Gurrib, Ikhlaas

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Momentum in Low Carbon and Fossil Fuel Free Equity Investing

Ikhlaas Gurrib*

Faculty of Management, Canadian University Dubai, UAE. *Email: ikhlaas@cud.ac.ae

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ABSTRACT

The Conference of the Parties to the United Nations Framework Convention on Climate Change (COP27) firmly echoed that climate change is a critical issue for humanity. Particularly, it stressed on the need to encourage a clean energy mix, including renewable and low-emission energies, as part of the continuing transition toward a cleaner and sustainable energy. Using daily indices data over the period January 1st, 2017–February 28th, 2023, this paper studies the performance of 2 family classes among sustainability indices, namely, low carbon and fossil fuel free indices. Specifically, this study sheds light by assessing the performance of trading strategies which are based on the momentum of low carbon and fossil-fuel free based indices. The performance is based on a thorough analysis of the relative strength index (RSI) and is captured through the Sharpe and Sharpe per trade measures. We decompose the analysis into pre and post COVID-19 to provide some insights how these sustainable energy investments were impacted by the coronavirus pandemic. Findings support an adjusted overbought/oversold RSI 75 (25) model resulted in fewer false signals than the traditional 70 (30) model. Relative to the post COVID-19 period, all selected equity indices performed poorly in the pre- COVID-19 period, with negative returns, except for the MSCI World Low Carbon Leaders and the SPDR MSCI Emerging Markets Fossil Fuel Free equity indices. Comparatively, in the post COVID-19 period, all indices witnessed superior return performance, though with increased risk levels. SPDR MSCI Emerging Markets Fossil Fuel Free index ranked first after adjusting for transaction costs. Investments in the post COVID-19 early impact period performed better than a naive buy-and-hold strategy for greener investments like low carbon and fossil fuel free equity indices.

Keywords: Low Carbon Index Investing, Fossil Fuel Index Investing, Technical Analysis, Performance, Sustainable Energy Investments
JEL Classifications: G11, Q42, Q43

1. INTRODUCTION

The United Nations progress report on the 17 Sustainable Development Goals (SDGs), concluded that, to the extent that affordable and clean energy is concerned, the present progress made is insufficient. Though total renewable energy consumption rose by 25% between 2010 and 2019, renewable energy consumption represented only 17.7% of the total energy consumed in 2019 (United Nations, 2022a). COP27 held in November 2022 acknowledged that climate change remains a critical matter for humanity (United Nations, 2022b). More importantly, it underscores the imperious need to tackle the entangled global crises of climate change and biodiversity loss in the broader context of achieving the SDGs, including the critical importance of protecting, conserving, restoring and sustainably using nature and ecosystems for effective and sustainable climate action. Global economic leaders acknowledged that effects of climate change worsen the global energy and food crises, and vice versa, notably in developing nations. In addition to setting a loss and damage fund to tackle devastating economic and non-economic losses such as forced displacement and impacts on cultural heritage, human mobility and the lives and livelihoods of local communities, COP27 emphasized on an urgent call for rapid and sustained reductions in global greenhouse emissions.

Global energy investment was expected to rise by nearly 8.5-$2.4 trillion in 2022 as per IEA (2022), which is well above pre COVID-19 levels. The key contributor remains the power supply sector, in advanced economies, Emerging Market and Developing Economies (EMDE) and China, with all the three witnessing an increasing power generation investments overall post COVID-19. Despite an increase in investments of clean energy from $1.1 trillion to $1.4 trillion over 2019-2022, investments in fossil fuels supply, represented by oil, gas and coal, account for nearly 97% of investments in total fuel supply worldwide, a percentage which barely changed since 2019. Investment in coal, oil, gas, and low-carbon fuel supply is the only area which remained below levels seen before to the 2019 coronavirus pandemic. The most conspicuous transition towards cleaner energies is in the power sector with continued upsurge in renewable power, where renewables, grids and storage presently representing more than 80 per cent of the total power investment.

Nevertheless, IEA (2022) also restates that global clean energy investments are still short to meet the increased demand for energy services in a sustainable manner. Unequivocally, clean energy spending in EMDEs excluding China in 2022 are still at 2015 levels, with various government owned entities being indebted with higher costs of borrowing because of deteriorated economic conditions, resulting in reduced capabilities to finance energy ventures. This resulted in most increases in renewables, grids and storage occurring in areas other than developing economies. This also led in slashed sales of clear energy products such as EVs. For illustration, more than ninety per cent of public spending on EVs systems are happening in US, China, and Europe. Poor nations with a shortage of accommodating community policies are faced with the likelihood of energy poverty, where roughly ninety million in Asia and Africa are unable to pay for basic energy needs.

To add salt to injury, attempts of Europe to reduce its dependence on Russia's oil supply, gas and coal following the Russian-Ukraine crisis, global inflationary pressures, and volatile energy prices, all augment the prevailing pressure for investors to consider green energy investments, especially in less attractive EMDEs. While higher energy prices in 2022 provide a rise in oil and gas producers' net profits, nearly half of the additional $200 billion in capital investments in 2022, would be absorbed by higher costs, instead of increasing energy supply capacities or future investments. These increasing costs are caused by several factors, including a limited market of specialized labor, supply chain pressures (e.g. the shortage of semi-conductors and uncertainty of automakers to meet the demand of electric vehicles), the impact of higher energy prices on cost of production of raw materials such as cement and steel, all of which ultimately render a total consumer energy bill in excess of $10 trillion in 2022.

Given the ambiguity on the long-term outlook for oil demand, higher investments in oil are not sustainably secured, supported by the refining sector which had its first diminution in global refining capacity in 2021. Equally, for gas, high prices question the long-term outlook for gas demand, especially in price sensitive developing nations, where new gas fired capacity was the lowest in fifteen years. Backed by CDP (2015) who support that climate friendly corporations deliver a higher return on investments, complemented with a lower cost of financing, financial markets have also advanced in the last decade, by (i) originating investment opportunities through the rise of new environmentally friendly assets classes or financial products; (ii) forming a paradigm shift among investors to consider climate change factors in investment decisions. Though there have been numerous actions from the investment community on the paradigm shift, e.g., the Portfolio Decarbonatization Coalition, the Montreal Carbon Pledge, and the Task Force on Climate Related Financial Disclosure, much less has been captured on the performance of sustainability indices which promote cleaner energies.

