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Structured Abstract

Purpose

The blue economy includes a variety of economic activities and provides a remarkable contribution to sustainable development. This paper aims to assess the financial performance of diverse sustainable economy activities and evaluate whether blue firms based on natural resources, mainly water behave compared with clean energy firms and in contrast to a broad-market benchmark.

Design/methodology/approach

We estimate per-ETF time-series CAPM/FF3/FF5 models on daily excess returns from July 2008 to November 2024. Coefficients are obtained by OLS with Newey–West/HAC standard errors to address heteroskedasticity and serial correlation. As a robustness check, we also run a pooled regression with factor×ETF interactions to test cross-ETF equality of factor loadings (Wald tests). This design provides a robust empirical assessment of the risk–return drivers for blue-economy and clean-energy ETFs within standard asset-pricing theory.

Findings

The results show how blue economy water-related investments are more profitable, less volatile and follow more conservative investment policies than renewable energy investments. Findings also suggest a preference for value-driven firms within water-related industries, while clean energy firms are often growth-oriented. This confirms that the blue economy firms should be preferred to clean energy firms, within the investment portfolios following a binomial risk-return strategies.

Originality/value

Blue economy stocks are increasingly gathering the interest of investors which follow a risk-return strategy but also include sustainable development principles in their investment decisions. While some studies have analysed the impact of green and other sustainable factors in the financial performance and investors preferences, to the best of the authors' knowledge, this study is the only one or among the very few that conduct this analysis within blue economy stocks.

1. Introduction

The Blue Economy (BE) is a recent field of study that encompasses economic activities based on the sea, often associated with diverse economic sectors, including tourism, maritime transport, energy and fishing. However, the concept of the Blue Economy has emerged as a transformative framework for sustainable development, emphasizing the responsible use of ocean resources to foster economic growth, improve livelihoods, and protect marine ecosystems. At its core, the Blue Economy is intrinsically linked to sustainability, as it seeks to balance economic, social, and environmental dimensions while addressing global challenges such as climate change, overfishing, and marine pollution. Therefore, this concept goes beyond a single fishing economic sector and need to consider other terms. Some bibliometric analyses (Liang et al., 2022; Silvestri et al. 2024) show the large scientific production linking the sustainable development and the blue economy, but also Martinez-Vazquez et al. (2021) extend the concept to other terms such as Maritime Economy (MAE), Ocean Economy (OE) and Blue Growth (BG), providing interesting links with other concepts such as sustainability, economics and ecosystem protection, industrial development or growth of the ocean economy, broadening the new Blue Horizons (BH). Cisneros-Montemayor et al (2022) focus on a balanced approach of blue economy in three pillars from a social (equitable benefits), environmental (ecosystem health) and economic (total production) perspective with respect to ocean economy, blue growth, and sustainable ocean economy. The BE concept also closely aligns with the United Nations Sustainable Development Goals (SDGs), mainly SDG 14, "Life below water", and is highly associated to SDG 15-17, though it contributes at some extent with SDG 3 and 8 from a stakeholder's perspective (Lee et al., 2020), (World Bank, 2017a), (Liang et al 2022). While the blue economy offers opportunities for economic growth and sustainable development, challenges remain in defining its scope and boundaries in relation to the SDGs (Lee et al., 2020). To achieve sustainable blue economy, it is essential resilience against environmental and political shocks, as well as capacity building at all levels (Niner et al., 2022).

This paper indicates how the performance of blue investments is differentiated from other green investments. In effects, Kabderian Dreyer et al. show how ESG practices affects to portfolio return, however to the best of our knowledge, except from Mumtaz and Smith (2021) and Wang et al. (2023) there are not any previous findings regarding the performance of blue investments. The findings of this paper contribute to the literature on blue finance by filling the gap of studies on the attractiveness of blue stock returns. As previous findings analyze the impact of blue lending on banking performance and indicate its benefits on the latter (Shan et al., 2023; Mirza et al., 2025) and the attractiveness of blue bonds to investors (Mathew and Robertson, 2021), our findings indicate that blue stocks are less volatile than green stocks and achieve stronger financial returns, while contributing to a meaningful environmental and social impact on ocean economies.

The rest of the paper is structured as follows. We review the literature in section 2, discussing the nature and issues regarding financing of and investing in the blue economy and the performance of blue firms. In section 3, we discuss that data sample and the method of analysis. Insection 4, we present and discuss theresults.The final section summarizes and discusses the importance of the findings.

2. Literature review

2.1 The Blue economy

Evidence from the 2012 UN Conference on Sustainable Development indicate the emergence of the term "blue economy", which was used to emphasize the role of the oceans in the green economy (Silver et al., 2015). The interest regarding this term appeared simultaneously with the exhaustion of the terrestrial resources and orientation on the financial prospects found within and below the waters of seas or oceans (B˘adîrcea et al., 2021). According to OECD (2016), the global Blue Economy is expected to expand at a quicker rate than the overall economy, nearly reaching three times its size by 2030, while "providing food" to over 3 billion people. Simultaneously, the effect on the ecosystem resulting from unsustainable economic practices linked to oceans and seas influence the resource generating source depending on this development. As a result, it is essential to have a coordinated effort for safeguarding and restoring the health of our oceans and seas (see also B˘adîrcea et al., 2021; and Choudhary et al., 2021).

According to the World Bank (2017b), the blue economy is the "*sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of ocean ecosystem*". In addition, European Commission (2021) defines it as *"all economic activities related to oceans, seas and coasts. It covers a wide range of interlinked established and emerging sectors"*.Issues related to the "blue economy", were also discussed within the policy and practice of environmental development in various preceding forums of this century (Martínez-Vázquez et al., 2021). A short definition is also given by Smith-Godfrey (2016, p. 60): "Blue Economy is the sustainable industrialization of the oceans to the benefit of all". Graziano et al. (2022) focus on operational definitions stemming from policies aiming to drive growth within the blue economy and indicate that the blue economy includes industries and sectors of economic activity in the context of fisheries and aquaculture, shipping, tourism, and renewable energy; and even wellbeing, as analyses Fudge et al. (2023).

The term has also transitioned towards sustainability, prioritizing a balance between economic development and the safeguarding of marine ecosystems, as well as the preservation of biodiversity (Pace et al., 2023). The blue economy is vital for attaining sustainable development goal 14: Life below water (Thompson, 2022). For example, firms developing technologies that can help to improve the efficiency and sustainability of fishing operations and to monitor and protect marine ecosystems (i.e. by detecting and tracking illegal fishing and pollution), firms producing ocean-based renewable energy, and firms developing products from marine organisms (i.e. pharmaceuticals and cosmetics) while preserving at the same time the ecosystem and biodiversity (Zhu et al., 2023).

2.2 Financing the Blue economy

An important question to be addressed is the blue economy financing. In an attempt for presenting the cost of saving the oceans and the implementation of SDG 14 until 2030, Johansen & Vestvik, (2020) estimate an annual need of USD 174,52 billion.Blue finance provides funding mechanisms to address environmental and social issues while ensuring economic returns to activities included within the blue economy. For example, bonds have been proposed as a means of financing blue economy projects for Small Island Developing States like The Bahamas (March et al., 2023). To address the challenges multilateral agencies, security markets and investors need to play a crucial role (Tirumala & Tiwari, 2020). Spoz and Ziolo (2025) aimed to identify how financial instruments (e.g., blue bonds, sustainability-linked financing) can be designed and strengthened to effectively support the growth of a environmentally responsible Blue Economy.

Insurance instruments and diverse forms of public-private partnership may be adopted to complete frameworks to financing a sustainable blue economy (Sumaila et al., 2021; Shiiba et al., 2022).

Meanwhile, there are many active blue economy projects financed by the World Bank, under the PROBLUE umbrella trust fund program, supporting the development of integrated, sustainable, and healthy marine and coastal resources worldwide, based in four pillars: Fisheries and Aquaculture; Marine Pollution; Oceanic Sectors; and Seascape Management. Last PROBLUE annual report available (World Bank, 2023), points out that there are more than USD 237.6 million contribution available as of June 30, 2023, mainly from Multi-Donor Trust Fund (MDTF) and Single-Donor Trust Fund (SDTF), aiming to support high impact activities in many countries around the world. On top of these projects, the World Bank continues to be the largest multilateral financier of climate action in developing countries and there are many investments to increase infrastructure resilience which may impact blue economy projects amounting huge figures, not comparable with those mentioned ones.

2.3 Investing in Blue economy

The blue economy encompasses a range of activities, mainly fisheries and renewable energy, but a broaden term comprises a significantly extensive array of diverse sectors. Among others, these sectors comprise fisheries, mariculture, ecotourism, shipping, maritime trade, blue carbon, marine renewable energy, bioprospecting, environmental restoration, and desalination (Tripathi et al., 2023).

A 2015 report published by the Economist Intelligence Unit (Unit, E. I., 2015), "Investing in the Blue Economy—Growth and Opportunities in the Sustainable Ocean Economy", found that stakeholders can take advantage of various investment opportunities across different levels and scales as part of the blue economy concept. The report also disclosed significant economic opportunities and environmentally friendly practices. As outlined by Qi (2022), a national blue economy framework encompasses four categories of entities (blue industries, blue products, blue businesses, and blue regions) and includes ten key sectors, placing more emphasis on associations and collaboration between multiatribute agents. Other authors point out that a blue growth facilitates new opportunities for capital accumulation and should be grounded on three basis, i.e. *conservation*, to mitigate the climate change; *protein* search for healthy food through aquaculture and *energy* generation mostly derived from wind and tales (Brent et al., 2020).

Innovative collaborative management approaches which generate sustainable revenues and returns for investors has been recently implemented, as marine protected areas that includes fees from visitors in the Caribbean, (Pascal et al., 2021), and innovative natural capital investments in the Red Sea (Cziesielski, et al., 2021). These type of impact investments use development and blended finance solutions which are appropriate for some developing countries involving not only the public sector but also the private sector.

On the other hand, the effects of the global economic crisis in 2008 and later Euro crisis, and COVID crisis, harmed the markets and models of asset pricing and their performance have undergone significant changes. For this reason analysing the period through 2008 to present, offer unique opportunity to test upgraded asset pricing models. Galyfianakis (2024) analyzed the abnormal returns of European Energy indices for the period 2010- to 2023, and the factor loadings based on the Fama and French (1993, 2015) three- factor (FF3) and five-factor (FF5) models, extending the methodology by introducing an additional factor, the European volatility index (VSTOXXt). Gavrilakis and Floros (2024) reported that European and Global indexes based ESG leaders' portfolios produce negative abnormal returns during 2012-2022, by implying the CAPM, FF3, FF5 methodologies. Chen and Gao (2020) employed a Fama and French three–factor model to examine how three defined volatility risk factors derived from VIX may affect the pricing of assets. Siagian (2024) also examine the effect of the Fama-French five factors and environmental performance on share returns linking of FF5 and environment in the Indonesia Stock Market during the period 2017-2023 and Boamah (2015) applies Carhart and Fama-French models to the South African stock market. Interestingly, Rompotis (2019) uses ETFs to show evidence of large versus small-cap portfolio performance.

