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The Impact of ESG Ratings on Investment Decisions in the Energy Sector During Uncertain Times

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Abstract

With increasing global awareness of sustainability, the financial sector must inevitably adapt. Our research investigates the role of Environmental, Social, and Governance (ESG) ratings in investment decision-making, particularly in the energy sector, by examining their impact on portfolio performance. The study aims to assess the impact of ESG integration on portfolio risk and returns. Using data from the SP500 index, econometric models and Monte Carlo simulations are employed to evaluate how ESG considerations influence portfolio optimization and risk management. The study reveals that integrating ESG criteria into investment strategies, especially during market volatility, may not always directly affect returns, they provide significant benefits in terms of risk mitigation and ethical investment alignment.

Keywords: ESG, Financial Crisis, Investment Decision, Energy Sector, Portfolio Risk

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Introduction

"History teaches us that, over the centuries, there has always been something new for every generation. From the industrial revolution a few centuries ago, to aviation in the early 19th century, to the internet (and e-commerce) in the 80s and 90s and, more recently, social media, facilitated by massive access to connectivity and innovation. And now comes the ESG. Like all these great things, they respond to a particular challenge of the time or to anticipated future problems in society (...) Any company or government that wishes to be relevant in the medium or long term cannot ignore [the preferences or opinions of today's millennials and post-millennials, who make up tomorrow's electorate and customers]"[1].

The social and environmental dimension of business is at the heart of new economic and financial guidelines. Faced with the challenges of international regulation, compliance standards linked to international investment directives have been tightened, and governance has become a key indicator for assessing investment compliance and performance. It is against this backdrop that ESG criteria, "developed by the financial community to designate criteria of interest to environmental, social and governance aspects (independence of the board of directors, management structure and presence of an audit committee)", have taken their place as essential elements of extrafinancial analysis.

Based on the United Nations Framework Conventions and the Sustainable Development Goals (SDGs), ESG criteria are essential indicators. These criteria oblige companies to report on non- financial factors influencing their performance, future cash flows and any associated risks. As a result, 57% of financial advisors believe that adopting these criteria offers an additional dimension of risk management for their client's investments.

In the current context, the indicators adopted are evolving in parallel with contemporary dynamics. These dynamics, shaped by global issues, require the development of mechanisms that are both anticipatory and forward-looking. These tools must also provide flexible assessments in response to changing concerns. For example, terrorist threats are altering companies' procurement patterns, while meeting contractual obligations to their employees. In addition, the Covid-19 pandemic underlined the imperative of developing effective resilience strategies, demonstrating the need for industries and investors to adjust in the face of potential crises. This reality underscores the importance of government bodies in establishing regulatory frameworks that guarantee the rigorous application of these indicators.

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[1] PWC, "ESG - The great next challenge of our generation. Africa cannot afford to be left behind", available at: https://afrique.pwc.com/fr/actualites/decryptages/esg-afrique.html

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In this context, the energy sector is an ideal field for analysis. The need for a thorough understanding of the parameters central to this study will guarantee results that are both relevant and adaptive.

- What impact have the recent Russian-Ukrainian tensions and the COVID-19 pandemic had on the implementation of ESG ratings for companies in the energy sector?
- Is it worth sticking to these ratings in times of uncertainty?
- What is the measured impact of including or not including ESG ratings in investment decisions?

To answer these questions, we begin with the context surrounding ESG by exploring the literature on ESG. This will be followed by a discussion of the theoretical underpinnings, before presenting the methodological framework. In particular, we will detail the data studied in relation to the questions posed. The last two points will focus on the analysis of our study and its possible constraints, paving the way for recommendations for future studies.

1. The ESG context: conceptual approach, history and current situation

1.1. The ESG concept

Assessing sustainability poses complex challenges, leading to the emergence of multiple theories and concepts. Sustainable investments, which seek to combine long-term financial returns with positive impacts, are a case in point. The acronym ESG refers to environmental, social and governance criteria, serving as an analytical tool to measure how a company integrates sustainable development and anticipates future challenges.

1.2. The emergence of SRI and ESG and their gradual mainstreaming

As understanding of sustainability and ESG issues has evolved, the terminology used has diversified, sometimes creating ambiguities among financial players, fund managers, and researchers. Several terms, such as "socially responsible investment" (SRI), "impact investment," "green investment," and "ESG investment," refer to this approach (Schueth, 2003).
The rise of sustainable investment has historical roots in religious convictions dating back to the 18th century. Religious groups, including Quakers, Methodists, and Muslims, established ethical guidelines for financial investments. In the 21st century, the sustainable investment approach continues to gain momentum.

Today, faced with growing demand from investors eager to combine social concerns with financial choices, there has been a proliferation of entities offering assessments based on ESG criteria. The field of ESG ratings is vast

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and diverse, comprising over 600 "products" from 150 organizations that provide ESG information (Hawley, 2017). These agencies enjoy considerable flexibility regarding their assessment criteria and methods, given the absence of uniform regulatory standards for the presentation and assessment of non-financial data (Chatterji et al., 2015). This leads to wide variations in ESG ratings from different sources (Berg et al., 2019), potentially creating uncertainty for investors.