The primary objective of this study is to assess the performance of both low carbon and fossil fuel free financial products which are linked with cleaner energy sources. Specifically, we look at the performance of sustainable investment indices whose constituents are meeting environmental, social and governance (ESG) needs of investors. Due to the scope of this study, we emphasize on alternative energy-based equity indices, and more predominantly, Morgan Stanley Capital International (MSCI) low carbon index family, State Street Global Advisors (SSGA) fossil fuel free Exchange Traded Funds (ETFs), and STOXX low carbon Europe 100 index. To assess the performance of these indices, we employ the Relative Strength Index (RSI), a popular technical analysis tool used to capture market momentum. We go beyond just applying the traditional RSI model by adjusting the model to reduce false signals, number of trades and improve performance results.

This paper contributes to existing literature, by being the first, to our knowledge, to (i) capture momentum information in low carbon and fossil-fuel free investments; (ii) use technical analysis tools to assess the performance of trading strategies which are based on momentum; and (iii) compare the performance of these alternative energy financial products pre and post COVID-19 early impact of March 2020. Key findings of this study have some important implications for investors, investment institutions and regulatory bodies. An assessment of the performance of sustainable equity investments allows the investor to make more informative decisions when deciding whether to invest in traditional financial products such as exchange traded funds (ETFs) which are based on traditional equity markets and oil-based, or rather in those indices whose constituents are aligned with climate change consciousness, and a gradual move away from traditional fossil fuel-based markets. Our findings also shed further light as to whether environmental technology and environmental opportunities indices offer a more attractive option to the investor in terms of his/her portfolio's excess return per unit of risk. A comparison among regional or industry specific indices provides further guidance as to whether MSCI or SSGA sustainable energy indices/ETFs provide better sustained financial performance. For investment institutions, due to the increased attention and investments in greener energies, particularly in US, EMDE and China, our findings provide some light into which direction sustainable investments are heading. Although we focus primarily on indices from the environmental markets' family class, performances of low carbon and fossil fuel free index series enable investment product providers to consider constructing financial products such as ETFs, derivatives, and retail/institutional funds where those abovementioned indices are used as benchmarks.

Finally, but not least, to financial regulators, the incremental shift of capital towards sustainable investing, means that industry, sectors, and individual companies are affected. Simply put, the changes in investors' likings through a shift away from companies pursuing fewer or no green objectives towards those pursuing greener objectives, means industries and sectors' contribution to the economy could alter. As these shifts are happening, higher returns are expected, particularly for those which are more closely related to risks such as climate change. Alternatively stated, if sustainability is valued by investors, asset prices should reflect those, relative to the risk sustainable investments add to existing risks. This means more rigor in regulation in terms of definitions, guidelines, and frameworks.

The rest of this paper provides an overview of the types of risk initiated by sustainable investments, policy actions in the area of sustainable investments, COVID-19 and energy markets, and a review on the use of technical analysis in financial markets. The methodology section provides a breakdown of the technical analysis indicator, followed by the data section which provides the data specifications of the financial products under analysis. The research findings are laid out, starting with some descriptive statistics. We rest our case with some concluding remarks.

2. LITERATURE REVIEW

2.1. Added Risks in Cleaner Energy Investments

Further than the gradual rise of investments in cleaner energies and fall in traditional fossil fuel investments, investors are subject to 2 environment-related risks, specifically investor level risks and asset level risks. In terms of individual level risks, this can be further classified into investment risk, regulatory risk, stranded asset risk, innovation risk, and reputational risk. Firstly, Corporate Knights (2015) report that funds with over $1 trillion of Assets Under Management (AUM) missed on $22 billion by investing in institutions which negative impact our climate. Secondly, Chan (2015) maintains that regulators can enforce investments which are not adversely affecting climatic conditions as seen in France, UK, and Europe. Thirdly, portfolios consisting of companies who rely on heavily fossil fuels can be affected if the non-renewables cannot be used anymore. Fourth, an increase in investors' interest in alternative renewable energies can disturb the business model of industries which rely heavily on fossil fuels. This is backed by studies like Nandha and Faff (2008), Huang et al. (1996), and McSweeney and Worthington (2008) who find that industries linked with energy are vulnerable to oil price changes. Fifth, campaigns such as 'divesting fossil fuel' can affect repute of investors who hold assets which harm the global space, including crude oil and natural gas. In terms of asset level risks, this can be classified as carbon pricing risk, litigation risk and regulatory risk. Firstly, carbon pricing through local/foreign taxes and emission trading schemes can affect the net income of companies with a heavy carbon footprint, which in turn affect the stock prices and returns of shareholders. Secondly, regulators can impose measures to protect the environment in some areas. Third but not least, companies with high carbon footprints can be made responsible for damaging the environment, and subject to financial penalties.

2.2. Policy Actions in Sustainable Energy

Individuals and governments participate towards much needed actions in the decarbonization process. For illustration, state policy makers have been called upon to clasp the development, deployment, and diffusion of technologies, and to implement policies, to move gradually towards low emission energy systems, including quickly scaling up the deployment of clean power generation and energy efficiency systems, including fast-tracking efforts towards the phase down of unabated coal power and phase out of inefficient fossil fuel subsidies. At individual levels, investors can participate in the process by positioning their portfolios with financial products concerned with cleaner energies such as wind, solar and hydroelectric, rather than energy commodities such as crude oil. However, there are challenges such as a slower pace of electrification, particularly to those who are hard to reach regions. Further, there are increasing energy, commodity, and shipping costs to manufacture and transport biofuel, solar and wind turbines. Nonetheless, as reported by Deloitte (2022), collection action to achieve net zero emissions by 2050 could increase the size of the world economy by nearly $45 trillion in today's worth from 2021 to 2070.

