Facultad de Ciencias Económicas y Empresariales
ICADE

INVESTING IN BIODIVERSITY: SIGNIFICANDE, ASSET CLASSES AND PORTFOLIO INTEGRATION THROUGH DIVERSIFICATION

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Introduction

Rationale and Results of the Study

The contemporary socio-economic landscape is increasingly recognizing the critical importance of nature and the environment. This growing awareness is reflected in the global commitment to the 2030 Agenda for Sustainable Development Goals (SDGs), which underscores the importance improving human practices to preserve our natural world, for current and future generations. On the other hand, businesses are now expected to report on the ESG framework, which represents 3 main areas in which businesses performance is rated: Environmental, Social and Governance. The goal is to capture non-financial risks and opportunities present in daily activities (Deloitte, 2024). Biodiversity is a key component under the "Environment" pillar of these objectives. It addresses all living organisms and the ecosystems that support them. It is critical to acknowledge that biodiversity is not just a key component for ecological balance but also a fundamental driver of the global economy. In the World Economic Forum Nature Risk Rising: *Why the Crisis Engulfing Nature Matters for Business and the Economy* report, it is estimated that over 50% of the world's global GDP is moderately to highly dependent on nature, ranging from industries like pharmaceuticals to agriculture. Biodiversity loss is a risk for businesses and investors manifesting in the form of physical and litigation risks (Baruah, Labrousse, & Drexler, 2022) . Therefore, it is literally "bad for business" to ignore the current situation. Nature enables human development and prosperity, yet our continuous demand for natural resources is not sustainable. Currently, human activities extract from the earth and produce waste like never before. Around 25% of species are under threat, which suggests that around 1 million species are on the brink of extinction, many within the next decade unless significant measures are taken to reduce the main drivers of biodiversity loss (Brondízio, Settele, Díaz, & Ngo, 2019). This concept is gaining traction not only among scholars and activists but also among investors and asset managers that are starting to appreciate the financial risks associated with biodiversity loss. However, despite this growing awareness there is still much to do; it is estimated that around $824 billion is needed to protect and restore nature, in comparison to the $140 billion spent annually, leaving a disturbingly big funding gap. It is also estimated that the share of climate finance destined for biodiversity is less than 2% (Baruah, Labrousse, & Drexler, 2022). Climate change and environment issues have traditionally captured more interest from the finance sector as they are easier to quantify and measure, for example the reduction of Co2 emissions is straightforward to measure and track. In comparison, measuring the value of biodiversity in a manner that is homogeneous and applicable to all

countries and ecosystems has proven really challenging as it cannot be narrowed down to a series of metrics and indexes (Baruah, Labrousse, & Drexler, 2022). Investors feel that reporting on biodiversity is weak, that is why it is important for scholars to do research and come up with ways to integrate biodiversity into the investment universe of asset managers. This study aims to contribute to the ongoing research by constructing a diversified portfolio that mixes a series of asset classes and most importantly a biodiversity focused index, the MSCI World Select Natural Resources Index. Guided by the principles of Modern Portfolio Theory (MPT), this study aims to propose a well-diversified and risk-adjusted investment opportunity for said investors interested in using their capital to contribute to preserving nature as well as making profit. MPT advocates for the creation of portfolios by combining various asset classes, in a way that the overall risk in minimized and potential returns are maximized. This portfolio will use the biodiversity focused index to address ecological risks and the sustainable management of ecosystems.

The results showed that the geographical diversification analysis of the S&P 500, EURO STOXX 50, S&P ASIA 50, and MSCI World Select Natural Resources Index reveals varying degrees of correlation. While the S&P 500 and EURO STOXX 50 are moderately to highly correlated, the S&P ASIA 50 offers lower correlation, enhancing diversification. The resulting portfolio, heavily weighted towards the S&P 500 (94.6%), with smaller allocations to the S&P ASIA 50 (3.4%), EURO STOXX 50 (1.0%), and MSCI World Select Natural Resources Index (1.0%), achieves an expected return of 10.7% and a volatility of 17.1%, reflecting a balance between risk and return while including ESG objectives.

