FTSE All World	1.5640	17.3503	7.2900	12.8992	0.0600	0.5246
Ardour Global Alternative Energy Solar		−0.3646	61.5850			−0.0144	
World Renewable Energy	MSCI World	29.9050	31.7931	7.9580	12.7490	0.9242	0.5832
S&P Global Alternative Energy	S&P Global 1200	−0.1940	30.1901	10.6850	12.9869	−0.0237	0.7825
S&P Asia Pacific LargeMidCap Carbon Efficient Index	S&P Asia Pacific BMI (USD)	7.6840	13.8538	7.4970	14.0408	0.5169	0.4967
BNP Paribas Global Renewable Energies Price Return Index	MSCI World	−0.1396	29.6625	7.9580	12.7490	−0.0223	0.5832
NASDAQ Renewable Edge US Liquid	NASDAQ Composite Index	9.1774	35.8738	15.5548	14.5799	0.2412	1.0310
S&P Global Clean Energy	S&P Global 1200	−6.6360	25.1097	10.6850	12.9869	−0.2851	0.7825
European Renewable Energy	DJ Eurostoxx	10.4400	40.1336	3.1560	13.3989	0.2471	0.1965
Wilderhill New Energy Global Innovation	MSCI World	2.3125	28.3624	7.9580	12.7490	0.0631	0.5832

Source: Own elaboration

DJSI	MRP	SMB	HML	RMW	CMA	*A*	R^2
DJSI World Sustainability Composite	0.7827*** (0.1307)	0.1544 (0.3377)	0.5595 (0.4398)	1.0975 (0.5711)	−0.2842 (0.7139)	0.0020 (0.0326)	0.7956
DJSI Europe	0.9496*** (0.0268)	−0.3038*** (0.0654)	−0.3859** (0.1580)	−0.5120* (0.1887)	0.2762 (0.1580)	−0.0101 (0.0078)	0.9952
DJSI North America	0.8926*** (0.0910)	0.0226 (0.2057)	0.2981 (0.2450)	0.3118 (0.2250)	−0.4229 (0.3880)	−0.0159 (0.0187)	0.9317
DJSI Asia Pacific	0.5864** (0.1716)	0.1519 (0.6984)	0.3615 (0.5003)	−0.3752 (0.6355)	−1.6632 (0.8625)	0.1234* (0.0501)	0.5702
S&P Global 1200	0.9616*** (0.0344)	−0.1652 (0.0888)	0.0815 (0.1157)	0.1061 (0.1502)	−0.0593 (0.1878)	0.0035 (0.0086)	0.9898
S&P Europe 350	0.9942*** (0.0190)	−0.2547*** (0.0464)	−0.0933 (0.1121)	0.0960 (0.1339)	0.2530* (0.1121)	−0.0110 (0.0055)	0.9978
S&P 500	0.9792*** (0.0237)	−0.2300** (0.0536)	0.0169 (0.0638)	0.0427 (0.0586)	0.0352 (0.1010)	0.0077 (0.0049)	0.9956
S&P Asia Pacific BMI	0.8849*** (0.1440)	0.5012 (0.5859)	−0.0663 (0.4197)	0.0052 (−0.5332)	−0.7227 (0.7236)	0.0671 (0.0420)	0.7964

Notes: Significant to 1%; **Significant to 5%; and *Significant at 10%

Table 5.
Regional DJSI – five-factor model of Fama and French

coefficient indicates that companies have high investment rates. Except for DJSI Europe, the remaining indexes have negative values. These values indicate that companies are conservative (i.e. have low investments). The significance is null in the sample index. That is, investors do not consider this factor, except in the reference index for Europe (S&P Europe 350). Therefore, we can reject $H1_0$, and accept the alternative one (*H1a*). That is, the sustainability DJSI and renewable energy indexes are not attractive to investors.

4.2 Renewable index and frame of reference

We now focus on the environmental factors within sustainability using the renewable energy index (Table 6).