In addition to future projections made by various entities on the economic value of cleaner energies, the role that private and public sector plays in the energy transition is another critical factor to attract investors to sustainable energy finance. For example, as part of COP27 Breakthrough Agenda, states representing over fifty percent of the global Gross Domestic Product (GDP) set out a 1-year action plan to help make clean technologies cheaper and more accessible globally. Particularly, a package of 25 collaborative actions have been set up to fasten decarbonization in 5 key sectors, namely, road transport, power, hydrogen, steel, and agriculture. For example, three agreements include (i) driving investment in agriculture Research, Development and Demonstration (RD and D) to create solutions to address the challenges of food insecurity, climate change and deprivation of the environment; (ii) developing common definitions for low-emission and near-zero emission steel, hydrogen, and sustainable batteries to help direct billions of pounds in investment, procurement, and trade; and (iii) accelerate the setup of essential infrastructure projects including a minimum of 100 hydrogen valleys, a minimum of 50 large scale net-zero emission industrial plants, and a various major cross-border power grid infrastructure projects (Climate Champions, 2022). An example of country collaborations includes the UAE and US who participated in the 100 GW Partnership to Accelerate Clean Energy (PACE) and the 10 GW wind energy agreement. AQ1

Moreover, in 2022, 65 global businesses joined the First Movers Coalition which targets to decarbonize heavy industry and long-distance transport sectors responsible for nearly one third of global emissions (World Economic Forum, 2022). They intend to invest in innovative green technologies, which will in turn ensure new technologies are available for scale up by 2030 and thereby make a significant contribution to achieve net zero emissions by 2050. Specifically, these companies, with market capitalization values $8 trillion, committed $12 billion in 2030 purchase commitments for green technologies as part of the decarbonization process (Scarselli, 2022). In the same vein, the European Investment Fund (EIF), Europe's largest venture capital and private equity financier, signed investments of €247 million to enable five equity funds to back €2.5 billion of climate action investment that helps to deliver the European Union's climate and energy targets. The new financing adds to the European Green Deal, the roadmap for Europe to become the first climate-neutral continent by 2050, and REPowerEU, the plan to swiftly reduce dependency on Russian non-renewable energy and speed up the transition towards sustainable greener energies. These funds are namely PureTerra Ventures, Growth Blue Fund I, Zintinus Fund I, SUMA Capital Climate Impact Fund III and the Eiffel Transition Infrastructure Fund (European Union, 2022).

2.3. COVID-19 and Energy

Severe shocks in oil prices have been observed since COVID-19, increasing investors' appetite for non-equity assets (World Bank, 2020). Additionally, the pandemic has caused a short-run liquidity and volatility shock, with one of the fastest historical declines in the stock market ever observed in Europe. Fu and Shen (2020) found a significant negative impact of COVID-19 on the performance of corporations in the energy industry, especially in heavily affected areas in China. Gil-Alana and Monge (2020) found the oil market became inefficient when incorporating COVID-19 crisis data. Polemis and Soursou (2020) examined the impact of the pandemic on Greek companies' returns, showing it affected returns of most firms negatively, yet with dissipating effect following the announcement of the national lockdown. Similarly, Albulescu (2020) assessed the impact of COVID-19 on oil prices and found only a marginal effect on crude oil after controlling for economic policy uncertainty and the U.S. market volatility. Gurrib et al. (2022) investigated intraday patterns in 11 US sector-based ETFs and found a positive impact of the COVID-19 first vaccination rollout on the energy sector. Bakas and Triantafyllou (2020) studied the impact of the pandemic's uncertainty on the volatility of commodity markets, showing a significant negative effect on crude oil. Gurrib et al. (2021) found that short selling ban policies imposed on European stocks due to early COVID-19 had a short-lasting impact on energy equity prices. Ambros et al. (2020) employed 30-minute tick returns to examine the impact of COVID-19 news onto international markets.

2.4. Measuring Technical Analysis Performance

The first proponents of technical analysis can be tracked back to more than fifty years ago to groundwork by Poole (1967) who used ten different trading filters in nine foreign exchange markets and reported excess returns. Allen and Taylor (1992) surveyed the literature of technical analysis. Two of the earliest seminal works on the effectiveness of technical analysis are Ball (1978) and Fama (1972). The first study found that market timing-based strategies result in negative returns, when adjusted for transaction costs. The second study supports the efficient market hypothesis that current market prices reflect all available information such that relying on this assumption would be unprofitable or result in a positive return that is accompanied by an unacceptable risk level. The findings of Fama and Ball were supported by Park and Irwin (2008) who found that trading using technical analysis rules were not profitable for US futures markets.

Although numerous trading strategies demonstrated evidence of success in traditional markets including cryptocurrencies, currencies markets, fixed income, and equity markets (Nadarajah and Chu, 2017; Neely et al., 2014; Shynkevich, 2016; Gurrib et al., 2022), uncertainty in financial markets complicates the choice between fundamental analysis and/or technical analysis techniques for investors and traders. Neely et al. (2009) found that both market conditions and profitability vary over time when applying technical analysis. This is backed by Gurrib (2018) who looked at the performance of the Average Directional Index as a market timing tool and found weekly trading horizons to be more profitable than monthly ones. Beyaz et al. (2018) analyzed various companies using both fundamental and technical analysis and found differences in the performance using either analytical techniques were less evident for energy equities and the combination of both techniques improved performance of equity prices. Gurrib et al. (2020) found the Ichimoku Cloud indicator useful to forecast energy stock price movements, and also recommends the capture of momentum through indicators such as RSI.

While Malkiel (1996) established that technical analysis has no real value, except for creating some occasional comfort and amusement to the investor, Pruitt and White (1988) found their trading system, which includes technical indicators such as RSI, volume, and moving average, to outperform the market after adjusting for transactions costs. In the same vein, Menkhoff (2010) found most fund managers in five countries use technical analysis. In support of technical trading, Szakmaryn et al. (2010) found trend following strategies to be profitable in commodity futures markets and Tsaih et al. (1998) found their trading-based system to outperform a traditional buy-and-hold strategy for S and P500 stock index futures. Likewise, Wong et al. (2003) found the use of RSI and moving average to yield significant positive returns in the Singapore Stock Exchange. More recently, Gurrib and Kamalov (2019) analyzed the use of RSI on USD based currency pairs, including crude oil and natural gas, and reported that the energy markets had the highest risk, compared to the most actively traded foreign exchange rates.