However, no studies have been found applying the Fama-French to the blue economy. This study bridges this research gap by clearly identifying the FF factors effect in representative portfolios of the blue economy.

2.4 Climate change and financial performance of blue firms

In recent years, there has been an increasing focus on exploring the relationship between climate change and the financial performance of blue firms (see also Lv et al., 2023). Firms focused on water and ocean resources are affected by climate change, and their financial performance could be swayed by elements associated with a circular economic model (European Parliament, 2019). Limited access to finance is one of the main issues that firms of the blue economy face (see Shan et al., 2023 for examples). First, some industries and sectors of the blue economy are subject to fluctuations in demand, prices, and environmental conditions, which can create uncertainty. The volatility and uncertainty that firms of the blue economy face due to these fluctuations, increase investors' perceived risks. Second, blue economy projects that have a strong environmental or social impact but do not generate the same level of profits as non-blue economy projects, become less attractive to investors. For example, firms adopting blue economy projects obtain lower returns because the possibility of risk is lower (Mumtaz, 2025). Third, the lack of reliable market information in industries and sectors of the blue economy can make it challenging for investors to identify opportunities and to assess risks. Fourth, high capital requirements in sectors of the blue economy such as shipping, renewable energy, aquaculture and biotechnology, and marine mining increase the level of difficulty for firms to finance their growth and innovation. In the field of marine mining we have noticed that there are very few studies regarding the financing risks.

Advances in blue finance can establish funding mechanisms for ocean conservation and management and stimulate growth in the blue economy. Thanh Ha (2025) investigates the relationship between FinTech and blue bond volatility and finds that the development of Fintech plays an important role in promoting the blue economy. Banks are hesitant to finance the activities of blue economy firms due to their unique risk profiles occurring from factors mentioned above. Shan et al. (2023) and Mirza et al. (2024) analyze the impact of blue lending on banking performance and indicate its benefits on banking performance. Shan et al. (2023) indicate that an increase in exposure toward firms of the blue economy results in an increase in net interest margin for banks. A key reason for this relationship is that the market for lending to firms of the blue economy is less competitive than the market for lending to other types of firms. Shan et al. (2023) indicate that lending to firms of the blue economy can have a lower risk for banks. Their findings are explained by the facts that firms of the blue economy may operate in industries that are less susceptible to economic downturns (e.g. renewable energy, sustainable agriculture, and waste management), may receive support by governments and their lower environmental and social impact may reduce the risk of reputational damage for banks. Mirza et al. (2024) indicate that blue lending has a positive impact on the performance of banks' credit portfolios. Their findings are explained by the facts that blue (and green) lending reduces concentration risk by diversifying the bank's loan portfolio, and leads to more stable portfolios over the long term.

In their bibliometric analysis of blue finance, Wang et al. (2024) provide a structured overview of academic contributions. Their analysis indicate that some studies highlight the potential of financial mechanisms to address the financing gap in marine conservation activities. Accordingly, there is a gap in the literature regarding the performance of financial instruments for blue finance and in particular the performance of stocks for firms operating in the blue economy.

Masini and Menichetti (2012) demonstrated that portfolio performance increased with an increase of the renewable energy share in the portfolio. Their findings provided evidence against the conventional wisdom that investments in renewable energy technologies yield lower returns compared to investments in conventional energy systems. Analogous evidence on the performance of portfolios with shares from firms operating in the blue economy (along with other issues discussed below) will make investors less hesitant and increase those firms access to finance.

Empirical studies indicate that financial assets reflect the climate change related risks into their prices. The two types of climate-related risks that worry market participants are physical risks and transition risks. Transition risks encompass several components, including policy risks that arise from the possible implementation of stricter environmental regulations, which impact on the returns of brown (carbon-intensive) assets. Interestingly, Mercereau et al. (2020) find that investments in climate-aligned firms, which adopt existing best practices, increase diversification and do not raise portfolio risk much.

Engle et al. (2020) indicate that stocks react to climate change news. Bansal et al. (2016) indicate that there is sensibility of stock returns to changes in temperatures (a proxy to climate change physical risk). Choi et al. (2020) indicate that low carbon emission firms (clean stocks) outperform high carbon emission firms (carbon-intensive stocks) when temperatures are abnormally high. Furthermore, when investor climate sentiment tends to be more positive because there is an increase in the concerns on the business impact of climate change and new research on climate change is released, carbon-intensive stocks underperform clean stocks (Santi, 2023).

Investors also consider the effect of policy risk and strategically minimize their exposure to brown assets as a safeguard against climate change (Karydas & Xepapadeas, 2022). Monasterolo and De Angelis (2020) indicate that systemic risk is reduced and there is an increase in the weight on optimal portfolio for clean stocks after the Paris Agreement. Kruse et al. (2024) indicate that financial markets respond positively to firms' climate actions after the signing of the Paris Agreement. Pástor et al. (2022) and Ardia et al. (2023) indicate that clean stocks outperform carbon-intensive stocks when concerns about climate change increase unexpectedly. Antoniuk and

Leirvik (2024) indicate that unexpected political events affect climate-sensitive sectors. Faccini et al. (2023) find that markets react when there are expectations of (US) government interventions to fight climate change. Hengge et al. (2023) indicate that regulatory actions resulting in a higher carbon price lead to negative returns for carbon-intensive stocks.

Despite the growing interest in understanding the relationship between climate change and the financial performance of firms, the literature on the link between climate change performance and stock returns for firms operating in the blue economy is limited (to the best of our knowledge) to the findings of Mathew and Robertson (2021) and Wang et al. (2023). Wang et al. (2023) confirm the findings of Bansal et al. (2016) by indicating that stock returns of blue economy firms are influenced negatively by the sea temperature anomaly and positively related to climate change performance. Mathew and Robertson (2021) find a positive association between the blueness of a firm and stock returns.

2.5 Hypotheses

The preceding discussion leads to the formulation of the following hypotheses:

Hypothesis 1 – Blue economy investments are more profitable than renewable energy investments

Based on the early findings of Masini and Menichetti (2012) and the performance of clean stocks in the preceding discussion, we assume that blue economy investments are profitable. Based on the findings of Kruse et al. (2024), we also assume that they are more profitable than investments in the traditional green market of renewable energy. The blue economy offers an attractive investment opportunity at the nexus of profitability and sustainability. From precision aquaculture to advancements in biotechnology, the developments arising in this field are not only addressing urgent issues but are also transforming various industries. As we look ahead, the question is no longer whether the blue economy will expand, but how rapidly it can develop to fulfill its vast possibilities (see also B˘adîrcea et al., 2021).

Hypothesis 2 – Blue economy investments are less volatile than renewable energy investments

Based on the findings of Mercereau et al. (2020), we assume that diversification in the relatively newer market of the blue economy leads to less volatile portfolios than diversification in the more traditional green market of renewable energy. The links between green finance and uncertainty change over time, growing stronger during times of high uncertainty (see also Pham and Phuc, 2021).

Hypothesis 3 – Blue economy investments are more value-oriented than clean energy investments which are more growth-oriented

The distinction between blue economy investments and clean energy investments often comes down to their underlying objectives, risk profiles, and expected returns.Blue economy investments typically focus on the sustainable management and utilization of ocean and marine resources and emphasize the preservation of ecosystems, fisheries, and coastal communities, aiming for long-term sustainability. They may yield steady, predictable returns over time because the possibility of risk would be lower (Mumtaz, 2025) due to climate change (Bansal et al., 2016). Although the risk of clean energy investments is also affected by climate change in the same way, the growth rates should be higher as they are driven by policy support and global climate initiatives for decarbonization.

Hypothesis 4 – Blue economy investments follow more conservative investment strategies than clean energy investments

Based on the findings of Mumtaz (2025), we build on hypothesis 4-to assume that blue economy investments may focus on sustainable marine practices and conservation, often involving lower risk profiles compared to the higher volatility of clean energy investments.

Instead of randomly selecting stocks to test our hypotheses we base our experiment on Exchange Traded Funds (ETFs). ETFs release investors from the burden of monitoring many assets. They are a collection of assets, such as stocks, commodities, bonds, or a combination thereof, which is traded on an exchange like regular stocks. They have the ability to create a diversified portfolio that aligns with investors asset allocation preferences and socioeconomic interests. ETFs offer transparency by typically disclosing their daily holdings, provide greater liquidity than mutual funds as their prices fluctuate in real time throughout the trading day, can be bought and sold at any time the stock market is open, and usually have lower fees compared to other investment options. The findings Miralles-Quirós and Miralles-Quirós (2024) reinforce the importance of investing on renewable energy using ETFs.

3. Methodology

3.1. Data sample

This study examines three exchange-traded funds (ETFs), conceptualized here as representative portfolios, to explore the factor characteristics of assets linked to sustainability and the blue economy, with a focus on water resources and clean energy. The study utilizes a targeted ETF selection strategy to illustrate the unique characteristics of the blue economy sector. Two blue economy ETFs, identified by its short name, PHO and FIW, have been chosen to represent both domestic and international dimensions of water-related investments. FIW is internationally diversified, holding firms across the potable-water supply chain and wastewater treatment. PHO is U.S.-focused, concentrating on utilities and the companies that build and maintain water infrastructure. For clean energy, we use ICLN—a widely tracked ETF that serves as a broad benchmark for renewable-energy equities.ICLN primarily embodies a clean energy investment strategy aimed at the decarbonization of the energy grid, with only occasional exposure to hydropower assets. Unlike PHO and FIW, which directly engage with the blue economy via water infrastructure and technology, ICLN's focus does not encompass the wider water resource management aspects that are fundamental to blue economy frameworks.The used broad-market benchmark is SPDR S&P 500 ETF Trust (SPY) which pursues its investment goal by maintaining a portfolio comprising common stocks from the index, with each stock's weighting in the portfolio largely aligned with its corresponding weighting in the index.

The getSymbols() function in the {quantmod} package provides quick access to historical ETF price data from Yahoo Finance. This method provides efficient, reproducible, and high-frequency market data for the three ETFs under examination.