MRP, or systematic risk, is the critical factor in the renewable and DJSI index investors. All indexes have a significant relationship with expected profitability, except for the BNP Paribas Global Renewable Energies Price Return Index and European Renewable Energy index. The MRP values are high and often above one. In indexes such as the S&P Asia Pacific LargeMidCap Carbon Efficient Index or European Renewable Energy, MRP is below one, denoting lower volatility to the reference market. The Ardour Global Alternative Energy Solar and NASDAQ Renewable Edge US Liquid Index have the highest systematic risks (3.7156 and 2.4354, respectively). In contrast, the conventional reference index behavior shows betas below one, except the NASDAQ Composite Index (1.1173).

Regarding the alpha factor, we only find two sustainable indexes with a positive alpha factor: S&P Asia Pacific LargeMidCap Carbon Efficient Index and European Renewable Energy index (0.0716 and 0.1738, respectively). These indexes also report an MRP below one. The conventional index also reports positive returns.

Regarding the size factor, or SMB, there is no significance in any of the indexes analyzed. The relationships are largely in the negative direction. This relationship indicates that the index is made up of highly capitalized companies, except for the S&P Asia Pacific LargeMidCap Carbon Efficient Index and the European Renewable Energy index which report positive values. The reference indexes exhibit very similar behavior. Based on these results, we reject our third hypothesis: renewable companies are small and growing enterprises.

The results for the HML factor are mixed. Six of the 12 renewable indexes have positive values, that is, they are composed of "value companies." However, for the reference indexes, all HML values are negative. The significance of this factor is null.

Next, we move on to the remaining two factors. For the profitability factor, or RMW, the results are not statistically significant. The values are negative for all renewable indexes (unprofitable companies), except the World Renewable Energy index and the S&P Asia Pacific LargeMidCap Carbon Efficient Index (3.7953 and 0.0622, respectively). The results are different for conventional indexes. Three of the six indexes have positive values. As for the investment factor, or CMA, there are significant results for three of the 12 sustainable indexes: the FTSE Environmental Opportunities Renewable and Alternative Energy 50 Index, World Renewable Energy index and S&P Global Clean Energy index. Values are negative except for the World Renewable Energy and the European Renewable Energy indexes. This means that companies do not have high investment rates (conservative companies), unlike benchmarks, where investment is more aggressive.

Similar to the regional DJSI indexes, we reject $H1_0$ for renewable indexes and accept the alternative (*H1a*). Therefore, in line with Sadorsky (2012a) and Rezec and Scholtens (2017), we find that sustainability and renewable energy indexes underperform or perform similar to conventional indexes.