Recent advancements in the field of average based techniques include Gurrib and Elshareif (2016) who tested an adaptive moving average model for the Euro/US dollar currency pair and achieved higher annualized returns, lower annualized risk, but accompanied with higher number of trades, than the naïve buy-and-hold strategy. Gurrib (2016) applied an optimized moving average crossover strategy over the SPDR S and P500 ETF and found that the trend following strategy outperform a buy-and-hold strategy. To capture inherent volatility, various measures have been used in the existing literature on investment strategies including standard deviation (Abushosheh et al., 2022) and ATR(Cohen, 2022; Gustafson, 2001).

Based on the above mix findings regarding technical analysis, for the purpose of this study, we adopt the RSI as a momentum indicator. To capture and compare performance across investments, the reward to volatility ratio or Sharpe ratio from Sharpe (1964), and the Sharpe per trade from Gurrib et al. (2021) are used. While the former represents the excess returns for each unit of risk where returns represent the difference between the risk-free rate and average return, the later adjusts the Sharpe to the number of trades as a proxy to capture transaction costs, since the more trades there are, the higher the transaction costs. As conventionally used in literature, the risk free is usually proxied by the 3-month US treasury bill rate. To our knowledge, there are no existing research which investigates the performance of sustainability energy indices, specifically low carbon, and fossil fuel free index family series, using technical analysis in the areas of momentum. Our major contribution is to bridge the gap in the area related to the performance of sustainable fossil fuel free and low carbon index investing as alternative energy sustainable investments. Our study is carried out over a period of 6 years, using daily data, where we decompose your analysis into 3 pre-early COVID-19 early impact (January 2017-March 2020), and 3 post early COVID-19 early impact (March 2020-February 2023). This enables us to obtain some insights whether the cleaner energy equity investments were affected by the COVID-19 pandemic, ceteris paribus.

3. METHODOLOGY AND DATA

Due to the scope of the study and availability of various technical analysis indicators, we focus on RSI to capture momentum information.

RSI - The RSI, introduced by Wilder (1978), is one of the most popular technical indicators used to determine momentum in price movements, i.e., the rate of the rise or fall of a security's price. Compared to constructing a momentum line which uses price differences, the RSI avoids the issue of having erratic shifts in the momentum caused by sharp price advances or declines, by smoothing the price changes. Further, as a momentum oscillator which fluctuates between 0 and 100, it provides a vertical range for comparison purposes. The RSI captures the cumulative gain in price relative to cumulative loss in price, and is calculated as follows:

$$RSI = 100 - \frac{100}{1 + RS} \quad (1)$$

where $RS = \frac{Sum\,of\ gains}{Sum\,of\ losses} = \frac{Average\ gain}{Average\,loss}$

$$\text{Average gain} = \left\{ \begin{array}{l} Average\ gain\ over\ last\ 14\ periods, 1^{st}\ average\ gain \\ \frac{\left[\left(Previous\ Average\ gain\ x\,13 \right) + current\ gain \right]}{14} \\ subsequent\ average\ gains \end{array} \right\},$$

$$\text{Average loss} = \left\{ \begin{array}{l} Average\ loss\ over\ last\ 14\ periods, 1^{st}\ average\ loss \\ \frac{\left[\left(Previous\ Average\ loss\ x\,13 \right) + current\ loss \right]}{14} \\ subsequent\ average\ losses \end{array} \right\},$$

For the purpose of this study, we adopted look back frequency of 14-month period, where 14 is the default setting on most trading platforms showcasing the RSI indicator. As per Wilder (1978), RSI values above (below) the 70 (30) levels are considered overbought (oversold). For the purpose of our study, price is analogous to the index value. Although, it can be argued that an index value is not price, all the environmental equity indices used in the study can be used to create financial products such as ETFs as mentioned earlier.

MSCI Low Carbon indices aim to help identify potential risks linked with the transition to a low carbon economy while representing the performance of the broad equity market. Launched in 2014 they are the first index series designed to address two dimensions of carbon exposure, i.e., carbon emissions and fossil fuel reserves. They can be split into two index classes, namely, the MSCI global low carbon target indices and the MSCI Global low carbon leader indices. MSCI Global Low Carbon Target Indexes re-adjust the weight of stocks based on their carbon exposure in the form of carbon emissions and fossil fuel reserves. The indexes are designed to achieve maximum carbon exposure reduction and achieve a 0.3% tracking error target while minimizing the carbon exposure relative to their parent indices. Similarly, the MSCI Global Low Carbon Leader indices intends to achieve at least 50% reduction in the carbon footprint of the parent index by excluding companies with the highest carbon emissions intensity and the largest owners of carbon reserves. The indexes intent to minimize the tracking error relative to their parent index. Due to the scope of the study, we focus on four related indices, namely, MSCI ACWI Low Carbon Target Index, MSCI World Low Carbon Target Index, MSCI ACWI Low Carbon Leaders Index, and MSCI World Low Carbon Leaders Index.

Two ETFs are sourced from the Fossil fuel free family index class, i.e., the SPDR S and P 500 Fossil Fuel Reserves Free ETF and the MSCI Emerging Markets Fossil Fuel Free ETF. The SPDR S and P 500 Fossil Fuel Reserves Free ETF aims to provide investment results that, before fees and expenses, correspond generally to the total return performance of the S and P 500 Fossil Fuel Free Index. The S and P 500 Fossil Fuel Free Index measures the performance of companies in the S and P 500 Index that are "fossil-fuel free", with companies that do not own fossil-fuel reserves. To be included in the index, fossil fuel reserves are defined as (i) thermal coal reserves, (ii) other non-metallurgical coal reserves (e.g., coal for chemical biproducts, coal briquettes, residential use, liquid fuel, cement production, paper manufacturing, pharmaceutical, alumina refineries, ferrochrome, anthracite) (iii) conventional or unconventional oil reserves (e.g., natural gas liquids, oil sands, condensates and liquid petroleum gas), (iv) natural gas reserves, (v) shale gas reserves, and (vi) oil and gas reserves that have not been disclosed transparently as specific types of oil or gas, or are disclosed as one aggregate quantity of oil and gas reserves combined (SSGA, 2023).