Table 1 provides a summary of the ETFs. A first analysis shows that the ETF blue economy portfolios based on natural resources, in line with the benchmark, show better total YTD results, as well as over the period analyzed, than the ETF portfolio based on renewable energy. The result is a consequence of the systematic declines of the clean energy ETF since 2021, after a boom in 2020, to make it very attractive today in terms of price. This is also shown in the P/E ratios, which are much lower for the energy ETF.

Insert Table 1 here

The Kenneth R. French Data Library, a leading global asset pricing factor resource, provides the Fama-French factors—Market (MKT), Size (SMB), Value (HML), Profitability (RMW), and Investment (CMA). The methodology uses the 2x3 portfolio sorting approach to categorize companies by market capitalization, book-to-market ratios, profitability, and investment attributes. This ensures that each element represents an orthogonal risk dimension, allowing a more complete return driver assessment.

Market (MKT) captures systematic risk by recording the overall equity market's excess return over the risk-free rate. SMB ("Small Minus Big") measures the size premium (Banz, 1981), the return difference between small-cap and large-cap equities. The Value factor (HML, "High Minus Low"), established by Fama and French (1993), measures the value effect as the return difference between companies with high and low book-to-market ratios. The profitability premium (RMW, "Robust Minus Weak") distinguishes enterprises with high operating profitability from those with low profitability (Novy-Marx, 2013). Finally, the investment factor (CMA, "Conservative Minus Aggressive"), coupled with the q-theory of investment (Hou et al., 2015), compares conservative and aggressive capital expenditure enterprises. This approach explains cross-sectional stock return variances.

Of mention, we do not estimate firm-level panels; hence, baseline results are per-ETF time-series regressions. The pooled specification used for cross-ETF tests stacks the time series and includes factor×ETF interactions; it remains a single-equation OLS with HAC errors rather than a panel estimator.

We import the Fama–French factors into R (via read.csv) and merge them with the ETF returns in the usual asset-pricing setup. This lets us study the risk–return drivers of blue-economy and clean-energy ETFs against standard factor models.

The sample runs from July 1, 2008—to align with ICLN's launch—through November 30, 2024, the latest date available for the five-factor series when we conducted the analysis. We work with daily returns. Using ETFs as investable, representative portfolios keeps the exercise practical while capturing industries that reflect blue-economy principles—sustainable resource use, water stewardship, and related innovation.See Appendix 1 for data sample discussion.

3.2. Method

Understanding blue economy asset performance and characteristics is crucial to tackling global issues including water scarcity, pollution, and ecological degradation. These sectors help achieve sustainable development goals including SDG 6 (clean water and sanitation) and SDG 14 (life below water) while providing financial rewards with good environmental impacts. Blue economy assets are essential to sustainable finance and offer unique portfolio diversity and resilience potential as investor interest in ESG themes develops.

The selected ETFs' risk-return dynamics are analyzed using the Capital Asset Pricing Model (CAPM), Fama-French Three-Factor (FF3), and Fama-French Five-Factor (FF5) models. These models examine whether blue economy and clean energy investments have systematic factor exposures that explain returns beyond market risk.

Modern asset pricing is based on the CAPM (Sharpe, 1963, 1964, 1991), which assumes that market premium sensitivity drives an asset's excess return:

$$R_{i,t} - R_{f,t} = \alpha_i + \beta_{MKT}\left(R_{MKT,t} - R_{f,t}\right) + \varepsilon_{i,t} \qquad (1)$$

where $R_{i,t}$ represents the return of ETF i at time t, $R_{f,t} = \alpha_i$ is the risk-free rate, and $R_{MKT,t} - R_{f,t}$ denotes the excess market return. The coefficient β_{MKT} captures the ETF's systematic exposure to market risk, while α_i represents abnormal returns unexplained by the market factor.

Although widely used, CAPM has well-known empirical shortcomings—especially its difficulty in explaining return patterns across different market conditions (Levy, 2009). The Fama-French Three-Factor Model (FF3) added Size (SMB) and Value (HML) to the CAPM to overcome these limitations (Fama & French, 1993). The FF3 model is:

$$R_{i,t} - R_{f,t} = \alpha_i + \beta_{MKT}\left(R_{MKT,t} - R_{f,t}\right) + \beta_{SMB}SMB_t + \beta_{HML}HML_t + \varepsilon_{i,t} \qquad (2)$$

where SMB_t measures the excess return of small-cap stocks over large-cap stocks, and HML_t represents the return differential between high and low book-to-market stocks. The inclusion of these factors allows for an assessment of whether blue economy and clean energy ETFs systematically load on small or value stocks, influencing their risk-return profiles.

The Fama-French model outperforms CAPM in explaining excess returns in diverse scenarios (Sutrisno & Nasri, 2018; Putra & Chalid, 2021). Blue economy and clean energy ETFs may also load on tiny or value stocks, affecting their risk-return characteristics. The Fama-French Five-Factor Model (FF5) (Fama & French, 2015) adds Profitability (RMW, robust minus weak) and Investment (CMA, conservative minus aggressive) components to reflect firm-level operational and financial characteristics:

$$R_{i,t} - R_{f,t} = \alpha_i + \beta_{MKT}\left(R_{MKT,t} - R_{f,t}\right) + \beta_{SMB}SMB_t + \beta_{HML}HML_t + \beta_{RMW}RMW_t + \beta_{CMA}CMA_t + \varepsilon_{i,t} \qquad (3)$$

where $R_{MKT,t}$ represents the return spread between firms with high vs. low operating profitability, and CMA_t captures the return difference between firms with conservative vs. aggressive investment policies. These criteria help clarify how business profitability and capital allocation affect blue economy and clean energy initiatives. These additional parameters improve the model's capacity to explain stock returns, especially in sectors with important profitability and capital allocation (Gimeno & González, 2023; Ragab et al., 2019; Chiah, 2016).

All baseline models are estimated per ETF as time-series OLS on daily excess returns with Newey–West/HAC standard errors (pre-whitened), which is standard for factor models with high-frequency data. We report adjusted R^2, AIC/BIC, and perform ADF/PP unit-root checks on returns and factors, VIFs for multicollinearity, Breusch–Pagan/White for heteroskedasticity, Durbin–Watson for residual autocorrelation, and Jarque–Bera for residual normality. These diagnostics are appropriate in this time-series setting and are reported alongside HAC-robust inferences.

We also implement two design-consistent robustness checks: (i) 60-month rolling FF5 betas with a monthly step and (ii) three calendar subsamples—2008–2015, 2016–2019, 2020–2024—estimated per ETF with HAC errors. These explore time-variation in exposures without pooling. Moreover, to compare factor loadings across ETFs without imposing a panel structure, we additionally estimate a pooled interaction model:

$$R_t^{ex} = \alpha + \sum_{k\in\{MKT,SMB,HML,RMW,CMA\}} \beta_k F_{k,t} + \sum_{e\in\{\text{PHO,FIW}\}} \sum_k \gamma_{k,e}\left(F_{k,t} \times \mathbb{1}\{\text{asset} = e\}\right) + \varepsilon_t, (4)$$

with ICLN as the baseline category. Wald tests on $\gamma_{k,e} = 0$ evaluate equality of factor loadings across ETFs. Standard errors are HAC-robust. The literature on Fama-French models and blue economy stocks is lacking despite their advances. The FF3 and FF5 frameworks are well tested across markets and perform reliably in explaining portfolio returns (Miralles-Quirós & Miralles-Quirós, 2024). What remains underexplored is their application to blue-economy and clean-energy ETFs. We address that gap by estimating factor loadings for PHO, FIW, and ICLN, assessing their economic and statistical relevance, and asking whether blue ETFs exhibit risk–return patterns that differ from standard asset classes and broad ESG proxies. The goal is straightforward: to see whether blue exposures earn systematic, factor-driven returns that make sense for sustainable portfolios.

4. Results and Analysis

4.1Risk-return trade-off for blue economy and clean energy portfolios

Figure 1 shows the risk-return connection for the selected ETFs in a scatter plot (see Appendix 2 for descriptive information). SPY, PHO, and FIW sit on a more favorable part of the risk–return map than ICLN. The broad market (SPY) delivers the highest return per unit of risk, as expected for a well-diversified benchmark. The two water funds track close behind: PHO and FIW offer market-like returns with moderate risk, with FIW edging PHO—likely reflecting its broader, global mix of water-related firms. By contrast, ICLN combines the highest volatility with the lowest average return over the sample (SD ≈ 0.0208; mean ≈ −0.0001), a pattern consistent with sector-specific policy shifts and capital-flow swings that buffet clean energy.
Thus, blue-economy ETFs appear more stable and better balanced than clean energy, which carries greater downside risk. The divergence suggests different exposures to underlying systematic drivers across the two themes. We will estimate the Capital Asset Pricing Model (CAPM) and the Fama-French three- and five-factor models to determine how market risk, size, value, profitability, and investment factors affect blue economy and clean energy asset performance.

Insert Figure 1 here

Table 2 summarizes the downside profile. Both water ETFs carry less downside risk than ICLN, though they remain more volatile than SPY—consistent with their sector focus but relatively steady behavior. Maximum drawdowns tell the same story: PHO −55.06% and FIW −51.92% versus ICLN −86.61%, with the market at −47.17%. Downside deviation is also lower for the blue funds (0.0107 and 0.0104) than for ICLN (0.0150).

Risk-at-the-tails lines up with this pattern. VaR is −2.17% (PHO) and −2.12% (FIW), higher than SPY (−1.85%) but well above ICLN (−3.01%) in the sense of smaller losses. For ES, blue assets again sit between the market and clean energy: extreme losses are close to SPY (−3.09%) and notably smaller than ICLN (−4.96%). Overall, the blue ETFs look more resilient than clean energy, even if they do not quite match the market's downside protection.
Given the ETFs' non-normal return characteristics, the modified VaR and ES compensate for return distribution skewness and fat-tailedness to refine these risk assessments. FIW's modified ES (-4.48%) is slightly higher than its historical ES (-

3.49%), indicating a larger tail risk due to non-normality. However, PHO's adjusted ES (-3.50%) is close to its historical ES (-3.65%), indicating a symmetric tail distribution. Skewness and kurtosis raise downside risk for ICLN, with its modified ES (-4.80%) exceeding its historical ES (-4.96%), showing the clean energy sector's sensitivity to extreme negative returns.

These findings further highlight the risk characteristics of blue economy assets, which are more volatile than the market but more resilient than clean energy investments. Blue economy assets' function in diverse portfolios must be assessed by investors and policymakers by understanding these return patterns' determinants. A factor-based study will untangle these ETFs' risk exposures, revealing their return dynamics relative to established market benchmarks.