Investing in Biodiversity

When discussing investing in biodiversity, the term “Conservation Finance” should be at the forefront of the conversation. This term addresses all efforts aimed at raising and managing capital specifically for the benefit of biodiversity. It has been largely studied by ecologists, scholars, and activists; however, finance scholars have yet to fully engage. These strategies range from direct investments to the development of innovative financial instruments that promote conservation efforts. The current crisis surrounding ecosystems and the extinction of species has been long discussed by governments but in a residual form. Even so, the primary funding sources for biodiversity conservation remain closely tied to grants, donations, and government budget allocations. The private sector should step in to salvage the shortcomings of governments and their policies, which are guided by short-term interests. Although the topic of biodiversity conservation is not new it has gained traction after the issue of the 17 Sustainable Development Goals by 2030, and the implication of the finance sector is crucial for the achievement of said commitments. Private capital flows into conservation efforts grew from less than a billion in 2004-2008 to US $8.2 billion in 2025; however, a much bigger inflow is needed to cover the funding gap. This breach is not a result of insufficient funds, the global economy is wealthier than ever, with financial assets worldwide valued over US$ 200 trillion. Therefore, it is theoretically feasible to close the gap, the real issue lies upon the direction and scalability of current investments. In 2021, the first draft of the new global guide for conservation actions until 2030 was published by the Convention on Biological Diversity (CBD). The first global agreement covering all aspects of the conservation of all biological diversity. The framework includes 21 objectives and 10 suggested targets for 2030. One main objective is to increase financial flow from all sources into biodiversity finance planning. However, the capital markets in this emerging sector are still weak with low liquidity and expectations of low returns. Therefore, improving their risk adjusted returns and creating larger investments vehicles might mobilize private capital in a bigger scale. Investing in conservation presents several challenges. Firstly, these investments are often slow to mature, long-term and carry significant risks. One major hurdle is accurately valuing nature as there isn’t an established standard for measuring the impact of conservation projects effectively. Furthermore, many of the benefits provided by conservation projects can be difficult to quantify in monetary terms. Additionally, natural systems are intrinsically unpredictable, making uncertain how they will react to certain interventions. This complexity makes it hard for investors to estimate potential returns as risks accurately (Karolyi & Tobin de la Puente, 2023).

This is why much research and guidance for factoring in these risks and making correct estimations is needed. In December 2022, the UN's COP 15 Biodiversity Conference in December 2022, underscored the critical need to protect biodiversity on a broader scale (Manulife Investment Managment , 2023). Simultaneously, an initiative surfaced aimed at integrating nature-related risk management and disclosure into financial and business decision-making. The Taskforce on Nature-related Financial Disclosures (TNFD), launched in 2021, has developed a framework for organizations to assess, disclose, and manage nature-related risks and impacts. The TNFD framework is inspired by the Taskforce on Climate-related Financial Disclosures (TCFD) and seeks to provide comparable and consistent reporting standards. This approach not only helps businesses understand their environmental impact but also guides investors in making informed decisions that support nature-positive outcomes. The framework is structured around four main pillars: governance, strategy, risk management, and metrics and targets, and includes an integrated risk and opportunity assessment method known as the LEAP approach (Taskforce on Nature Related Financial Disclosures, 2024). There is a list known as the TNDF Adopters List which registers companies that have pledged to incorporate disclosures consistent with the TNFD Recommendations into their corporate reports by the financial year 2024 (or sooner), or by 2025.

There is a regulatory momentum surrounding biodiversity investments. The European Union, for example, is leaning towards declaring that all products sold within its borders be deforestation free. Moreover, they are currently developing the EU Taxonomy on sustainable finance, which will provide investors with more reliable tools to identify and evaluate the impacts of sustainable investments. As these regulatory frameworks mature, they are expected to substitute the various voluntary standards and commitments that are currently widespread in the industry. Therefore, there is a growing need for advanced metrics and tools to measure risks and the impact of biodiversity. The TNFD mentioned above, and other groups like the Science Based Targets Network or Exploring Natural Capital Opportunities, Risks and Exposure are investigating the development of said tools (Atwell, Bristsch, & Jia, 2023) (Deutz, et al., 2020).

Impact investing, described as a strategic approach that tackles sustainability challenges while also yielding financial returns, is widely acknowledged as a method for progressing towards the United Nations Sustainable Development Goals. Currently experiencing rapid expansion, impact investing is now estimated to encompass approximately $500 billion in assets. In recent years, there has been a significant shift towards using impact investments to finance biodiversity conservation (Pineiro, Dithrich, & Dhar, 2018). Although private, profit-driven capital is

increasingly attracted to green financial products, the availability of these products—offering both competitive risk-return profiles and clear environmental benefits—has not consistently matched the growing demand. Recent years have seen the introduction of numerous innovative green investments, which are often custom transactions of modest size and challenging to replicate. However, to truly meet both market demands and environmental objectives, green financial products must be capable of directing substantial capital towards conservation activities with significant impacts (Atwell, Bristsch, & Jia, 2023).