In the same vein, the SPDR MSCI Emerging Markets Fossil Fuel Reserves Free ETF seeks to provide investment results that, before fees and expenses, correspond generally to the total return performance of the MSCI Emerging Markets ex Fossil Fuels Index. The MSCI Emerging Markets ex Fossil Fuels Index is designed to measure the performance of companies in the MSCI Emerging Markets Index that are "fossil fuel reserves free," which are defined as companies that do not own fossil fuel reserves. For purposes of the composition of the Index, fossil fuel reserves are defined as proved and probable coal, oil or natural gas reserves used for energy purposes, but do not include metallurgical or coking coal, which is primarily used in the production of steel. Last but not least, we include STOXX low carbon 100 Europe index, in order not to over emphasize on developed, emerging markets and US. The STOXX Industry Leaders Low Carbon Indices represent the top industry leaders, as defined by the Industry Classification Benchmark (ICB), with the lowest carbon emissions considering estimated and reported carbon intensity data. All product specifications are laid out in Table 1. We do not distinguish between index and ETFs in this study, as most ETFs are constructed to track index performance. Hence, the terms index and ETFs are used interchangeably. The 3-month treasury bill rate is used as a proxy for the risk-free rate and is sourced from the St Louis Federal Reserve database. The daily average risk free rate was 1.316%. The study is conducted over the period January 1st, 2017-February 28th, 2023, using daily data from Factset, MSCI, and SSGA.

Figure 1 Panel A displays the index values of the select indices and ETFs. As observed fossil fuel free and low carbon indices and ETFs values from MSCI, SSGA and STOXX fluctuated in a similar fashion. The significant drop in values witnessed during the period January 2020-March 2020 reflects the impact of early COVID-19 on all global markets. Panel B reports the daily cumulative percentage change in the index and ETFs over the period January 1, 2017-February 28, 2023. As observed, despite covering different markets (developed, emerging, Europe), and different financial product/index providers using different definition criteria for constituents to be included in an index, and using different benchmarked index, all of the seven index/ETFs displayed a similar performance visually. Most values resumed an uptrend post the earlier COVID-19 impact of March 2020, until January 2022 where most indices/ETFs dropped in performance. Furthermore, Panel C, which reports the daily percentage change in index and ETFs values support that the fluctuations in the daily price change were more pronounced post the early January-March COVID-19 impact.

4. RESEARCH FINDINGS

4.1. Descriptive Statistics

Graphical representations in Figure 1 support that the indices behave in the same fashion over the period January 2017-February 2023. Using 1550 daily observations, we first conduct a Pearson product-moment correlation analysis to gauge the strength of this relationship. Correlation values ranged from 0.57 to 0.99. The lowest correlation of 0.57 was expected for the Low Carbon 100 Europe and the MSCI Emerging Markets Fossil Fuel Free ETF, as they cover different markets. Similarly, the highest correlation of 0.99 observed between the ACWI low carbon target and leaders indices was expected as they are both benchmarked against the MSCI ACWI index, with however different index aims as mentioned earlier. The minimum (maximum) returns observed across all 1550 observations varied between -12.62% for the Emerging Markets Fossil Fuel Free ETF to 9.15% for the S and P 500 Fossil Fuel Reserves Free ETF. Range fluctuated between 17.62% for the ACWI Low Carbon Target index and 20.99% for the Emerging Markets Fossil Fuel Free ETF. Average daily returns for all indices from 0.017% to 0.046%. The ACWI Low Carbon Target index (Emerging Markets Fossil Fuel Free ETF) had the smallest (highest) risk with a standard deviation of 1.009% (1.355%). All the seven indices were negatively skewed with values varying between −0.57 and −0.92. Return distributions of all indices were leptokurtic.

4.2. Momentum in Low Carbon and Fossil Fuel

RSI is used as the technical analysis indicator to capture momentum in the low carbon and fossil fuel indices. Most RSI values for all select indices fluctuated between the overbought and oversold levels. All open positions are closed by the end of February 2023 to be able to measure the risk and return over the period under study. Several buy and sell orders are allowed, such that a buy order is not necessarily followed by a sell order and vice versa. Short selling is allowed.

As observed, all Low Carbon indices performed poorly under the momentum-based trading strategy, with total returns varying between −333% and −407%. Based on the different overbought and oversold signals, this resulted on fairly similar average returns, fluctuating between −8.14% and −8.64% for the four low carbon equity indices. All MSCI ACWI and World based indices reported similar risk values between 10.95% and 11.92%, explained by the fact that they are benchmarked against the MSCI ACWI index and MSCI World index respectively. This resulted in excess return per unit of risk to be all negative. It was also noticed that the number of trades were the highest compared to the fossil fuels equity-based indices and STOXX low carbon 100 Europe index, suggesting that the poorly performance in the MSCI low carbon indices can be attributed to various false overbought and oversold signals. The fossil fuel free based equity indices performance was mixed, with the S and P 500 fossil fuel reserves free ETF also posting an average negative return of −11.9% with a risk of 2.98%.