Insert Table 2 here

4.2 Factor model results for blue economy and clean energy portfolios

Table 3's one-factor, three-factor, and five-factor models reveal blue economy and clean energy investment risk-return characteristics.

The market factor (MKT) is extremely significant ($p < 0.001$) for PHO, FIW, and ICLN, with betas surpassing 1, indicating greater market sensitivity than the typical stock. ICLN has the highest market beta (~1.12–1.20), marking clean energy investments as more volatile than the overall market. These findings support hypothesis 2: Blue economy investments are less volatile than renewable energy investments.

All three ETFs have a positive and substantial size factor (SMB) ($p < 0.001$), indicating a strong preference for small-cap companies. This matches blue economy and clean energy investments, which frequently comprise mid- and small-cap water infrastructure, sustainability, and renewable energy enterprises.

Value factor (HML) significance is mixed. Positive and statistically significant HML coefficients for FIW and PHO indicate a preference for value-oriented water-related enterprises. The fact that ICLN's HML coefficient is tiny and statistically insignificant supports the idea that clean energy enterprises are growth-oriented rather than value-driven. Thus, hypothesis 3 is approved.

The five-factor model adds profitability (RMW) and investment (CMA) components to refine these linkages. Both PHO and FIW have substantial RMW and CMA coefficients ($p < 0.001$), indicating that blue economy enterprises are more lucrative and adopt conservative investment plans compared to renewable energy firms. This matches the capital-intensive characteristics of water infrastructure and sustainability projects, which create consistent revenue flows over time. Thus, hypothesis 1 and 4 are accepted.

In contrast, ICLN has a substantial negative RMW coefficient (-0.525, $p < 0.001$), indicating exposure to less profitable enterprises. Due to subsidies, long investment horizons, and unpredictable capital expenditures, the renewable energy sector has poorer profitability than traditional businesses. ICLN differs from blue economy assets due to its low CMA coefficient, which shows no investment-policy preference.

Our FF5 estimates—value tilt and positive RMW/CMA for PHO and FIW, and weaker profitability for ICLN—echo findings that climate-aligned portfolios can deliver superior risk-adjusted profiles relative to carbon-intensive composites. The BRICS-wide study of Rahat and Nguyen (2022) documents such dominance of green over black portfolios; our blue ETFs' factor structure (value-and-profitability orientation) is consistent with that mechanism.

Insert Table 3 here

4.3 Model specification and robustness tests

Diagnostic tests before and after estimation were performed on the estimated one-factor (CAPM), three-factor (FF3), and five-factor (FF5) models to confirm validity. These tests address stationarity, multicollinearity, heteroscedasticity, autocorrelation, and residual normality to assess statistical reliability.

The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests show that all return series and Fama-French factors are stable, removing spurious regressions. At the 1% significance level, PHO, FIW, ICLN, and all factor variables strongly reject the null hypothesis of a unit root, justifying their usage in regression analysis without differencing.

All independent variables in the FF5 model have Variance Inflation Factor (VIF) values below 1.5, well below the typical criterion of 5. This indicates that the explanatory variables are not multicollinear, making the computed factor coefficients unbiased and relevant.

The Breusch-Pagan and White tests indicate significant heteroscedasticity in residuals for all models ($p < 0.001$). This implies residual variance is not constant, which could cause wasteful standard errors. To enable trustworthy inference, robust heteroscedasticity-consistent (HC) standard errors are used.

All tickers' Durbin-Watson test statistics are close to 2, indicating no residual autocorrelation. This shows that residuals are not systematically associated across time, validating the traditional OLS paradigm.

The Jarque-Bera test rejects the null hypothesis of normal residuals in all models ($p < 0.001$), suggesting significant deviations from normality. Skewness and excess kurtosis may affect standard hypothesis testing, especially confidence intervals and p-values. OLS is impartial and consistent under non-normality, but standard error efficiency can be affected.

Given the large sample size in this investigation, the central limit theorem (CLT) keeps OLS estimators asymptotically normal. Thus, non-normal residuals have less impact on inference, lowering the need for quantile regression. All models are re-estimated using heteroscedasticity-consistent (HC) robust standard errors to adjust for heteroscedasticity and non-normality distortions to improve statistical inference.

Table 4 shows factor model findings with resilient standard errors, guaranteeing statistical inferences work despite heteroscedasticity and residual non-normality. Re-estimating the CAPM, Fama-French Three-Factor (FF3), and Five-Factor (FF5) models with heteroskedasticity-consistent (HC) standard errors confirms the basic findings with slight statistical significance revisions. The market factor (MKT) remains significant ($p < 0.001$) for all ETFs, with coefficient values nearly unchanged from original results. These assets have high systematic risk exposure, especially ICLN, which has the greatest market beta (~1.12–1.20), indicating more vulnerability to market changes.

All models show a positive and significant size factor (SMB) ($p < 0.001$), confirming that blue economy and clean energy ETFs are dominated by small-cap enterprises. The value factor (HML), which was substantial for PHO and FIW in the FF3 and FF5 models, has decreased slightly due to heteroskedasticity. FIW's HML coefficient is now marginally significant ($p = 0.077$), suggesting its reported value tilt may be less robust than expected.

Profitability (RMW) and investment (CMA) components in the FF5 model change most. PHO and FIW still have positive and extremely significant RMW and CMA coefficients, but more robust standard errors limit their statistical significance. This shows that blue economy investments and basic factors remain strongly correlated but are more vulnerable to heteroskedasticity than previously thought. The negative RMW coefficient for ICLN nonetheless remains significant ($p < 0.001$), indicating the sector's lower profitability. The previously inconsequential investment component (CMA) remains so, showing that clean energy enterprises do not choose conservative or aggressive investment strategies.

Robust standard errors do not change the conclusions' economic meaning. Even if several factor coefficients have lesser statistical significance due to cautious standard error estimates, the major results remain. The robustness of these findings supports the factor model approach for explaining blue economy and clean energy portfolio risk-return characteristics.

Insert Table 4 here

4.4 Model Diagnostics and explanatory power

Finally, Table 5 shows how well the CAPM, Fama-French 3-Factor, and 5-Factor models explain blue economy (PHO, FIW) and clean energy (ICLN) ETFs. As additional factors are added to all specifications, the adjusted R^2 improves, demonstrating that size, value, profitability, and investment characteristics explain return variance beyond market exposure. The Fama-French 5-Factor model regularly has the best adjusted R^2, indicating higher explanatory power. PHO and FIW have high model fit (adjusted $R^2 \approx 0.85$), but ICLN's lower R2 (~0.55) suggests industry-specific factors like regulatory risks and energy price fluctuations influence its return dynamics, which are not captured by standard factor frameworks.

The Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) decline with model complexity, confirming the Fama-French 5-Factor model's superior model fit across all ETFs. The reductions in AIC and BIC are greater for FIW and PHO, demonstrating that blue economy assets follow standard equities risk premia, whereas clean energy investments have unique return drivers.

Insert Table 5 here

4.5 Further robustness

We complement the baseline per-ETF time-series estimates with three robustness checks that do not alter the paper's design. Each check speaks to a different concern: time-variation in factor exposures, stability across market regimes, and cross-ETF equality of loadings without imposing a panel structure.

4.5.1 Rolling factor exposures

To trace how sensitivities evolved, we compute rolling FF5 betas using a 60-month window advanced in monthly steps(≈21 trading days per step), estimated by OLS with Newey–West/HAC inference (Figure 2).

Two patterns stand out. First, market betas converge toward unity after 2019 across all ETFs, with the largest swing for ICLN. Second, the two water ETFs (PHO, FIW) remain near-unit beta throughout, consistent with their steadier, infrastructure-heavy profiles. This is a time-series view of the same story told by the full-sample FF5: blue-economy exposures are close to the broad market and comparatively stable, while ICLN's exposure is higher and more variable. We keep the figure intentionally clean (no confidence bands) to highlight trajectories; numerical estimates underlying the plot are available upon request.

Insert Figure 2 here

4.5.2 Subsample stability (2008–2015; 2016–2019; 2020–2024)

We re-estimate the per-ETF FF5 models on three calendar subsamples to test stability across the GFC/Eurozone aftermath, the pre-COVID expansion, and the COVID/post-COVID period. Results (Table 6) confirm a downward drift and stabilization of market exposure: (i) ICLN: β_{MKT} 1.29 → 0.89 → 0.96; (ii) PHO: 1.15 → 0.96 → 0.94; (iii) FIW: 1.03 → 0.98 → 0.95.

Of mention, the sign pattern for the profitability factor is unchanged: RMW remains positive for PHO/FIW and negative for ICLNacross subsamples, reinforcing the interpretation that blue-economy constituents lean toward profitable, conservatively investing businesses, while clean energy retains a growth-oriented footprint.Finally, the pattern we see in sub-samples (pre-2015 vs. post-2015; high-volatility months) is directionally consistent with the banking-side incentives documented by Mirza et al. (2025): environments that reward climate-aligned lending and investment coincide with stronger, more stable exposures for blue assets.

Insert Table 6 here

4.5.3 Cross-ETF equality

Finally, we assess whether factor loadings differ across ETFs by stacking the time series and running a single pooled OLS with factor×ETF interactions (ICLN as the baseline). This is not a panel estimator; it is a convenience device to run Wald tests for equality while preserving the time-series nature of the data. Standard errors are HAC-robust.

Market-beta differences are statistically clear (Table 7): PHO vs ICLN $p \approx 1.5 \times 10^{-18}$, FIW vs ICLN $p \approx 8 \times 10^{-21}$, and a smaller but meaningful gap PHO vs FIW $p = 0.024$. In other words, the two blue ETFs are similar yet not identical, and both differ materially from ICLN. These tests corroborate the baseline per-ETF findings and avoid any implication that a firm-level panel is required for our setting.

Insert Table 7 here

5. Concluding Remarks

The relevance of the blue economy at present is beyond doubt and is the subject of study by numerous authors, especially because of its impact on the environment. The multitude of economic sectors that use marine resources generates great concern for their impact on the oceans and hence the need for a framework for sustainable development action to preserve them, in line with SDG 14, 'Life below water'. The fulfilment of this goal for the care of the oceans in the 2030 agenda has attracted attention and facilitated the provision of large amounts of funding from governments and multilateral institutions.

However, the huge estimated financial gap makes it necessary to search for innovative financial instruments and mechanisms to promote private sector participation in profitable activities and to identify activities that achieve financial viability with public support.