1.3. ESG fund performance and investment growth

ESG funds face several challenges. Some investors prioritize financial performance over ecological considerations, putting these funds under pressure. Tensions in Ukraine, the impact of technology, inflation, and rising interest rates complicate the situation. In 2022, ESG funds fell by 18%, compared to a decline of 15.8% for non-ESG funds. Only 31% of ESG funds met their objectives in the first half of 2022, compared to 41% of non-ESG funds.

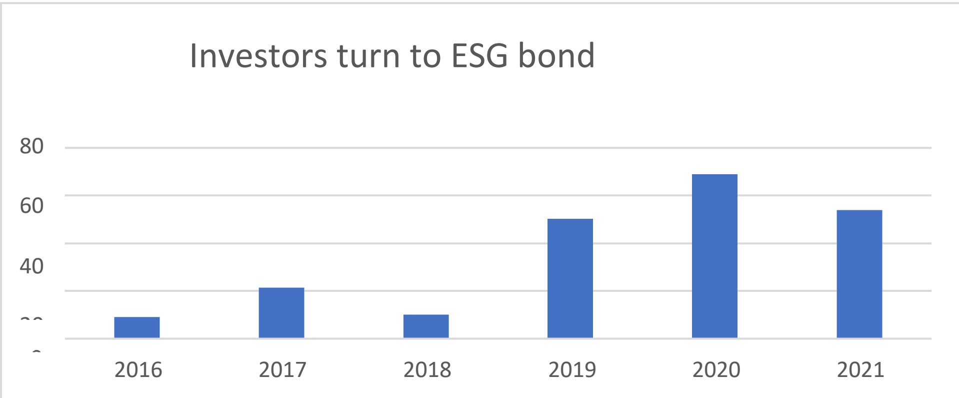

Figure 2: Investors invest in ESG funds
Source: Morningstar, 2022

Investor reactions to uncertainty and crises are nuanced and often depend on the type of investor. In fact, investor reactions are not uniform. While some seek security, others may view crises as buying opportunities.
As such, the rise of sustainable finance raises a fundamental question: is it a genuine commitment based on ethical principles, or simply a reaction to market trends? Recent events, such as the COVID-19 pandemic and the Russian-Ukrainian tensions, offer an opportunity to observe and analyze investor behavior. Will these crises reveal whether sustainable finance is a true conviction or merely a "fair-weather strategy"?

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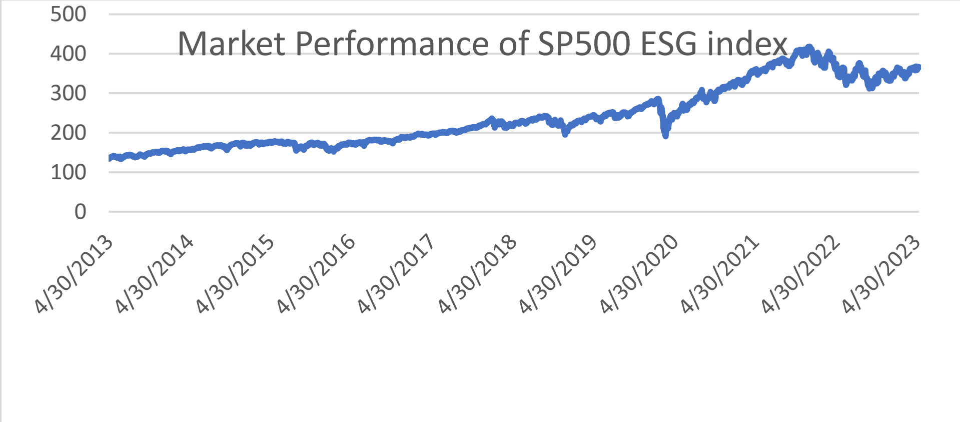

Figure 3: 10-year performance of the SP 500 ESG index
Source: SP 500 Global

2. Literature review

It should be noted that most of the literature on uncertainties focuses on the COVID-19 pandemic, while data on the Russian-Ukrainian war remains limited. For the sake of clarity and organization.

2.1. ESG investment during crisis (in particular COVID 19).

In their study, Díaz, Ibrushi, and Zhao (2021) analyzed daily data for companies listed on the U.S. stock market between January and April 2020. Regression models were used to assess how ESG ratings affected the returns of different sectors during the COVID-19 pandemic. The authors incorporated control variables, such as the Fama-French factors and an ESG factor, which measured the difference in returns between companies in the top and bottom quartiles based on their ESG ratings.

The analysis highlights the importance of ESG ratings in determining sector returns during the COVID-19 crisis. The ESG factor, reflecting the difference in ESG performance between companies in the top and bottom quartiles, was found to be significant. When integrated with the Fama-French variables, it becomes evident that ESG is a key determinant of sector performance (Díaz, Ibrushi, & Zhao, 2021). Furthermore, they examined each of the three ESG components individually: environmental, social, and governance. The results indicate that the environmental and social dimensions had the greatest impact on corporate performance (Díaz, Ibrushi, & Zhao, 2021).

The COVID-19 pandemic has heightened the importance of ESG investment strategies. The major trends identified in the literature suggest that the environmental and social aspects of ESG are driving the majority of current investment trends.

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During this period, ESG played a dominant role in industrial portfolio returns, as noted by Díaz, Ibrushi, and Zhao (2021).