Comparatively, the emerging markets fossil fuel free ETF delivered a strong and positive performance with an average

Table 1: Low carbon and fossil fuel free indices/exchange traded funds

Family class	Index/ETF	Markets
MSCI low carbon index family	MSCI ACWI low carbon target	Developed+emerging markets
	MSCI ACWI low carbon leaders	Developed+emerging markets
	MSCI world low carbon target	World
	MSCI world low carbon leaders	World
S and P fossil fuel free index family	SPDR S and P 500 fossil fuel reserves free ETF	US
	SPDR MSCI emerging markets fossil fuel free ETF	Emerging markets
STOXX Low carbon index	Low Carbon 100 Europe Index	Europe

Source: Factset, MSCI and SSGA. ETF: Exchange traded fund, MSCI: Morgan Stanley Capital International

Figure 1: Performance of fossil fuel free and low carbon indices/ETFs (January 2017-February 2023)
Panel A: Low carbon and fossil-fuel free index/ETFs daily values
Panel B: Cumulative daily percentage change in fossil fuel free and low carbon index/ETFs
Panel C: Daily percentage change in fossil fuel free and low carbon index and ETFs values (January 1, 2017-February 28, 2023)

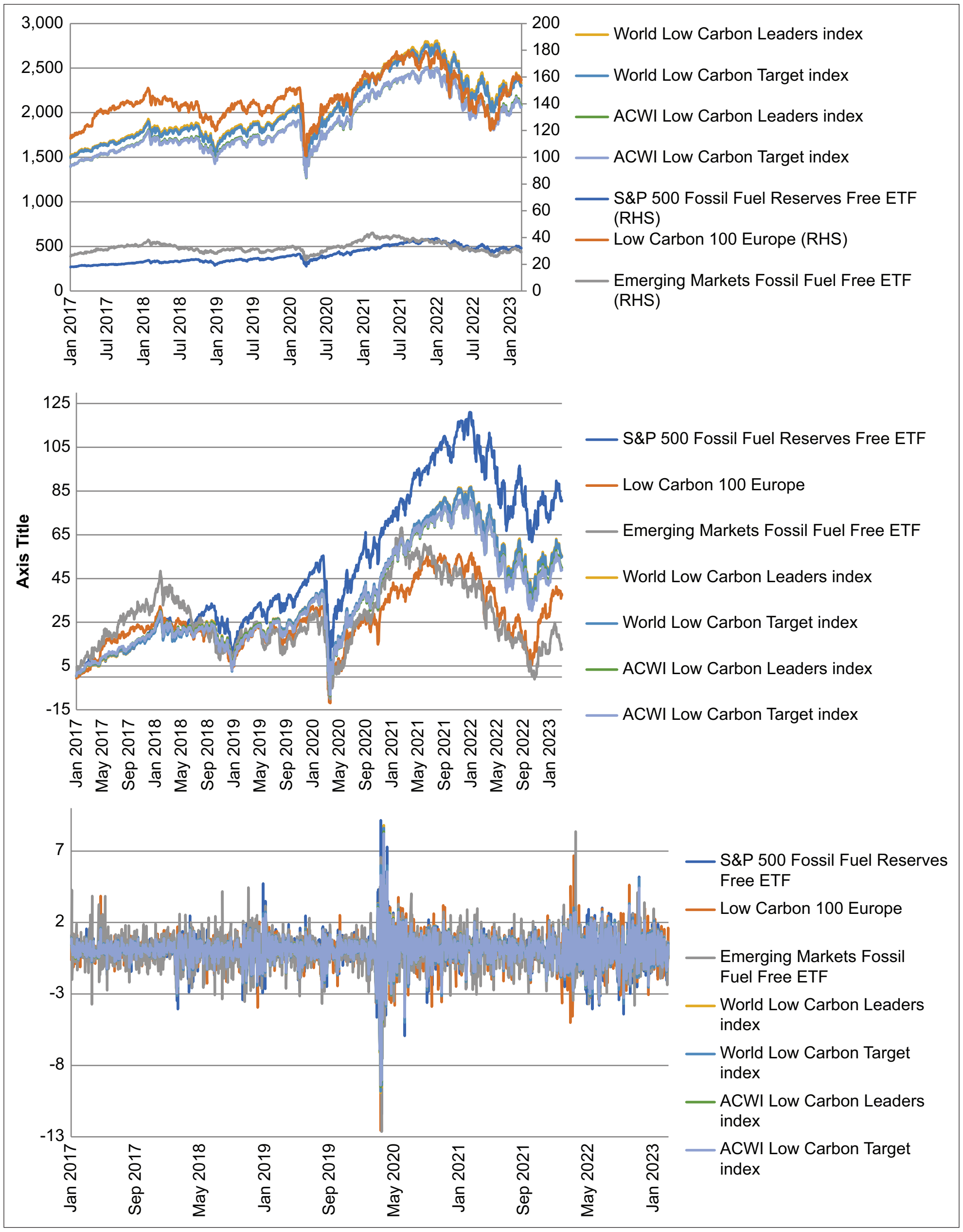

Figure 1 Panel A shows the daily index and ETFs values for the period 1st January 2017-28th February 2023. The S *and* P 500 Fossil Fuel Reserves Free ETF, Low Carbon 100 Europe, and Emerging Markets Fossil Fuel Free ETF are displayed on the right-hand side vertical axis. Source: Factset, MSCI, SSGA.

return of 12.43% with however the highest risk among all indices, with a standard deviation of 21.69%. This translated into a robust Sharpe value of 0.512. The SPDR based ETF also reported the lowest number of trades compared to the other indices under study, suggesting the RSI was able to track overbought and oversold periods more efficiently. After adjusting for the number of trades as a proxy for transaction costs, this resulted in a Sharpe per trade of 0.01. Further, the STOXX low carbon index also delivered a total return of 52.73% over the period under study, with an average return of 1.76% and risk value of 11.48%. However, this resulted into a relatively low positive Sharpe of 0.038 and a Sharpe per trade of 0.001, due to the relatively high number of trades.

Due to the earlier findings, where the high number of trades resulted in false signals and accumulated losses, the overbought (oversold) boundary levels were adjusted at 75 (25). The widening of the boundaries consequently leads to a reduced number of signals, but also, buy and sell signals being captured later than with the earlier 70 (30) RSI model. All open positions are closed by the end of February 2023 to be able to measure the risk and return over the period under study. Several buy and sell orders are allowed, such that a buy order is not necessarily followed by a sell order and vice versa. Short selling is allowed. Table 2 reports the performance of the 7 fossil fuel free based and low carbon indices based on the 80 (20) RSI trading strategy.