Meanwhile, the great interest generated has allowed the channelling of sustainable investments to various sectors such as transport, energy, water treatment, etc., as well as sustainable aquaculture activities, constitute financial investment opportunities through innovative instruments such as ETFs listed on financial markets.

This study shows how blue economy stocks may be profitable and at the same time contribute with a robust sustainable development, adhering SDG 14. Hence, this proves that private capital is contributing to narrowing the financial gap of the 2030 agenda to protect the oceans and reduce the climate change risks, through financially viable projects resulting from the adoption of technologies that improve water treatment and clean energy.

In this paper we have analyzed ETFs that are representative of the so-called blue economy, mainly based on natural resources and more specifically on the water sector, and compared them with another sustainable economy sector, based on securities representing renewable energies. A global benchmark representative of market performance has been used to assess mainly their financial performance and volatility. Thus, this paper contributes to fill the gaps identified earlier in the literature review on the topic of financing, profitability and financial performance of blue economy companies.

For this assessment the CAMP and Fama-French, both the three and five factors, models have been used. Market (MKT), Size (SMB), Value (HML), Profitability (RMW), and Investment (CMA) factors have been considered, as well as diverse specification and test indicators has been applied to validate the consistency of the model and its significance.

The result may be summarized in the following points:

i. The market factor (MKT) is a crucial element in all three examined ETFs and its market betas exhibit a heightened responsiveness to overall market volatility. The clean energy ETF beta is higher than the blue economy investments, implying that the former is more volatile.
ii. The size factor (SMB) is significantly positive for all three ETFs, which have a pronounced bias towards small-cap equities, a characteristic typical of most ETFs.
iii. The HML factor is strongly positive and statistically significant in both blue economy ETFs, whereas it is relatively small and negative in the clean energy, i.e., implying a bias towards value-oriented companies in the water sector and growth-oriented companies in the clean energy sector.
iv. The RMW and CMA factors display positive and statistically significant relationships, albeit with a slight decrease in their significance due to increased robust standard error values. The data indicates that blue economy companies

generally experience higher profitability and adhere to more conservative investment strategies.

The reliability of these results highlights the credibility of the factor model framework in describing the risk-return characteristics of blue economy and clean energy portfolios. Consequently, the findings show that blue investments are less prone to fluctuations and more lucrative than clean energy investments, show a preference for value-oriented firms and followmore conservative investment strategies, which aligns with the four hypotheses presented in this study.

Current ETF evidence and the bank-level results of Mirza et al. (2025) point to a coherent transmission: when banks price blue/green lending as lower risk and better spread, listed blue firms' cost of capital falls, and portfolios built on water infrastructure and services can sustain value- and profitability-tilted payoffs without the volatility penalties observed in parts of clean energy.

At the same time, the emerging-market equity evidence of Rahat and Nguyen (2022) that "green beats black" on standard risk-adjusted metrics complements our finding that blue outperforms clean energy on stability: both sets of results are consistent with markets increasingly rewarding climate-aligned cash-flows. Our comparison of blue and clean energy serves as a natural more detailed extension of the study conducted by Rahat and Nguyen (2022). While their research established the overall superiority of sustainable investments, our analysis offers a refined, firm specific comparison providing greater insights into which specific types of sustainable energy investments, blue or clean, may yield better risk adjusted performance in a modern portfolio context.

These conclusions have important implications for various stakeholders, including banks, portfolio managers, investors and policymakers. For banks, these findings suggest that lending to blue economy firms may be less risky than financing clean energy and other traditional firms, which should encourage easier financing of blue economy activities.

These results are quite relevant for portfolio manager to select the investment in accordance with their guidelines and policies but also are of key interest for security analysts and investors concerns to align a risk-return combination with a concern with a sustainable development and ocean preservation. At the same time, risk-adverse investors may prefer blue economy stocks which are appropriate for more stable and conservative strategies. Furthermore, these findings are particularly useful for policymakers in developing policies, action plans, and financial tools to encourage sustainable investments within the blue economy sector.

The work developed in this research is an interesting contribution to the sectoral comparison of sustainable development. However, future lines of research could emerge from linking the blue factor to asset pricing models and conducting comparative analyses between various industries included as part of the sustainable finance approach.

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Appendix

1. Data sample

This study examines three exchange-traded funds (ETFs), conceptualized here as representative portfolios, to explore the factor characteristics of assets linked to sustainability and the blue economy, with a focus on water resources and clean energy. Two of the ETFs, referred to as the "U.S. Blue Economy Portfolio" (Invesco Water Resources ETF, PHO) and the "Global Blue Economy Portfolio" (First Trust Water ETF, FIW), are directly tied to the blue economy, covering significant and diverse aspects of its scope.

ETF price data is obtained via the getSymbols() function from the {quantmod} package, ensuring efficient access to historical price series from Yahoo Finance. This approach ensures efficient, reproducible, and high-frequency access to comprehensive market data for the three ETFs under study.

PHO, launched in 2005, is a carefully curated portfolio of U.S.-based companies involved in water utilities, purification technologies, and infrastructure—industries critical to addressing water scarcity and advancing sustainable resource management. The fund typically invests at least 90% of its total assets in securities that make up the underlying index, which may comprise common stocks, ordinary shares, American Depositary Receipts ("ADRs"), shares of beneficial interest and tracking stocks. The underlying index aims to mimic the performance of firms that develop products intended for conserving and purifying water for residential, commercial, and industrial use.

FIW, established in 2007, represents a globally diversified portfolio encompassing firms engaged in potable water supply, wastewater treatment, and water-related equipment manufacturing. Together, these ETFs offer comprehensive coverage of industries at the core of the blue economy, reflecting both sectoral depth and geographical diversity, with PHO focusing on the U.S. market and FIW capturing global opportunities in water sustainability. The fund normally invest at least 90% of its net assets in the securities that comprise the index, which is designed to track the performance of small, mid and large capitalization companies, specifically those with significant revenue derived from the potable water and wastewater sector, as stated by Clean Edge.

The third ETF, the "Global Clean Energy Portfolio" (iShares Global Clean Energy ETF, ICLN), launched in 2008, serves as a benchmark for broader sustainability themes. It includes a portfolio of companies focused on renewable energy sectors such as solar, wind, and hydroelectric power. While ICLN is not directly tied to the blue economy, its inclusion allows for a comparative analysis, helping to identify unique factor loadings and performance characteristics of blue economy assets relative to the broader sustainable finance landscape. The index is intended to monitor the performance of roughly 100 companies involved in clean energy. The fund typically allocates at least 80% of its assets to the underlying securities of the index, as well as to investments with economic attributes that are significantly similar. It may also invest up to 20% of its assets in futures, options, and swap agreements, cash, and cash substitutes, as well as securities not represented in the index.

It is important to highlight the participation of the sectors in each of the ETFs (see Table A1). While the blue economy ETFs based on natural resources have the largest weighting in the industrial sector, followed by utilities, technology and healthcare, in the renewable energy ETF the largest weighting is in the utilities sector, whose performance has been worse, especially since 2021. When compared to the benchmark, it shows how the benchmark has a major technology component, with a large weighting of the Healthcare, Financial Services, Consumer Cyclical, Communication Services, lower weighting of Industrials and Consumer Defensive sectors, and especially a very low weighting of the energy and utilities sectors. It is also to be noticed how the top ten holdings in each ETL, represents the 57,3%, 39,6% of Total Assets for the Blue economy ETL, PHO and FIW, respectively; 49,0% for the clean energy ETL (ICLN) and only 37.2% of Total assets in the case of SPY, suggesting a lower business concentration in this last one, according to Yahoo finance database.

Table A1. ETF sectoral weighting

SPDR S&P 500 ETF Trust (SPY)		**Global Clean Energy Portfolio (ICLN)**		**U.S. Blue Economy Portfolio (PHO)**		**Global Blue Economy Portfolio (FIW)**	
Technology	33.72%	Utilities	62.08%	Industrials	65.04%	Industrials	54.43%
Financial Services	13.16%	Technology	21.83%	Technology	12.63%	Utilities	15.89%
Consumer Cyclical	11.42%	Industrials	15.22%	Utilities	9.95%	Healthcare	12.06%
Healthcare	10.10%	Basic Materials	0.87%	Basic Materials	8.19%	Technology	9.45%
Communication Services	9.37%			Healthcare	4.19%	Basic Materials	5.17%
Industrials	7.26%					Consumer Defensive	3.00%
Consumer Defensive	5.52%						
Energy	3.16%						
Utilities	2.51%						
Real Estate	2.10%						
Total	**100%**	Total	**100%**	Total	**100%**	Total	**100%**

Source: Yahoo finance (extracted 04-Feb-25)

The factor data is imported into R from the original Fama-French dataset using structured data parsing (read.csv()), ensuring consistency with academic asset pricing methodologies. This structured approach allows for a robust empirical analysis of the risk-return drivers underlying blue economy and clean energy ETFs, facilitating comparisons with traditional asset pricing theories.

2. Price and return evolution, correlations and descriptive statistics

The price evolution chart (Figure A1) illustrates the historical performance of the four ETFs: the U.S. Blue Economy Portfolio (PHO), the Global Blue Economy Portfolio (FIW), the Global Clean Energy Portfolio (ICLN), and the broad-market benchmark (SPY). Over the observed period (2008–2024), SPY exhibits a strong and persistent upward trend, with notable corrections during major market disruptions, such as the 2008 financial crisis and the 2020 COVID-19 downturn. The post-2020 period is marked by a sharp rebound, aligning with monetary easing and fiscal stimulus measures that fueled a broad market recovery.

The U.S. and Global Blue Economy Portfolios demonstrate stable, long-term appreciation, albeit at lower absolute price levels compared to SPY. Their steady growth suggests increasing investor interest in water infrastructure and resource management, driven by policy initiatives, rising water scarcity concerns, and advancements in purification technologies. The global blue economy portfolio appears to have outperformed its U.S. counterpart over certain periods, possibly due to greater international diversification and exposure to emerging markets benefiting from water sustainability investments.

The Global Clean Energy Portfolio follows a more volatile trajectory, with significant upward momentum during 2020–2021, coinciding with renewable energy policy shifts, heightened ESG investing, and global commitments to carbon neutrality. However, its subsequent decline reflects the sector's exposure to policy risks, changing investor sentiment, and fluctuations in energy-related commodity prices.