Table 6.
Renewable index – five-factor model of Fama and French

Renewable index	MRP	SMB	HML	RMW	CMA	*A*	R^2
Ardour Global Alternative Energy	1.7205** (0.5187)	−1.2593 (1.3407)	0.4270 (1.7463	−2.4409 (2.2674)	−2.6879 (2.8345)	−0.0195 (0.1294)	0.8018
Ardour Global Alternative Energy Extra Liquid	1.7793** (0.6128)	−1.4330 (1.5838)	0.4640 (2.0630)	−2.6505 (2.6787)	−2.7159 (3.3486)	−0.0172 (0.1529)	0.7576
FTSE Environmental Opportunities Renewable and Alternative Energy 50 Index	1.0507*** (0.2075)	−0.6877 (0.5362)	0.4274 (0.9685)	−1.1626 (0.9069)	−2.1498* (1.3370)	−0.0363 (0.0518)	0.9052
Ardour Global Alternative Energy Solar	3.7156** (1.2205)	−1.0112 (3.1545)	−0.2549 (4.1089)	−1.1801 (5.3351)	−4.0664 (6.6695)	−0.3350 (0.3045)	0.7489
World Renewable Energy	1.5770* (0.7382)	−1.3040 (1.9080)	−3.4985 (2.4852)	3.7953 (3.2269)	6.9425* (4.0340)	−0.1150 (0.1842)	0.6593
S&P Global Alternative Energy	1.6307** (0.5662)	−1.4345 (1.4634)	0.2534 (1.9061)	−2.0801 (2.4750)	−3.3613 (3.0940)	−0.0810 (0.1413)	0.7713
S&P Asia Pacific LargeMidCap Carbon Efficient Index	0.8785*** (0.1267)	0.5841 (0.5157)	−0.0073 (0.3694)	0.0622 (0.4693)	−0.8318 (0.6369)	0.0716* (0.0370)	0.9278
BNP Paribas Global Renewable Energies Price Return Index	1.1100 (0.8909)	−0.6265 (2.3027)	−0.5296 (2.9994)	−2.3045 (3.8945)	−1.9561 (4.8686)	−0.042 (0.2223)	0.4243
NASDAQ Renewable Edge U. S. Liquid	2.4354** (0.7169)	−0.5720 (1.6199)	−0.0569 (1.9294)	−1.4355 (1.7714)	−1.0474 (3.0552)	−0.2039 (0.1472)	0.7918
S&P Global Clean Energy	0.9265*(0.4859)	−0.8914 (1.2557)	0.5745 (1.6357)	−1.6466 (2.1238)	−4.5298* (2.6550)	−0.0784 (0.1212)	0.7512
European Renewable Energy	0.7981 (1.3261)	1.1735 (3.2419)	−4.8364 (7.8286)	−5.8827 (−9.3468)	3.7254 (7.8251)	0.1738 (0.3841)	0.2714
Wilderhill New Energy Global Innovation	1.7700* (0.4530)	−0.6928 (1.1708)	0.556 (1.5250)	−1.13645 (1.9801)	−2.6856 (2.4754)	−0.0890 (0.1130)	0.8357
FTSE All World	0.9441*** (0.0252)	−0.1626* (0.0652)	−0.0135 (0.0850)	0.0676 (0.1103)	0.0339 (0.1379)	0.0233** (0.0063)	0.9974
S&P Global 1200	0.9586*** (0.0720)	−0.1347 (0.1860)	−0.0492 (0.2423)	−0.0122 (0.3146)	0.0104 (0.3933)	−0.0290 (0.0180)	0.9807
S&P Asia Pacific BMI	0.8849*** (0.1440)	0.5012 (0.5859)	−0.0663 (0.4197)	0.0052 (0.5332)	−0.7227 (0.7236)	0.0671 (0.0420)	0.9049
NASDAQ Composite Index	1.1173*** (0.0656)	−0.2043 (0.1483)	−0.1396 (0.1766)	−0.2738 (0.1622)	−0.2214 (0.2797)	0.0056 (0.0135)	0.9893
DJ Eurostoxx	0.7829** (0.2067)	−0.1529 (0.5053)	−2.0888 (1.2202)	−1.9104 (1.4569)	1.8580 (1.2197)	0.01580 (0.0599)	0.8397
MSCI World	0.9441*** (0.0252)	−0.1626* (0.0652)	−0.0135 (0.0850)	0.0676 (0.1103)	0.0339 (0.1379)	−0.2330** (0.0063)	0.9974

Notes: Significant to 1%; **Significant to 5%; and *Significant at 10%

4.3 Risk-return ratio

We have seen how investors' most significant factor is the MRP factor or systematic risk. This factor is closely related to the alpha factor or the index profitability. A beta below one and a high return give us a way to consider an attractive investment. Investors facing these positions are considered to be adverse to risk (Fama and French, 2015). To clarify and consider both factors as the most representative, in Table 7, we analyze the values extracted for the MRP and alpha factors in percentage.

The reported data show that the sustainable indexes with positive returns are DJSI World Composite and DJSI Asia-Pacific. The latter stands out with a return of 12.34% and a statistical significance of 10%. The alpha factor is higher in the conventional index, except for DJSI Asia-Pacific. Sustainable indexes are accompanied by a beta less than one. Therefore, based on volatility, they are not risky assets compared to the benchmark market.