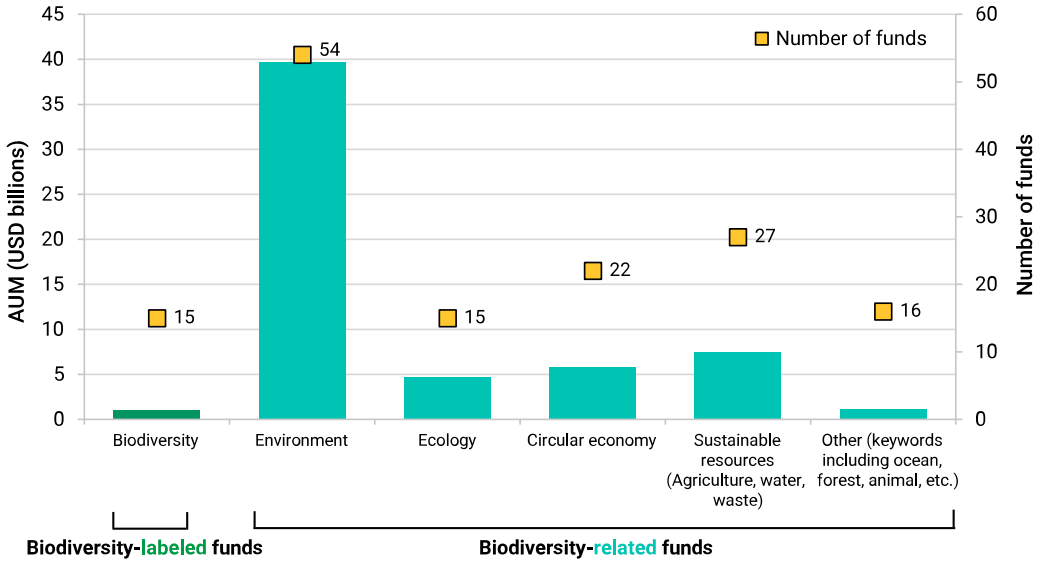
The green finance market is characterized by its diverse array of investment products, which cover a broad range of risk levels and aim to provide various environmental benefits. At one end of the spectrum, well-understood and market-ready products like green bonds, green loans, and sustainability-linked loans offer liquidity and lower-risk investment options. At the opposite end, green private equity funds are available for those seeking higher returns and willing to tolerate greater risk. Additionally, other financial instruments like insurance, guarantees, and blended finance structures are critical in mitigating risks and enhancing the attractiveness of investments. However, the use of these products for biodiversity conservation remains limited compared to their application in promoting clean energy transitions or sustainable construction and infrastructure. For instance, of the US$ 271 billion raised through green bond issuances in 2019, less than 0.7% was directed towards biodiversity conservation efforts. Similarly, only between US$ 2.3 and 3.0 billion (<0.5%) of social and environmental investments were destined to these efforts, highlighting a disparity in funding allocation within the sector. It's notable that many green investment products that have the capacity to attract and utilize substantial amounts of capital while yielding returns in biodiversity are still in the initial phases of development. Meanwhile, the more mature products have been involved in a relatively small number of transactions that have directly contributed to biodiversity benefits (Atwell, Bristsch, & Jia, 2023). In the following sections, we will dive into some of the main options for investing in biodiversity.

Biodiversity Funds

In the aftermath of the UN's COP 15 and the TNFD, biodiversity has emerged as popular investing theme. The asset management industry has listened, and several funds have surfaced in the past years. Biodiversity investing exhibits a wide array of approaches and terminology, which can create confusion for investors trying to navigate this space. According to MSCI Research, as of Q3 of 2023, there is an estimated total of around USD 1 billion AUM, invested across 15 funds specifically labeled as "biodiversity" funds. In contrast, biodiversity-related funds capture a broader range of investment with about USD 59 billion in AUM across 134 funds. When

comparing, funds that explicitly include the term “biodiversity” in their name with their peers, they tend to have, on average, double the exposure to revenue from conservation impact solutions. This highlights how there is greater potential for a bigger impact on nature by investing in funds that are specifically dedicated to biodiversity (Mahmood & Go, 2023).