Finally, they suggest that investors must integrate the specific E, S, and G rankings in addition to the overall ESG rankings when formulating their investment plans.

Other study by Broadstock, Chan, Cheng, and Wang (2020) conducted an event-driven analysis using data from companies listed on the CSI300 in China. Their findings indicate that portfolios with higher ESG (Environmental, Social, and Governance) ratings demonstrated greater resilience during crises compared to those with lower ESG ratings. Moreover, amid the COVID-19 pandemic, they identified a positive correlation between ESG performance and short-term cumulative returns, suggesting that companies with favorable ESG ratings may exhibit greater resilience to financial disruptions, potentially influencing future investment decisions.
The authors also examined the impact of ESG ratings specifically during the financial crisis triggered by the COVID-19 pandemic. Given this unprecedented context, their inquiry focused on whether investors perceived ESG scores as indicators of future stock performance or as risk-reduction mechanisms. Their analysis revealed that (i) portfolios with high ESG ratings tended to outperform those with low ratings, (ii) positive ESG ratings could help reduce financial risks during times of crisis, and (iii) the influence of ESG ratings was less pronounced in 'normal' times, underscoring their heightened importance during crises.

2.2. The impact of ESG investments on financial returns

Nevertheless, there is ongoing debate about the impact of ESG investments on portfolio performance. On one hand, studies such as Cortez et al. (2009) suggest that ESG integration could limit diversification and lead to opportunity costs. This view is based on the study by Merton (1987) who argues that ESG stocks, being less preferred, tend to have a lower price but higher expected returns.

Pedersen, Fitzgibbons, and Pomorski (2020), however, contend that although socially responsible stocks may offer lower returns, investors are willing to tolerate this because these stocks are more socially responsible. Pastor, Stambaugh, and Taylor (2019) add that high-ESG-impact stocks typically have a lower cost of capital and lower returns due to investor preference for socially responsible investments.

Conversely, some authors, including Pedersen, Fitzgibbons, and Pomorski (2020), argue that ESG stocks could outperform if excellent ESG performance is associated with future earnings not yet reflected in the market. They observe this trend particularly in the ESG governance dimension, where it predicts an increase in corporate earnings. Mnescu (2011) points out that

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investors often misjudge ESG-related costs, leading to inaccuracies in the valuation of these factors.

Ipso facto, other analysis reveals a divergence of opinions on the impact of ESG investments. Under these circumstances, it is crucial for investors to stay informed and adapt their strategies accordingly (Lina Nassar, 2022).

3. Methodology

This study will employ a combination of econometric modeling and Monte Carlo simulations to evaluate the integration of Environmental, Social, and Governance (ESG) criteria in portfolio optimization within the energy sector. Historical data from the S&P 500 index, including ESG ratings from Sustainalytics, will serve as the primary data source for the analysis. Additional consideration will be given to alternative ESG data providers such as MSCI, Bloomberg, and Dow Jones Sustainability, with Sustainalytics chosen based on its frequent use in empirical studies and the robustness of its scoring methodology.

The portfolios will be constructed using mean-variance optimization techniques derived from Modern Portfolio Theory, aiming to achieve an optimal risk-return balance along the efficient frontier. Key performance indicators such as expected returns, volatility, and the Sharpe ratio will be calculated to assess portfolio performance under various scenarios.

Monte Carlo simulations will be applied to evaluate portfolio performance across a range of market conditions, generating numerous random scenarios to account for uncertainties and market volatility. Different ESG scenarios—comprising portfolios with high, low, and mixed ESG risk levels—will be tested to analyze the impact of ESG integration on risk management and portfolio selection. Given the challenges associated with ESG data standardization and the variability in reporting across companies, the study will account for data inconsistencies and potential biases. Comparative analysis of ESG ratings from Sustainalytics with other data providers will also be considered to validate the findings.

Python programming will be utilized for statistical modeling, simulations, and visualizations, ensuring a rigorous examination of the trade-offs between risk, return, and ESG factors. This approach will allow for a comprehensive analysis of ESG integration, highlighting both the benefits and limitations of incorporating ESG criteria in portfolio optimization within the energy sector.

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4. Theoretical approaches

4.1. Mean-variance analysis

Harry Markowitz's conceptual theory outlines how to select securities to form an optimal portfolio, aiming for the highest return with the lowest risk, with a focus on diversification. To illustrate this theory, we concentrate on financial principles and the associated mathematical equations. For investors, portfolio optimization is crucial, as portfolios should not be substituted if another offers the same or better performance with less risk (Fama & MacBeth, 1973). Thus, risk and return are essential in investment decisions. In this regard, Markowitz emphasizes that, in certain situations, an investor's choices are centered on two pillars: expected return and the risk associated with the portfolio.

Mathematical formulation

$$E\,[Rp\,] = \sum_{k=0}^{n} W_k \times E[R_k\,]$$

Formula 1: Expected portfolio return
Where: W_k is the weight of asset k

$$Var\,[Rp\,] = \sum_{k=0}^{n} W_k \times Cov\,[R_k R_p]$$

Formula 2: Portfolio variance
Where: W_k is the weight of asset k
$Cov\,[R_k R_p]$is the covariance between the expected return on asset k and the expected return on the portfolio

Explaining the theory

There is a positive correlation between risk and return. The more risk an investor is willing to take, the higher the expected return. Conversely, a low level of risk is often associated with lower rewards. This relationship between risk and return is fundamental.