DJSI	Alpha 5 factors (%)	Beta 5 factors	R^2
DJSI World Sustainability Composite	0.2	0.7827***	0.7956
DJSI Europe	−1.01	0.9496***	0.9952
DJSI North America	−1.59	0.8926***	0.9317
DJSI Asia Pacific	12.34*	0.5864**	0.5702
S&P Global 1200	0.35	0.9616***	0.9898
S&P Europe 350	−1.10	0.9942***	0.9978
S&P 500	0.77	0.9792***	0.9956
S&P Asia Pacific BMI	6.71	0.8849***	0.7964
Renewable index			
Ardour Global Alternative Energy	−1.95	1.7205**	0.8018
Ardour Global Alternative Energy Extra Liquid	−1.72	1.7793**	0.7576
FTSE Environmental Opportunities Renewable and Alternative Energy 50 Index	−3.63	1.0507***	0.9052
Ardour Global Alternative Energy Solar	−33.46	3.7156**	0.7489
World Renewable Energy	−11.53	1.5770*	0.6593
S&P Global Alternative Energy	−8.07	1.6307**	0.7713
S&P Asia Pacific LargeMidCap Carbon Efficient Index	7.16*	0.8785***	0.9278
BNP Paribas Global Renewable Energies Price Return Index	−4.18	1.1100	0.4243
NASDAQ Renewable Edge US Liquid	−20.39	2.4354**	0.7918
S&P Global Clean Energy	−7.84	0.9265*	0.7512
European Renewable Energy	17.38	0.7981	0.2714
Wilderhill New Energy Global Innovation	−8.86	1.7700*	0.8357
FTSE All World	2.33**	0.9441***	0.9974
S&P Global 1200	−2.91	0.9586***	0.9807
S&P Asia Pacific BMI	6.71	0.8849***	0.9049
NASDAQ Composite Index	0.56	1.1173***	0.9893
DJ Eurostoxx	1.58	0.7829**	0.8397
MSCI World	−23.3**	0.9441***	0.9974

Notes: Significant to 1%; **Significant to 5%; and *Significant at 10%

Table 7. Risk-return ratio in DJSI and renewable index (continue)

By benchmarking conventional indexes, we see how the benchmarks have a higher beta factor than those reported by conventional indexes.

Regarding renewable indexes, the S&P Asia Pacific LargeMidCap Carbon Efficient Index and European Renewable Energy are the only renewable indexes with positive returns (7.16% and 17.38%, respectively). The rest reports negative alpha factors. Therefore, we reject the second null hypothesis ($H2_0$) in favor of the alternative hypothesis (*H2a*). That is, the sustainable and renewable indexes underperform or similar to the conventional indexes.

5. Discussion

The main goal of this research was to answer two questions: Can investors in sustainable indexes and renewable energy indexes expect a return according to their risk level? Is it more cost-effective to invest in sustainability and renewable energy indexes than conventional indexes? Two hypotheses were constructed to address these two questions. The empirical results show that investing in sustainable indexes is not attractive, except for the DJSI World and DJSI Asia Pacific, which are not suitable for investors' optimal investment alternatives (Sadorsky, 2012a; Rezec and Scholtens, 2017; Reboredo *et al.*, 2017). Consequently, both hypotheses are rejected.

The beta coefficient of the sustainable indexes is close to one. The average beta for the sustainable index is 0.7905, which is less volatile than the conventional index with an average beta of 0.9463. Sustainable companies are highly capitalized and valuable entities that have a negative momentum in their profitability. The SMB factor or size factor is not significant. This contrasts with Sokolovska and Kešeljević's (2019) findings, who report significance in the factor for under-capitalized companies. The non-significance of this factor could be because the companies are highly capitalized.

Regarding alpha, DJSI World and DJSI Asia Pacific report positive alphas (0.0417 and 0.0287, respectively). These data are corroborated by previous literature, which identifies a low risk and a positive oversized return (Chia *et al.*, 2009; Fang *et al.*, 2020). Others, such as Rezec and Scholtens (2017), find that sustainable companies are less attractive for investors. This supports our conclusions for indexes such as DJSI North America or DJSI Europe.

For variables other than systemic risk, the five-factor model offers significant results only for the European sustainable indexes. Our results show that for DSJI Europe, the variables SMB, HML and RMW are significant. The European Sustainable Index companies have large capitalization with a market value exceeding book value and with negative operating profitability. As Fama and French (2015) demonstrate, large-cap companies are less profitable than small-cap companies. The lower annual return for this index than conventional ones may be because of investors discounting the overvaluation of the market and negative operating results.

Next, we consider RMW and CMA. The profitability or RMW factor has mixed results. Companies are profitable only in the DJSI World and DJSI North America indexes. This fact does not give us absolute certainty that sustainable companies are profitable only because they are sustainable (Sokolovska and Kešeljević, 2019). Regarding CMA, sustainable companies do not invest aggressively. The positive relationship between investment and profitability cannot be corroborated (Cedrick and Long, 2017). Authors such as Safarzyńska and van den Bergh (2017) and Wiser and Pickle (2017) provide evidence that very high investment can lead to negative returns on companies and financial instability that increases financing costs.