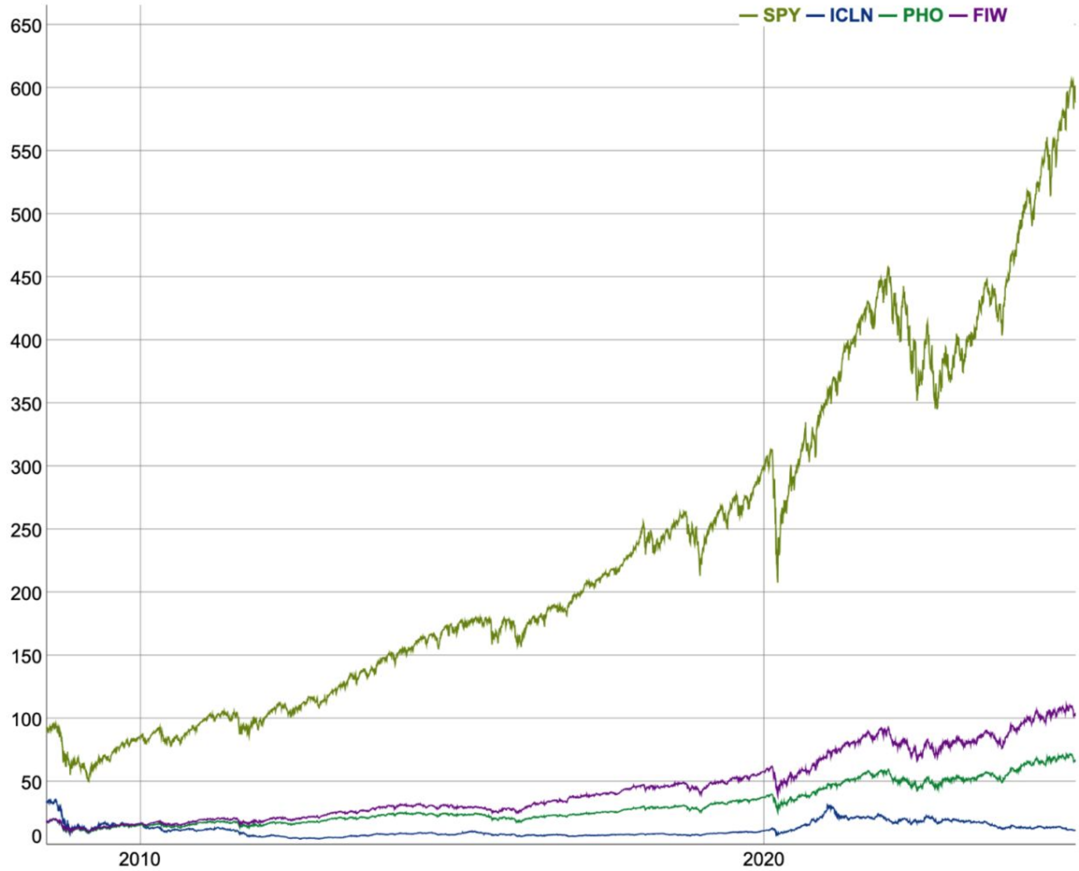

Figure A1. Price Evolution of Blue Economy and Clean Energy Portfolios (2008-2024); Authors' representation in R software, {dygraphs} package.

The daily return series (Figure A2) highlights distinct volatility characteristics among the ETFs, revealing both systemic market movements and asset-specific fluctuations. The 2008–2009 period exhibits extreme volatility, reflecting the impact of the Global Financial Crisis, with large positive and negative return spikes across all assets. Similarly, early 2020 shows a sharp increase in return variability, coinciding with the COVID-19 market crash, where financial markets experienced unprecedented drawdowns and rapid rebounds.

Throughout the observed period, SPY exhibits relatively lower volatility compared to the sectoral ETFs, reinforcing the expectation that a broad-market index has greater diversification and lower idiosyncratic risk. In contrast, the Global Clean Energy Portfolio (ICLN) appears to experience more pronounced return fluctuations, particularly during 2020–2021, aligning with heightened investor interest in renewables and policy-driven capital flows. The blue economy portfolios (PHO and FIW) demonstrate more stable return patterns, though they remain influenced by broader market cycles.

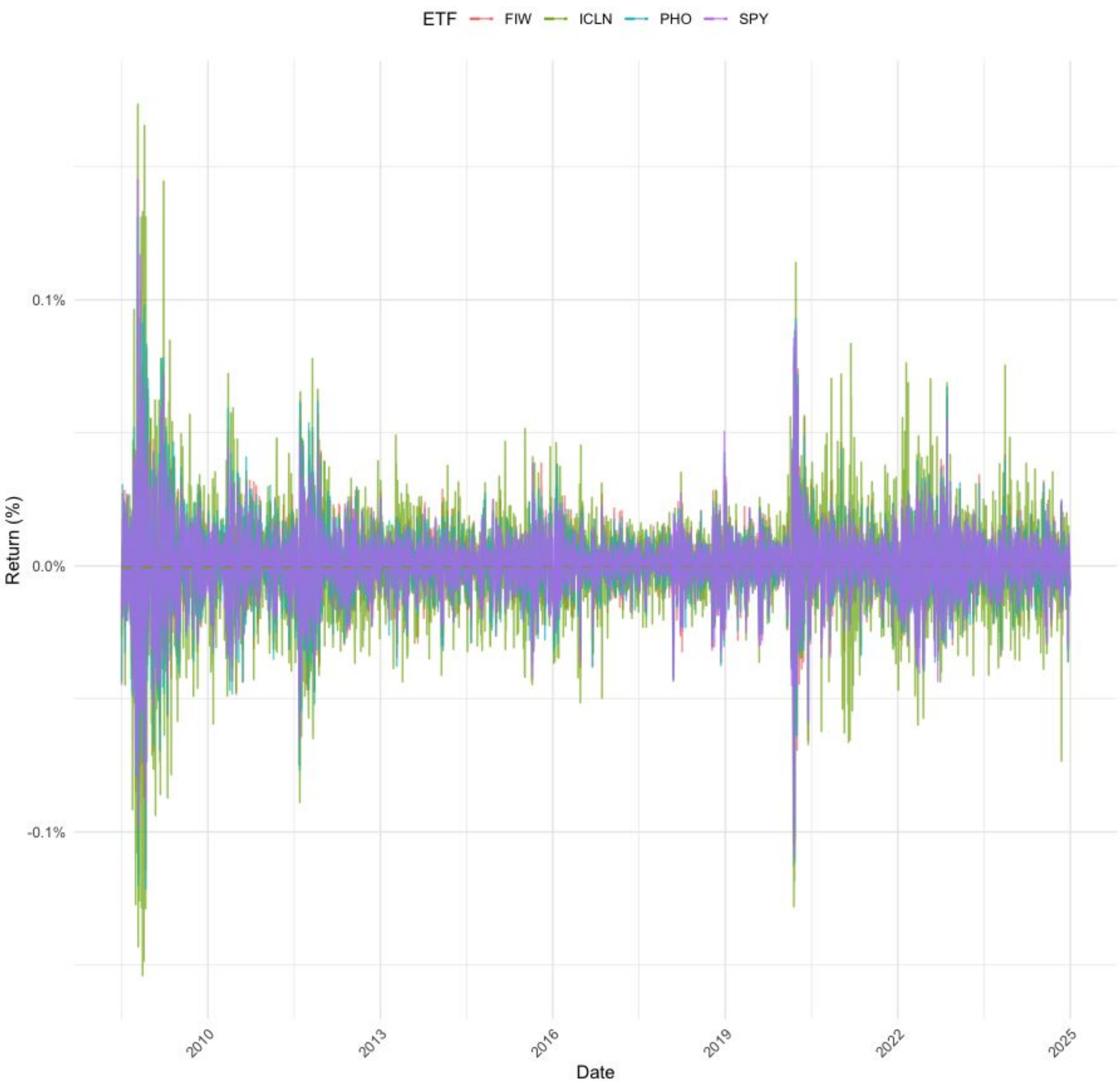

Figure A2. Daily Returns of Blue Economy and Clean Energy Portfolios (2008-2014); Authors' representation in R software, {ggplot2} package.

The correlation matrix in Figure A3 further highlights the interdependencies between the four ETFs' returns, revealing strong positive correlations, particularly between the U.S. and Global Blue Economy Portfolios (ρ = 0.96), and between SPY and the U.S. blue economy portfolio (ρ = 0.90). These high correlations suggest that despite sector-specific drivers, blue economy investments remain closely tied to broader equity market movements. The strong correlation between the blue economy portfolios underscores their shared exposure to water infrastructure, purification technologies, and sustainability-driven investment trends. While the global blue economy portfolio offers greater geographic diversification, its performance remains highly synchronized with its U.S. counterpart, suggesting that macroeconomic and industry-wide factors play a dominant role in driving returns. The global clean energy portfolio exhibits a slightly weaker correlation with the other assets ($\rho \approx 0.72$), implying that clean energy investments have a degree of sectoral independence. This aligns with expectations, given that the renewable energy sector is subject to unique regulatory, technological, and market forces that do not necessarily impact traditional infrastructure and water-related investments.