A rational investor aims to maximize return for a given level of risk, or to minimize risk while achieving a target return.

Diversification plays a central role in portfolio theory, particularly in risk management.

Portfolio selection

According to Markowitz, an investor should choose a portfolio that maximizes return for a specific level of risk, or minimizes risk for a defined level of return. However, several authors have developed more appropriate

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mathematical formulas to describe portfolio efficiency. Sharpe's ratio and Treynor's ratio are two important performance measures.

Sharpe ratio

In 1966, William F. Sharpe formulated the Sharpe ratio, which measures the risk-adjusted return on a financial portfolio (Sharpe, 1966). It measures the extra return an investor receives in exchange for the increased volatility incurred by holding riskier assets.

Mathematical formulation

$$SR = \frac{E(R_P) - R_f}{\sigma_p}$$

Formula 3: Sharpe ratio

Where $E(R_P)$expected portfolio return

R_f return on assets at risk-free rate

σ_p Portfolio standard deviation

Treynor ratio

The Jack L. Treynor ratio is used to assess risk, by establishing the risk-adjusted value of an investment and analyzing market volatility. This approach evaluates returns above those possible on a risk-free investment, for each unit of market risk. Like the Sharpe ratio, the Treynor ratio assesses the efficiency of the portfolio under review; a higher value indicates that the investor has generated high returns for each level of market risk assumed.

Mathematical formulation

$$TR = \frac{E(R_P - R_p)}{B_p}$$

Where

$E(R_P)$: Expected portfolio return

R_p: Return on risk-free assets

B_p: Portfolio beta

4.3. Regression methods

Econometric methods, including simple and multiple linear regression, are used to analyze relationships between variables. Simple linear regression examines the relationship between two variables, providing a straightforward model for prediction. In contrast, multiple linear regression accounts for several independent variables, offering a more comprehensive understanding of how various factors influence a dependent variable. These methods are

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essential for making informed decisions based on empirical data. The aim of simple (resp. multiple) regression is to explain a variable Y using a variable X (resp. several variables X1,..., Xq). The variable Y is called the dependent variable, or variable to be explained, and the variables Xj (j=1,..., q) are called the independent variables, or explanatory variables.

Simple linear regression

In statistics, simple linear regression is a model involving a single explanatory variable. It is represented by the equation $y_i = \beta_0 + \beta_1 x_i + \epsilon_i$, where y is the dependent variable, x is the independent variable, β0 is the intercept, β1 is the slope and ϵi is the error term. It is generally assumed that $E(\epsilon) = 0 \; and \; E(\epsilon x) = 0$.

The value β_1 measures the change in y in response to a one-unit change in x, and can be calculated as Δy/Δx.

The aim is to estimate the values β̂ 0 and β̂ 1 that give the best possible fit to the data. We also wish to test the statistical significance of the parameters, in particular β1, which quantifies the impact of x on y.

A common method for estimating simple linear regression is the least squares approach, which minimizes the sum of squares of the residuals. This translates into the equation min $\beta 0, \beta 1 \; \Sigma_i (y_i - \beta_0 - \beta_1 x_i)^2$.

Multiple linear regression

Normally, we can run a multiple linear regression (main variables + control variables) to control for the effect of confounding variables.

$$yi = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_{mxim} + \epsilon_i$$

There are m independent (explanatory) variables. We can also write multiple linear regression in matrix form (more compact and easier for further derivation). $Y = X\beta + \epsilon$

$$Y = X\beta + \epsilon$$

where $Y = [y_1 \; y_2 \; y_n]_{n\times 1}$, $X = [1 \; x_{11} \; x_{12} \; 1 \; \vdots \; x_{21} \; \vdots \; x_{22} \; \vdots \; 1 \; x_{n1} \; x_{n2} \; \ldots \ldots \; x_{1m} \; \ldots \; \vdots \; \ldots \; \vdots \; x_{2m} \; \vdots \; \ldots \ldots \; x_{nm}]_{n\times(m+1)}$

$$\beta = [\beta_0 \; \beta_1 \; \vdots \; \beta_m]_{(m+1)\times 1}, \quad \epsilon = [\epsilon_1 \; \epsilon_2 \; \vdots \; \epsilon_n]_{n\times 1}$$

$$\beta_j = \frac{\partial_y}{\partial_{xj}} \qquad \forall 1 \le j \le m$$

βj measures the change in y in response to a one-unit change in xj after controlling for other confounding factors (i.e. x_1, x_2,..., x_{j-1}, xj+1,..., xm).

We can also estimate the β matrix by minimizing the sum of squared errors. The minimization program is as follows.