Compared to earlier findings where only 2 out of 7 indices reported gains, implementing the revised RSI model resulted in far better results, with 6 out of 7 indices reporting gains. Among the low carbon index family, all four indices reported positive total returns ranging from 121% to 144%. Average gains fluctuated being 7.44% for the ACWI low carbon leaders index to 9.31% for the World low carbon leaders index. Risk among the four low carbon indices were fairly consistent, ranging from 16.62% to 17.88%. This resulted in stable positive Sharpe values between 0.343 and 0.459. As expected, the number of trades decreased significantly, from a previous high of 94 trades to a current high of 34. Sharpe per trade ranged between 0.010 and 0.018 for low carbon indices.

It is also observed that the risk values increased for low carbon indices, due to the broadening of the RSI overbought/oversold boundary levels. This was also apparent for the European counterpart, where the STOXX low carbon 100 Europe index reported an increase in risk, with the standard deviation increasing from 11.48% to 13.20%. Compared to earlier results, the average return for the Europe based index however also increased to 4.43%, accompanied with a much lower number of trades. This ended with a Sharpe of 0.235 and a Sharpe per trade of 0.01. Regarding fossil fuel free based indices, both SPDR indices witnessed an improvement in performance. Although S and P 500 fossil fuel reserves free index still reported a loss of −167%, this was much lower than the earlier reported loss of −405%. This translated in a Sharpe of −0.854, with a total number of 24 trades compared to 68 under the 70-30 RSI model. Furthermore, although total return decreased from 323% to 120% for the MSCI emerging markets fossil fuel free index, the average gain increased from 12.4% to 17.12%. With a reduced risk, this translated into the highest excess return per unit of risk of 0.882. With the lowest number of trades under all indices, the Sharpe per trade was the highest at 0.063.

Although the first US coronavirus case was reported by the Centers for Disease Control and Prevention (CDC) on the 20th of January 2020, President Donald Trump officially declared the U.S. outbreak a public health emergency on the 31st of January 2020. While significant negative impacts on the global financial arena were observed around early March 2020, for e.g., on 6th March when stock markets worldwide were closed down, the early negative impact was seen towards on the 24th of February when major equity indices such as the FTSE 100 (UK) and the Dow Jones Industrial Average (US) started to drop above 3%. This followed in Asia and Europe where some major indices like the IBEX 35 (Spain), DAX (Germany), CAC 40 (France) and the FTSE MIB (Italy) fell over 4% respectively. To capture the impact of the early COVID-19 on the low carbon and fossil fuel free based indices, we decompose our data into pre- and post- early COVID-19 impact periods, where pre- COVID-19 covers the period 1st January 2017-19th February 2020, and post- COVID-19 covers 20th of February 2020-28th of February 2023. Further, due to the superior performance of the 75-25 RSI model over the traditionally used 70-30 RSI model, we retain the former model for later analysis. For both pre- and post- periods, we assume that the trader close out all open positions on the last day of the sample under analysis. Alternatively stated, for the purpose of this study, the performance of the indices is captured over the pre (post) early COVID-19 impact period of 787 (762) days respectively. Table 3 reports the results for both pre- and post- early COVID-19 impact on the select low carbon and fossil fuel free equity indices.

As evidenced in Table 2, the performance of the low carbon and fossil fuel free indices differed in the pre and post early COVID-19 periods. Compared to the post COVID-19 period, all selected equity indices performed poorly in the pre- early COVID-19 period, with negative total returns ranging from −130% to −6%. The only exceptions were MSCI World Low Carbon Leaders indices which reported a positive, yet insignificant total return of 2.27%, and SPDR MSCI Emerging Markets Fossil Fuel Free index which reported a total return of 46.30%. This translated to an excess return per unit of risk of −0.122 for the former and 0.493 for the later. Interestingly, during the post early COVID-19 performance, all the indices reported superior performance, with all posting positive average returns ranging from 14% for the MSCI Emerging Markets Fossil Fuel Free index to 19% for the MSCI ACWI Low Carbon Target index. Average returns for all indices, except for MSCI Emerging Markets Fossil Fuel Free index, fluctuated around 17-19%, showing a consistent and sustained performance in the post COVID-19 period.

Table 2: Performance of fossil fuel free and low carbon indices based on 80-20 relative strength index strategy

Fossil fuel free and low carbon indices	Total return (%)	Average return (%)	Risk (%)	Sharpe	Number of trades	Sharpe per trade
MSCI low carbon index family						
MSCI ACWI low carbon target	144.11	8.48	17.69	0.405	34	0.012
MSCI ACWI low carbon leaders	126.51	7.44	17.88	0.343	34	0.010
MSCI world low carbon target	121.06	9.31	17.41	0.459	26	0.018
MSCI world low carbon leaders	121.17	8.65	16.62	0.442	28	0.016
S and P Fossil fuel free index family						
SPDR S and P 500 fossil fuel reserves free	−167.29	−13.94	17.86	0.854	24	0.036
SPDR MSCI emerging markets fossil fuel free	119.82	17.12	17.91	0.882	14	0.063
STOXX low carbon index						
Low Carbon 100 Europe Index	53.10	4.43	13.20	0.235	24	0.010

MSCI: Morgan Stanley Capital International

Table 3: Pre- and post-early COVID-19 impact performance

Fossil fuel free and low carbon indices	Pre-COVID-19 performance						Post-COVID-19 performance					
	Total return (%)	Average return (%)	Risk (%)	Sharpe	Number of trades	Sharpe per trade	Total return (%)	Average return (%)	Risk (%)	Sharpe	Number of trades	Sharpe per trade
MSCI low carbon index family												
MSCI ACWI low carbon target	−6.24	−0.57	8.80	0.214	22	0.010	58.24	19.41	17.74	1.020	6	0.170
MSCI ACWI low carbon leaders	−23.69	−2.37	7.66	0.481	20	0.024	56.77	18.92	17.73	0.993	6	0.165
MSCI world low carbon target	−6.86	−0.86	12.46	0.174	16	0.011	56.77	18.92	19.08	0.923	6	0.154
MSCI world low carbon leaders	2.27	0.25	8.70	0.122	18	0.007	56.34	18.78	19.13	0.913	6	0.152
S and P fossil fuel free index family												
SPDR S and P 500 fossil fuel reserves free	−130.57	−14.51	9.42	1.680	18	0.093	56.74	18.91	21.70	0.811	6	0.135
SPDR MSCI emerging markets fossil fuel free	46.30	7.72	12.99	0.493	12	0.041	42.59	14.20	10.98	1.173	6	0.195
STOXX Low carbon index												
Low Carbon 100 Europe Index	−14.07	−1.76	3.47	0.887	16	0.111	50.01	16.67	17.59	0.873	6	0.145