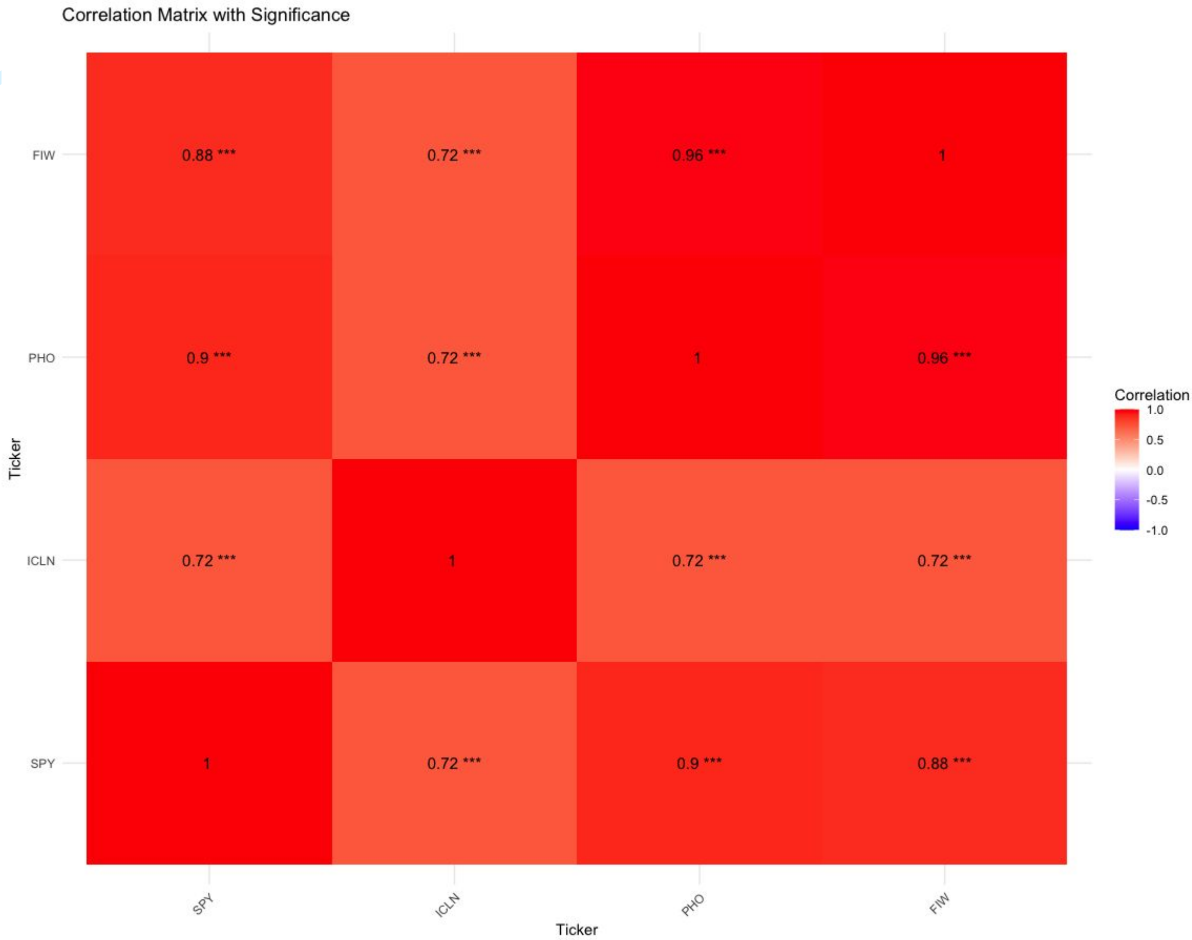

Figure A3. Correlation Matrix of Blue Economy and Clean Energy Portfolios; Authors' representation in R software, {Hmisc} package; *The heatmap displays correlation coefficients, with statistical significance denoted by asterisks (*** p < 0.001, ** p < 0.01, * p < 0.05).

The return distributions of the U.S. and Global Blue Economy Portfolios (PHO, FIW), the Global Clean Energy Portfolio (ICLN), and the broad-market benchmark (SPY) reveal distinct risk-return profiles, as per Table A2.

The mean returns indicate that while SPY, PHO, and FIW exhibit positive average daily returns, ICLN demonstrates a marginally negative mean return (-0.0001), highlighting the sector's inherent volatility and policy sensitivity. Of note, median returns for all ETFs remain close to zero; however, FIW (0.0010) exhibits a slightly higher central tendency compared to ICLN (0.0000), suggesting that while most daily price movements cluster around zero, FIW demonstrates a marginally stronger upward bias. The standard deviation of returns underscores significant differences in volatility, with ICLN (0.0208) displaying the highest risk profile, followed by PHO (0.0151) and FIW (0.0146), while SPY exhibits the lowest volatility (0.0126). This confirms that clean energy investments are more susceptible to large price fluctuations, whereas blue economy ETFs offer a relatively stable return profile. The presence of negative skewness across all ETFs suggests a greater frequency of extreme negative returns, with FIW (-0.4274) exhibiting the highest downside risk potential. Additionally, excess kurtosis (all > 8) indicates fatter tails compared to a normal distribution, implying an elevated likelihood of extreme return events, particularly for SPY (14.66) and ICLN (10.12). From an investment perspective, these findings suggest that the blue economy portfolios provide a balanced risk-return trade-off, while ICLN's elevated volatility and tail risk may necessitate more active risk management. The strong presence of kurtosis across all assets further emphasizes the need for diversification strategies to mitigate tail risk exposure in sustainability-themed investments.

Table A2. Descriptive statistics (2008 -2024)

Statistic	SPY	ICLN	PHO	FIW
Observations	4152	4152	4152	4152
NAs	0	0	0	0
Minimum	-0.1094	-0.1540	-0.1215	-0.1156
Quartile 1	-0.0040	-0.0093	-0.0063	-0.0063
Median	0.0007	0.0000	0.0007	0.0010
Arithmetic Mean	0.0005	-0.0001	0.0004	0.0005
Geometric Mean	0.0004	-0.0003	0.0003	0.0004
Quartile 3	0.0060	0.0099	0.0075	0.0076
Maximum	0.1452	0.1735	0.1311	0.0999
SE Mean	0.0002	0.0003	0.0002	0.0002
LCL Mean (0.95)	0.0001	-0.0007	0.0000	0.0001
UCL Mean (0.95)	0.0009	0.0006	0.0009	0.0010
Variance	0.0002	0.0004	0.0002	0.0002
Standard Deviation	0.0126	0.0208	0.0151	0.0146
Skewness	-0.0822	-0.1753	-0.1424	-0.4274
Kurtosis	14.6574	10.1184	9.2955	8.0184

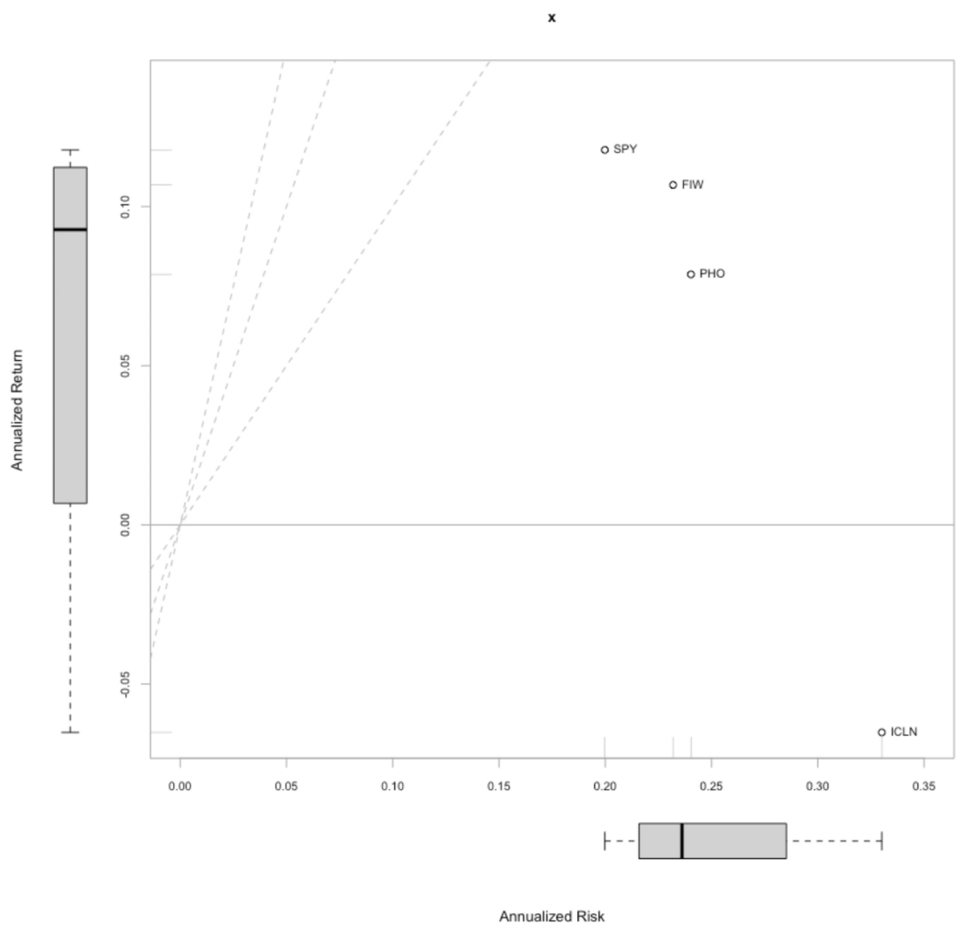

Figure 1. Risk-Return Trade-Off for Blue Economy and Clean Energy Portfolios (2008 – 2024); Authors' representation in R software, {PerformanceAnalytics} package. The x-axis represents annualized risk (standard deviation of returns), while the y-axis denotes annualized return. The boxplots illustrate the dispersion of risk and return across the ETFs.

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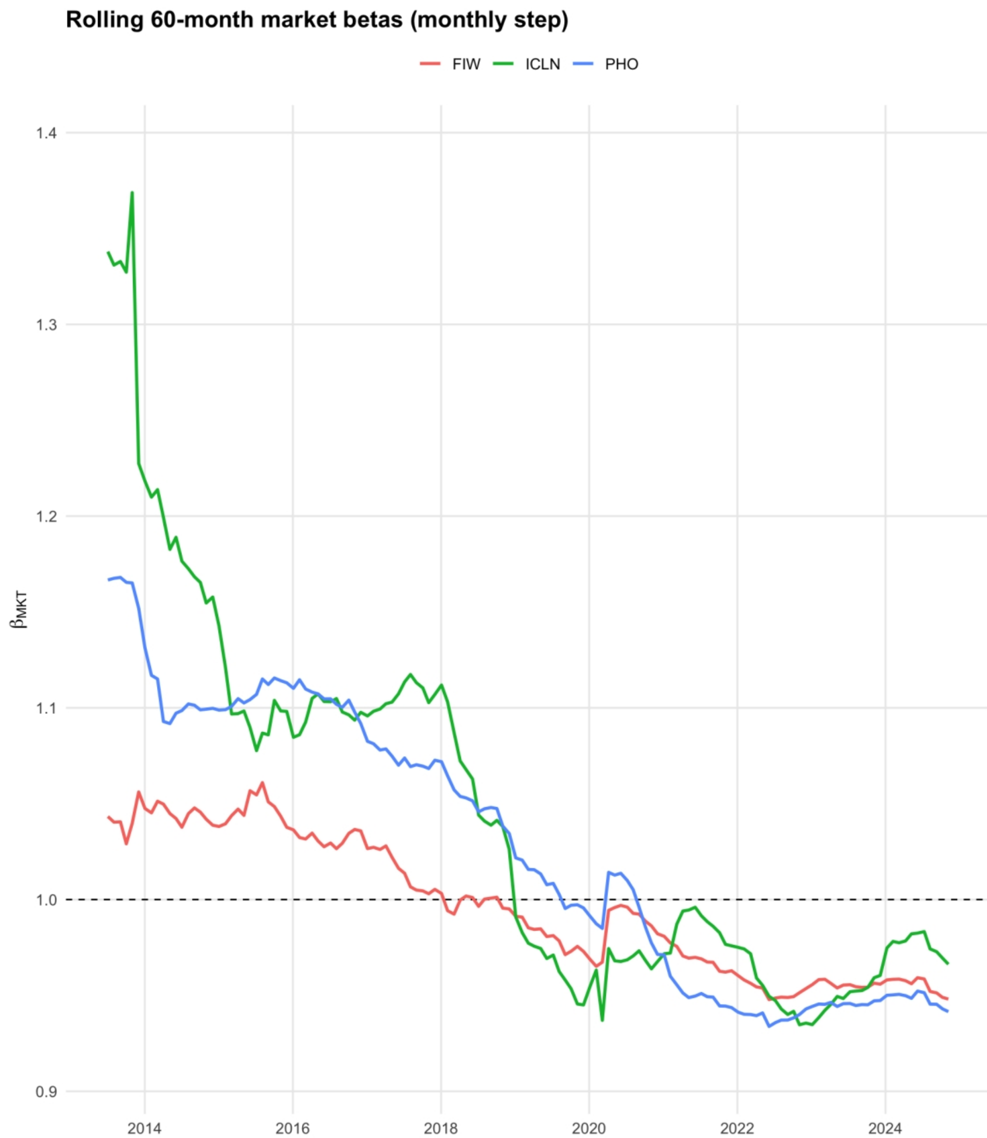