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$$\epsilon = Y - X\beta$$
$$min_{\beta}\epsilon^T\epsilon = (Y - X\beta)^T(Y - X\beta)$$
$$= (Y^T - \beta^T X^T)(Y - X\beta)$$
$$= (Y^T Y - Y^T X\beta - \beta^T X^T Y + \beta^T X^T X\beta)$$
$$= (Y^T Y - 2Y^T X\beta + \beta^T X^T X\beta)$$

The last step is because $(Y^T X\beta)^T = \beta^T X^T Y$ and they are both 1×1 matrix (a scalar). Therefore $Y^T X\beta = \beta^T X^T Y$

Logistic regression

In logistic regression, the dependent variable (outcome variable) is binary (i.e. 1/0). In real life, many outcomes are binary, such as whether or not to invest, or whether the price will rise (or fall). In our case, we can analyze whether the company will have a high environmental risk or not.

$$E\ (Y\ |X\ =\ x)\ =\ X\beta$$
$$E\ (Y\ |X\ =\ x)\ =\ P\ (Y\ =\ 1|X\ =\ x)$$

However, this linear probability model (LPM) has certain drawbacks. The predicted probability $P\ (Y\ =\ 1|X\ =\ x)$ may be < 0 > or < 1 > if the new x is not in the estimation (learning) sample.

Impossible to model "diminishing returns - changing the probability p by the same proportion requires a greater change in x when p is already large (or small) than when p is close to ½.

Let Y* be a latent (unobserved) variable that is continuous Y* = Xβ + ϵ

4.4. Monte Carlo simulation

Monte Carlo simulations are a statistical technique that uses random sampling to model the probability of different outcomes in complex processes. By generating a large number of random inputs based on defined probability distributions, this method allows researchers to assess risks and forecast potential scenarios effectively. Here, we discuss the use of Monte Carlo methods to solve integration problems, while examining sampling techniques, convergence concepts and variance reduction strategies. To improve uniformity, the points of a quasi-random sequence are interconnected. This approach, known as quasi-Monte-Carlo quadrature, has a high convergence rate (Caflisch, 1998).

In our simulation, we calculate the efficient frontier of different portfolios. The aim is to determine the impact of various ESG variants on investment decisions; the risk-return trade-off is the primary factor influencing investment choices. For this reason, calculating the efficient frontier of each

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portfolio is crucial for understanding the real impact on investors' decision-making.

The efficient frontier

Portfolios that maximize returns for the taken-on risk are represented by the efficient frontier. Returns are determined by the portfolio's investment combinations. Risk is equated with a security's standard deviation. In an ideal world, a portfolio would be filled with investments that not only offer great returns, but also have a cumulative standard deviation that is lower than the standard deviations of the individual investments.

In our case, we calculate the efficient frontier for randomly selected energy companies in the stock market. To do this, we use the standard S&P 500 index as a benchmark. By calculating the risk-return trade-off, we aim to assess the impact of introducing the S&P 500 ESG index as a replacement for the standard index. Then we use Sustainalytics' ESG ratings in the energy sector to create various stock portfolios with different ESG ratings and examine the impact of these ratings on investment decisions, particularly concerning the risk-return trade-off.

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5. Empirical Analysis and Results Presentation

5.1. Descriptive statistics

Table 1: Descriptive statistics for all variables used

	FRU, TO	TPZ, TO	VNOM	^TNX	CNQ	REP, HM	TTE, PA	BP	CVX	SHELL, AS	2222, SR	NOG	XOM	SP500ESG	SP500ENERGY
Count	328	328	328	328	328	328	328	328	328	328	328	328	328	328	328
Mean	10,260	16,804	20,698	2,072	39,180	10,392	40,057	25,730	119,763	19,523	29,217	18,164	60,489	356,74	472,253
Std	3,793	3,506	7,391	0,955	13,857	2,2472	8,2680	4,613	33,567	4,983	3,136	7,299	17,531	29,800	133,254
Min	3,196	11,45	5,853	0,801	13,434	4,566	21,240	13,35	61,042	9,318	25,348	3,251	27,480	280,11	216,41
25 %	6,932	13,244	14,96	1,369	27,197	9,069	33,299	22,628	93,423	15,137	27,083	12,163	50,782	332,725	369,945
50 %	10,554	16,498	20,227	1,639	37,80	10,187	39,637	25,711	107,602	18,571	27,472	18,560	57,175	356,36	433,405
75 %	13,649	20,048	27,478	2,886	52,439	12,001	46,459	29,255	153,212	24,531	31,829	23,614	76,034	379,52	588,8
Max	16,775	23,595	33,016	4,234	63,085	15,278	58,192	35,167	182,474	27,950	36,710	34,923	101,09	418,01	720,16

5.2. Data summary

Table 2: Summary of selected data

Data	Source	Sampling (Dates°)	Specifications
SP500	SP500 GLOBAL	2011-2022	-
INDICE SP500ESG	SP500 GLOBAL	2011-2022	-
SP500 ENERGYIND EX	SP500 GLOBAL	2011-2022	-
SHARE DATA	YAHOO FINANCE		USE DATA SCRAPPING IN PYTHON
ESG ratings	Sustainable development		Only companies in the energy sector are concerned by ESG risk.

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In our study, we will use multiple linear regressions and simple linear regressions to assess the persistence of the statistical model, as well as logistic regression (with a binary output of 0 or 1) to examine the direct impact of the ESG score on return on equity as a measure of performance. We will adopt a quantitative research approach for our analysis. When researchers attempt to quantify social phenomena and the relationships between them, they typically use a quantitative research methodology (Bell, Bryman, and Harley, 2019). In our case, the tools employed include the Python Spider, a tool dedicated to data analysis, and Excel analysis tools.