For renewable energy indexes, the systematic or beta risk is very high compared to conventional benchmarks. This denotes that the former are very unattractive investments.

Beta is significant for all indexes except for the BNP Paribas Global Renewable Energies Price Return Index and the European Renewable Energy index. Companies are highly capitalized and have good momentum for their performance. The results are mixed for the HML factor or value, we find both "value companies" and "growth companies." These results are in line with López *et al.* (2007a, 2007b) and Sokolovska and Kešeljević (2019). The RMW factor or profitability factor denotes that most indexes are made up of unprofitable companies. According to the investment factor or CMA, renewable companies do not invest substantially. The relationship between investment and performance is not favorable. These results contrast with those of Currier (2015) and Justice (2009).

The positive risk–return relationship is not found in our results. We see low and even negative returns, accompanied by beta values above one. The attractiveness of the investment is null. This result seems to refute the common belief that there is a positive relationship between risk and return. Thus, our findings provide support for the theoretical framework of Bowman's paradox (Núñez Nickel and Cano Rodriguez, 2002).

The results also do not demonstrate the "green premium" (sustainable and renewable indexes outperform conventional indexes), except for the following indexes: DJSI World Sustainability Composite, DJSI Asia Pacific, S&P Asia Pacific LargeMidCap Carbon Efficient Index and European Renewable Energy index. Recently, Fang *et al.* (2020) do find a green premium for a set of sustainable companies belonging to the Chinese Stock Exchange.

6. Conclusions and implications

Here, we used Fama and French's (2015) five-factor model to examine a set of sustainable indexes and a wide range of renewable energy indexes, being the latter a subject little used in the previous literature. The main conclusion is that investments in sustainability and clean energy listed companies are risky and unprofitable.

Owing to the large sample size and the focus on clean energy indexes, we can demonstrate that the environmental dimension is less attractive (lower profitability and more risk) than the sustainability dimension. The beta coefficient of renewable energy indexes is significant and high, being above one in many cases. These positive beta values, accompanied by a negative alpha factor, mean that renewable energy investments are unattractive. Nevertheless, we provide evidence that for Asian and European companies, investment in renewables and sustainability offers a good risk-return ratio. The DJSI indexes also provide an acceptable risk-return ratio.

Compared with conventional indexes, we note that the DJSI indexes report a lower systematic or beta risk. Even prevailing returns outperform conventional indexes, except for DJSI North America. Regarding renewable energy indexes, the risk-return ratio is more attractive than conventional benchmarks.

These results show that investment in clean energy may not be an appropriate alternative for private investors. It seems that investors will not be willing to commit their resources to clean energy investments compared to the current benchmark investments. The latter are better known, and therefore, are less risky. Thus, currently, the risk–return relationship seems insufficient. This means that public administrations must exert a large effort to reach a satisfactory solution that facilitates the arrival of more resources to the system at a lower cost. That is, clean energy investments with large alphas and low betas.

Therefore, governments in different countries or regions must provide significant capital to make clear energy investments more profitable. Then, the sector will grow exponentially and private investment will positively respond to the transition to clean energy (Gamel *et al.*, 2016; Wüstenhagen and Menichetti, 2012). A recent example of public initiatives is the "Great Green European Pact." This is an initiative that falls within the 2030 Agenda of the

United Nations (United Nations, 2019) to transform the EU into an equitable society with a modern economy, efficient resource usage and no net greenhouse gas emissions in 2050 (Comisión Europea, 2019).

Our study does have some limitations. First, we stick to Fama and French's five-factor model. This limits us from checking the goodness of the model against others, such as Carhart's four-factor model. Future research can address this issue and use a variety of models. Second, both the sample and the period analyzed can be extended to accommodate more data, besides considering more complex methods such as multiple time series analysis. Third, future research should cover aspects such as the study of relevant historical facts (the COVID-19 pandemic) and their interaction with renewable energy (Arefeen and Shimada, 2020), the valuation of investments for a specific type of renewable energy (Ciarreta *et al.*, 2014; Tagliapietra *et al.*, 2019) and the analysis of direct government policy outcomes for a given region or country (Meadowcroft, 2009).

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