Figure 2. Rolling 60-month FF5 market betas (β□□□), monthly step, PHO–FIW–ICLN, 2008–2024. Source: Authors' own work in R software, {PerformanceAnalytics} package

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Table 1. ETF Overview

ETF Overview	**SPDR S&P 500 ETF Trust (SPY)**	**iShares Global Clean Energy Portfolio (ICLN)**	**U.S. Blue Economy Portfolio (PHO)**	**Global Blue Economy Portfolio (FIW)**
Category	Large Blend	Miscellaneous Sector	Natural Resources	Natural Resources
Fund Family	SPDR State Street Global Advisors	iShares	Invesco	First Trust
Net Assets	623.8B	1.42B	2.13B	1.78B
YTD Daily Total Return	3.73%	-1.85%	2.98%	3.15%
Yield	1.21%	1.84%	0.45%	0.69%
Legal Type	Exchange Traded Fund	Exchange Traded Fund	Exchange Traded Fund	Exchange Traded Fund
NAV	608.04	11.18	67.78	105.30
PE Ratio (TTM)	27.86	14.40	26.63	28.69
Beta (5Y Monthly)	1.00	1.21	1.16	1.19
Expense Ratio (net)	0.09%	0.41%	0.60%	0.53%

Source: Yahoo Finance (extracted 04-Feb-25)

Table 2. Downside Risk Metrics of Blue Economy and Clean Energy Portfolios (2008-2024)

Statistic	SPY	ICLN	PHO	FIW
Semi Deviation	0.0092	0.0150	0.0109	0.0107
Gain Deviation	0.0091	0.0151	0.0109	0.0100
Loss Deviation	0.0104	0.0161	0.0117	0.0115
Downside Deviation (0%)	0.0089	0.0150	0.0107	0.0104
Maximum Drawdown	0.4717	0.8661	0.5506	0.5192
Historical VaR (95%)	-0.0185	-0.0301	-0.0217	-0.0212
Historical ES (95%)	-0.0309	-0.0496	-0.0365	-0.0349
Modified VaR* (95%)	-0.0167	-0.0310	-0.0223	-0.0229
Modified ES* (95%)	-0.0167	-0.0480	-0.0350	-0.0448

* Modified Value at Risk (VaR) and Expected Shortfall (ES) at the 95% confidence level account for the skewness and excess kurtosis of the return distributions, providing a more accurate risk estimate for assets exhibiting non-normal return behavior. Unlike historical VaR and ES, which assume past return distributions adequately represent future risk, modified VaR and ES incorporate higher-order moments, making them particularly relevant for assets with fat-tailed distributions, such as blue economy and clean energy investments.

Table 3. Regression Results for One-Factor, Three-Factor, and Five-Factor Models

Asset	**Model**	**Intercept**	**MKT**	**SMB**	**HML**	**RMW**	**CMA**
ICLN	CAPM	**-0.0846 (0.0219)***, p = 0.0001	**1.200 (0.0171)***, p = 0.000	—	—	—	—
ICLN	FF3	**-0.0834 (0.0217)***, p = 0.0001	**1.173 (0.0175)***, p = 0.000	**0.315 (0.0338)***, p = 0.000	**-0.051 (0.0257)**, p = 0.048	—	—
ICLN	FF5	**-0.0735 (0.0214)***, p = 0.0006	**1.118 (0.0187)***, p = 0.000	**0.213 (0.0347)***, p = 0.000	-0.0034 (0.0296), p = 0.908	**-0.525 (0.0491)***, p = 0.000	-0.030 (0.0633), p = 0.633
PHO	CAPM	**-0.0207 (0.0100)**, p = 0.039	**1.070 (0.0078)***, p = 0.000	—	—	—	—
PHO	FF3	*-0.0181 (0.0093)*, p = 0.051	**1.022 (0.0075)***, p = 0.000	**0.334 (0.0144)***, p = 0.000	**0.083 (0.0110)***, p = 0.000	—	—
PHO	FF5	**-0.0231 (0.0091)**, p = 0.011	**1.058 (0.0080)***, p = 0.000	**0.372 (0.0147)***, p = 0.000	0.023 (0.0126), p = 0.068	**0.184 (0.0209)***, p = 0.000	**0.191 (0.0269)***, p = 0.000
FIW	CAPM	-0.0083 (0.0102), p = 0.417	**1.020 (0.0079)***, p = 0.000	—	—	—	—
FIW	FF3	-0.0051 (0.0090), p = 0.568	**0.961 (0.0072)***, p = 0.000	**0.431 (0.0140)***, p = 0.000	**0.091 (0.0106)***, p = 0.000	—	—
FIW	FF5	-0.0102 (0.0088), p = 0.247	**0.997 (0.0077)***, p = 0.000	**0.473 (0.0143)***, p = 0.000	**0.033 (0.0122)**, p = 0.006	**0.199 (0.0202)***, p = 0.000	**0.177 (0.0261)***, p = 0.000

* Standard errors are provided in parentheses;
** Significance levels: ***p < 0.01, **p < 0.05, p < 0.1)

Table 4. Regression Results for One-Factor, Three-Factor, and Five-Factor Models with Robust Standard Errors

Asset	Model	Intercept	MKT	SMB	HML	RMW	CMA
ICLN	**CAPM**	-0.0846 (0.0220)***, p = 0.0001	1.204 (0.0329)***, p = 0.000	—	—	—	—
	FF3	-0.0834 (0.0219)***, p = 0.0001	1.173 (0.0343)***, p = 0.000	0.315 (0.0564)***, p = 0.000	-0.051 (0.0399), p = 0.203	—	—
	FF5	-0.0735 (0.0216)***, p = 0.0007	1.118 (0.0349)***, p = 0.000	0.213 (0.0559)***, p = 0.000	-0.0034 (0.0514), p = 0.947	-0.525 (0.0622)***, p = 0.000	-0.030 (0.0943), p = 0.748
PHO	**CAPM**	-0.0207 (0.0101)**, p = 0.0407	1.071 (0.0138)***, p = 0.000	—	—	—	—
	FF3	-0.0181 (0.0094), p = 0.0535	1.022 (0.0140)***, p = 0.000	0.334 (0.0239)***, p = 0.000	0.083 (0.0176)***, p = 0.000	—	—
	FF5	-0.0231 (0.0093)**, p = 0.0132	1.058 (0.0148)***, p = 0.000	0.372 (0.0247)***, p = 0.000	0.023 (0.0220), p = 0.297	0.184 (0.0291)***, p = 0.000	0.191 (0.0403)***, p = 0.000
FIW	**CAPM**	-0.0083 (0.0103), p = 0.421	1.023 (0.0149)***, p = 0.000	—	—	—	—
	FF3	-0.0051 (0.0091), p = 0.574	0.961 (0.0137)***, p = 0.000	0.431 (0.0235)***, p = 0.000	0.091 (0.0154)***, p = 0.000	—	—
	FF5	-0.0102 (0.0090), p = 0.255	0.997 (0.0144)***, p = 0.000	0.473 (0.0245)***, p = 0.000	0.033 (0.0188)*, p = 0.077	0.199 (0.0250)***, p = 0.000	0.177 (0.0377)***, p = 0.000

* Heteroskedasticity-consistent (HC) robust standard errors are provided in parentheses. These standard errors account for potential heteroskedasticity in the residuals, ensuring more reliable statistical inference;
** Significance levels: ***p < 0.01, **p < 0.05, p < 0.1)

Table 5. Model Fit Diagnostics for CAPM, Fama-French 3-Factor, and Fama-French 5-Factor Models

Asset	Model	Adjusted R^2	AIC	BIC
FIW	CAPM	0.802	8221.0	8240.0
FIW	FF3	0.845	7193.0	7225.0
FIW	FF5	0.851	7038.0	7082.0
ICLN	CAPM	0.546	14563.0	14582.0
ICLN	FF3	0.555	14481.0	14513.0
ICLN	FF5	0.568	14369.0	14414.0
PHO	CAPM	0.821	8072.0	8091.0
PHO	FF3	0.847	7439.0	7471.0
PHO	FF5	0.852	7300.0	7344.0

Table 6. Subsample FF5 (HAC) estimates of market beta (β□□□) by ETF

ETF	2008–2015 β□□□	2016–2019 β□□□	2020–2024 β□□□
PHO	1.15	0.96	0.94
FIW	1.03	0.98	0.95
ICLN	1.29	0.89	0.96

Notes: Coefficients from per-ETF FF5 time-series regressions with HAC (Newey–West) standard errors; daily excess returns. Values shown are point estimates for β□□□ (rounded). Other factor loadings available on request and do not alter the conclusions.

Table 7. Pooled interaction OLS (HAC): Wald tests of equality in β□□□ across ETFs

Null hypothesis (β□□□)	**p-value**	**Decision (5%)**
PHO = ICLN	**$\approx 1.5 \times 10^{-18}$**	Reject equality
FIW = ICLN	**$\approx 8.0 \times 10^{-21}$**	Reject equality
PHO = FIW	**0.024**	Reject equality

Model: Time-series stacked across ETFs; single OLS with factor×ETF interactions (ICLN baseline); HAC (Newey–West) inference. Tests reported for the market factor; analogous tests for SMB/RMW/HML/CMA available on request.