5.3. Econometric model

First model: Multiple linear regression model Addition $Y = aX_1 + bX_2 + cX_N + \dots + nX_n + e$

Multiple regressions are run to study the relevance of ESG data and to extract possible relationships between variables. The first regression uses SP500 variant analysis:

Y is the standard SP500; this variable is used because of its importance on the stock market, as it gives an idea of the market trend. The SP500 is widely used as a benchmark for equity investments. It is therefore relevant to use it as the dependent variable.

X1: The SP500 offers the possibility of filtering its components. For this reason, there are many variants of the SP500, the most important in our study being the SP00 ESG index; this variant is derived from a negative filtering method[2] by filtering the standard SP500 and retaining only the "good stocks".

⇨ X2: SP500 Energy index, following the same logic of filtering the overall SP500, and as our study focuses more on the energy sector, we'll take the SP500 Energy index as the second variable for our model.

Note that the data is filtered using Power Query, and the regression is run as a first test in Excel, using the full set of analysis tools. The data runs from 2011 to 2022, the idea being to take account of crises that have caused market collapses, in particular the pandemic of COVID-19 and the war between Russia and Ukraine.

[2] Negative and positive screening: Companies from "controversial" sectors such as oil and gas could be screened favorably if they can demonstrate that they have made significant ESG commitments and are in a position to improve.

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Discussion of results

Table 3: Regression statistics

Regression statistics	
Coefficient of multiple determination	0,999 074 472
Coefficient of determination R^ 2	0,998 149 801
Coefficient of determination R^ 2	0,998 148 335
Standard error	37,635 140 77
Observations	2528

The results of this tables emphasis on the strong relationship between variables, the R squared is almost one which implies that the model is strong and the two variables explain statistically the dependent variable Y.

Table 4: ANOVA[3] test

	Degree of freedom	Sum of squares	Average square	F	Critical value of F
Regression	2	1 929 415 359	964 707 680	681 096,496	0
Residues	2525	3 576 419,65	1416,403 82		
Total	2527	1 932 991 779			

This table satisfies the normality hypothesis. If all the variables in the model are normally distributed, we can accept H0 (the null hypothesis), because if we reject the normality test, the study will not be significant. Thus, the P-value is 0, perfectly respecting the null hypothesis.

Table 5: Regression model coefficients

	Degree of freedom	Sum of squares	Average square	F	Critical value of F
Regression	2	1 929 415 359	964 707 680	681 096,496	0
Residues	2525	3 576 419,65	1416,403 82		
Total	2527	1 932 991 779			

In Table 5, we summarize the regression equation. Writing it as a mathematical formula, we obtain: $Y = 11.079X_1 - 0.182\,X_2 + 269{,}672$

Interpretation:

The impact of the S&P 500 (X1) is positive, as an additional unit of the S&P 500 leads to an increase of approximately 11.1 units in the standard

[3] ANOVA is a statistical analysis technique that divides systematic components from random factors to account for the overall variability observed within a data set.

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S&P 500. Conversely, the S&P 500 Energy index (X2) has a negative impact, reducing the standard S&P 500 by 0.2 units for every additional unit increase. Overall, the influence of the S&P 500 is significantly greater than that of the S&P 500 Energy index in this model.

This result confirms the literature studying this relationship, particularly in areas related to ESG investment, such as the relevance of ESG data to the stock market.

5.4. Results of Monte Carlo Simulations and the Efficient Frontier Analysis

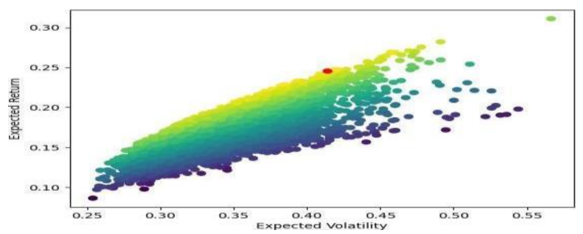

Chart 1: Efficient frontier without ESG variant

This graph shows the risk and return parameters for a portfolio of energy stocks. The optimal portfolio is represented by a red dot, with an approximate volatility measure of 0.40 and an expected return of 0.25. If we take into account the number of returns per unit of risk (simple division of risk and return), we obtain approximately 1.6.

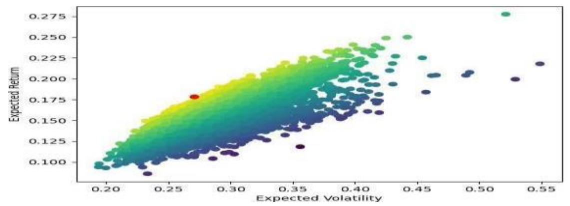

Chart 2: Efficient frontier with ESG variant

For each additional unit of yield, there are 1.6 units of volatility.
The ESG variant is important for hedging risk but does not clearly affect returns.
This graph shows the risk and return parameters for a portfolio of energy stocks. The optimal portfolio is represented by a red dot, with an approximate volatility measure of 0.27 and an expected return of 0.18

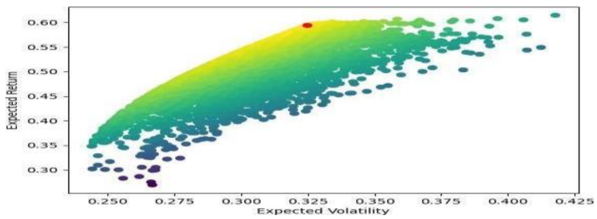

Chart 3: Efficient frontier with low ESG risk

This chart displays the risk and return parameters for a portfolio of energy stocks. The red dot represents the optimal portfolio, with an approximate volatility measure of 0.32 and an expected return of 0.60. If we take into account the returns per unit of risk (simply dividing risk by return) or calculate the maximum Sharpe ratio using Python code, we obtain a Sharpe ratio of 1.829.