Table 3 reports the performance of low carbon index family and fossil fuel free index family during pre-early COVID-19 impact (1st January 2017-19th February 2020) and post-early COVID-19 impact (20th February 2020-28th February 2023). Total returns, average return, risk, sharpe and sharpe per trade are reported, where the latter two represent risk-adjusted performance for the select low carbon and fossil fuel free equity investments. Number of trades include both buying and selling positions. All positions are closed at the end of the sample period to estimate return and risk. Values in brackets are negative. MSCI: Morgan Stanley Capital International

Furthermore, the superior performance in the post COVID-19 period was accompanied with heightened risk levels with standard deviation ranging from 11% to 22%. Fossil fuel free indices reported both the lowest (highest) risk levels for the MSCI Emerging Markets Fossil Fuel Free (S and P = 500 Fossil Fuel Reserves Free) indices. This resulted in positive Sharpe values ranging from 0.811 to 1.173, suggesting more stable risk adjusted performance for both the select low carbon and fossil fuel free equity indices. The SPDR MSCI Emerging Markets Fossil Fuel Free index witnessed the best performance, with the highest excess return per unit of risk. After adjusting for number of trades as a proxy for transaction costs, the same index reported the highest Sharpe per trade of 0.195.

Although the pre- COVID-19 performance for MSCI Emerging Markets Fossil Fuel Free index was accompanied by a higher total return of 46.3% compared to post COVID-19 with only 42.59%, average returns were higher in the post COVID-19 period. This is explained by the lower number of trade signals in the post COVID-19 period under study. It is also worth mentioning that although post COVID-19 had better performance across the board, the number of trades also decreased in the 3 years following the early COVID-19 impact time. All the indices had only 6 trades, compared to pre- COVID period where trades ranged from 12 to 22. The comparison of the post- COVID-19 period with a buy-and-hold strategy from 1st January 2017 to 28th February 2023, shows that the investing after February 2020, would have resulted in better risk adjusted return performance. This can be explained by the emergence of various environmentally based equity indices such as FTSE Russell environmental markets indices and financial products such as ETFs by investment product providers such as MSCI, due to the heightened interest of more environmentally sustainable equity investments.

5. CONCLUSION

Correlation values among the low carbon and fossil fuel free reserves equity indices ranged from 0.57 to 0.99. Using RSI to capture momentum in these cleaner energy-based investments, most RSI values fluctuated between overbought and oversold levels. All Low Carbon indices however performed poorly under the momentum-based trading strategy. The Emerging markets fossil fuel free ETF delivered a strong and positive performance with an average return of 12.43% with however the highest risk among all. Although SPDR based ETF and STOXX Low carbon index both deliver positive returns, after adjusting for number of trades, the excess return per unit of risk was insignificant. To reduce false signals, overbought/oversold boundaries were widened to 75 (25). This resulted in improved performance, with 6 out of 7 indices reporting gains and a significant decrease in the number of trades. Noticeably, although total return decreased from 323% to 120% for the MSCI emerging markets fossil fuel free index, the average gain increased from 12.4% to 17.12%. With a reduced risk, this translated into the highest excess return per unit of risk of 0.882.

The impact of the early COVID-19 on the low carbon and fossil fuel free based indices was also captured in the study, by decomposing the data into pre- and post- early COVID-19 impact periods, where pre- COVID-19 covers the period 1st January 2017- 19th February 2020, and post- COVID-19 covers 20th of February 2020–28th of February 2023. Compared to the post COVID-19 period, all selected equity indices performed poorly in the pre- early COVID-19 period, with negative returns, except for MSCI World Low Carbon Leaders and the SPDR MSCI Emerging Markets Fossil Fuel Free index. In the post early COVID-19 period, all indices reported superior performance, with all posting positive average returns. This was however also accompanied with increased risk levels. Fossil fuel free indices witnesses both the lowest (highest) risk levels for the MSCI Emerging Markets Fossil Fuel Free (S and P 500 Fossil Fuel Reserves Free) indices, resulting in positive Sharpe values ranging from 0.811 to 1.173. This suggests more stable risk adjusted performance for both low carbon and fossil fuel free equity indices. SPDR MSCI Emerging Markets Fossil Fuel Free index ranked first, even after adjusting for number of trades, as a proxy for transaction costs. Further, number of trades fell during the post- COVID-19 window. Last, but not least, investing during the post COVID-19 period yielded superior returns to a naive buy-and-hold strategy over January 2017–February 2023. This can be explained by the surge of cleaner energy equity indices and ETFs in the financial marketplace.

The primary policy implications of this study are directed (i) to the investor, where the study supports that greener based financial products are capable of generate superior risk adjusted returns than before 2020, suggesting that higher expected returns is possible, but a higher risk level is also warranted; (ii) to financial institutions in the investment industry, where superior performance of green investments post 2020 suggests there is a need for continued work in the construction of further well-defined greener indices which can eventually translate into ETFs and portfolio constituents; and (iii) to financial regulators, where there is a need to continue to monitor the emergence of financial products which tend to capture greener, climate-change conscious initiatives. In a post COVID-19 era period, where there is more interest from investors to venture in greener investments related to ESG and SDGs, it is critical to continually assess the performance of low carbon and fossil fuel free equity indices, as volume and price gain momentum away from non-renewable to greener energies. Future research avenues can tap into whether sector, industry or geographical based green equity investments' performance are sustainable compared to traditional fossil-fuel based equity investments.

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