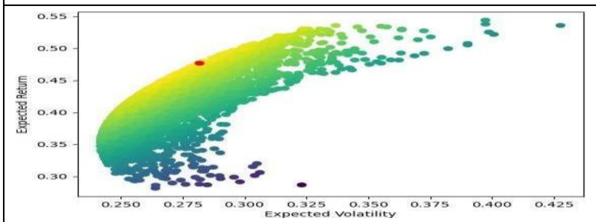

chart 4: Efficient frontier with Medium ESG risk

The portfolio consists of stocks from the energy sector, including companies like Total Energies and the Canadian National Energy Company, all with an average ESG score. Considering the returns per unit of risk, the Sharpe ratio is calculated to be 1.695.

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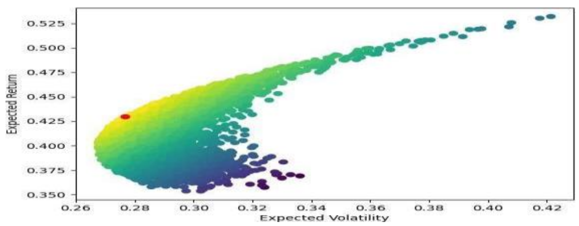
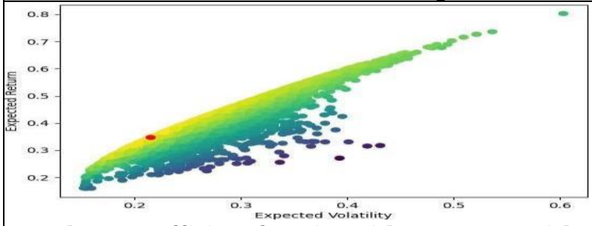
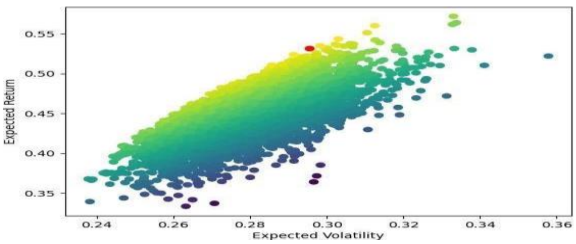
 **Chart 5: Efficient frontier with high ESG risk**	This graph shows the risk and return parameters of a portfolio of shares in the energy sector for companies with a high ESG risk, i.e., a poor ESG rating according to Sustainalytics. The optimal portfolio is represented by a red dot; the Sharpe ratio of this portfolio that is equal to 1,553
 **Chart 6: Efficient frontier with sever ESG risk**	This graph illustrates the risk and return parameters for a portfolio of stocks within the energy sector. The red dot represents the optimal portfolio, which, in the worst-case scenario, comprises solely companies with a high ESG risk and consequently a very low ESG rating. By considering the returns per unit of risk (calculated through a simple division of risk and return).
 **Figure 7: Efficient boundary of the envelope scenario**	This chart shows the risk and return parameters of a portfolio of equities in the energy sector. This represents an envelope scenario, subsequently developed in the form of proposals. The optimal portfolio is indicated by a red dot and includes companies with both high and low ESG risk. Taking into account the returns per unit of risk (calculated by the simple division of risk and return), the Sharpe ratio for this portfolio is 1.799.

6. Analysis of results/data

ESG investing consists of proposing portfolios that meet certain ethical investment standards. As such, rating agencies provide ratings to facilitate the selection of portfolios for "responsible" investors. If we see ourselves as investors who are aware of this investment scheme, we will look directly at the risk and return provided by these portfolios.

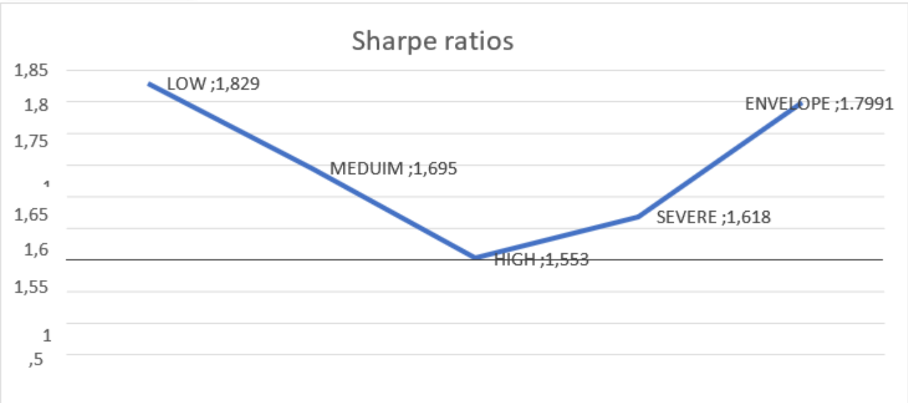


Figure 8: Sharpe ratios for the different portfolios

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In general, a higher Sharpe ratio is preferable, as it indicates a greater return relative to the risk assumed. However, it is important to remember that the Sharpe ratio is not the only factor to consider when choosing an investment. Factors such as investment objectives, time horizons, and personal risk tolerance should also be taken into account.

The low ESG risk portfolio has the highest Sharpe ratio (1.829), making it the best portfolio in our investment decision schema. Finally, the medium-risk portfolio lies between the low- and high-risk portfolios, with a Sharpe ratio of 1.695, while the high-risk portfolio has a Sharpe ratio of 1.553.

The issue with the order lies with the severe portfolio, which is an outlier with a better risk/return trade-off compared to the high-risk portfolio. Descriptively, both are poor portfolios with little difference when their Sharpe ratios are compared.

In fact, ESG ratings are dissociated from any financial criteria and, therefore, do not directly influence risk and return. As a result, ESG investment aligns more with an ethical approach than a purely financial one.

7. Limits and proposals

Nevertheless, our study has intrinsic limitations related to the methodology adopted and the availability of data:

The model we use is based on a positive/negative selection approach specific to responsible investment. Despite its often "naïve" criticisms, this methodology is still widely used in investment decision-making.

- ⇨ We suggest a more rigorous selection of countries to enhance the relevance of our study; however, this improvement is highly dependent on data availability.
- ⇨ We observe that small-cap stocks, perceived as riskier, present interesting opportunities. Indeed, they are often considered more volatile than large-cap stocks. This is because the latter, typically held by well-established firms, do not generally aspire to rapid growth, as noted by Investopedia.

In our study, the size factor plays a central role. By considering this factor, we could provide significant additional information. Separate research on the size factor would be particularly beneficial and would enrich the literature on the subject. As part of our approach, we conducted a test to evaluate this hypothesis. By applying the positive/negative selection methodology to our study and evaluating efficient frontiers, then comparing Sharpe ratios, we arrived at specific results.

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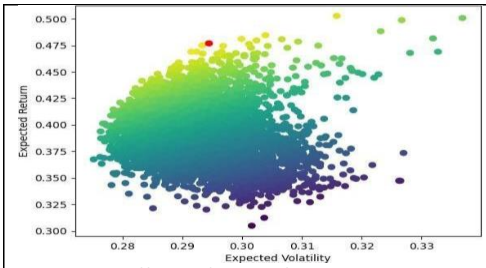

Chart 9: Efficient frontier for the 5 companies with the worst ESG ratings

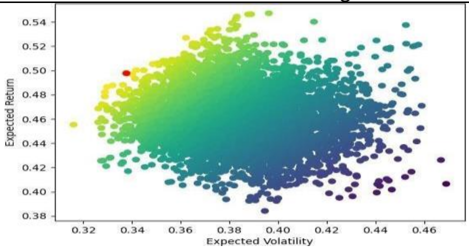

Chart 10: Efficient frontier for the top 5 ESG-rated companies

In analyzing the efficient frontiers and associated metrics, we observe a notable gap between the Sharpe ratios of the highest-ranked and lowest-ranked companies. The top-ranked companies, primarily small- and mid-cap stocks, have a Sharpe ratio of 1.474, while the bottom-ranked companies, largely large-cap stocks, have a ratio of 1.623. This difference underscores the need to examine this feature in greater detail.

Additionally, a sharper focus on the energy sector could provide a better understanding of the observed disparities. We could consider using industry sub-codes to refine the model and specifically target those branches of the sector most impacted by ESG investment decisions. It should be noted that our research focuses primarily on companies in the oil and gas sector. In the future, exploring the renewable energy sector could prove promising for our research.

Conclusion

In this paper , we explore the relevance of ESG ratings in the investment decision- making process, particularly in the face of uncertainties in the energy sector. There's no denying that, when it comes to investing, the risk/return trade-off is at the heart of investors' concerns. The first reflex is often to review the various portfolios available and assess their respective risks and returns.

Our research was based on data from the global SP500 index. The aim of our econometric model was to assess the usefulness of the SP500 ESG index as a benchmark. The results show a strong correlation and statistical convergence between these two indices. What's more, integrating ESG data into a portfolio by substituting the SP500 with the ESG SP500 index generates a significant reduction in risk and a higher Sharpe ratio.

In addition, our risk/return analysis, carried out by calculating the efficient frontier for various equity portfolios based on ESG scores, confirms the relevance of the scoring method.

Specifically, we found a more favorable Sharpe ratio for low ESG risk portfolios than for high ESG risk portfolios.

However, our conclusions must be tempered by the intrinsic limitations of this study, notably those associated with data availability and the constraints of the model employed. We have suggested improvements to make this study even more relevant, including a more rigorous selection of countries and a more thorough consideration of the size factor.

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An "envelope scenario" has also been established to further explore this ESG investment opportunity. With the limitations identified and improvements suggested, we are convinced that there is still much to discover and learn in the vast field of ESG investing.

Conflict of Interest: The authors reported no conflict of interest.

Data Availability: All data are included in the content of the paper.

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