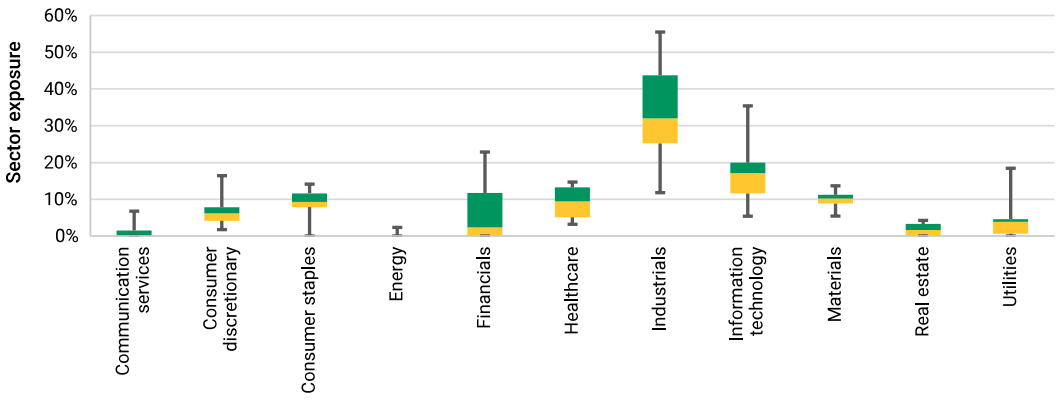
Figure 1: The canopy of biodiversity funds



Source: https://www.msci.com/www/blog-posts/biodiversity-funds-br-welcome/04075535373

Focusing on the top 10 funds explicitly focused on biodiversity, MSCI Research has observed the prevalence of cyclical sectors within their investments. Industrials, on average, emerged as the most represented sector; followed by information technology and materials. Notably, these funds showed almost no investment in the energy sector (Mahmood & Go, 2023).

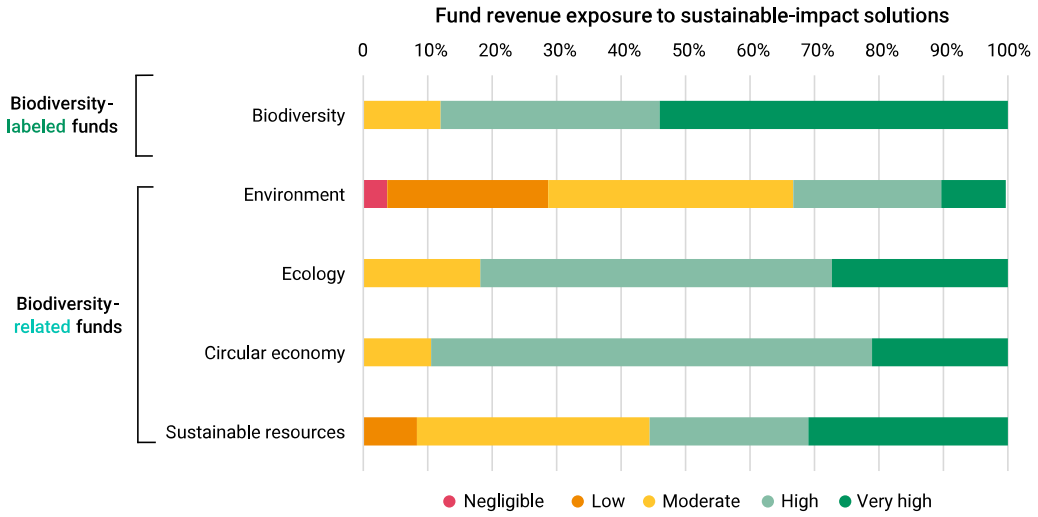
Figure 2: Cyclical sectors favored in biodiversity-labeled funds.



Source: https://www.msci.com/www/blog-posts/biodiversity-funds-br-welcome/04075535373

According to MSCI research, in the past years biodiversity focused funds have lower risk-adjusted returns on average. Which is partly consistent with the large distribution of AUMs in cyclical sectors, particularly, information technology which experienced several downturns in 2022. Based on the MSC research, asset-class diversification is not yet achieved in these funds as 90% of funds are invested in equity from developed markets (Mahmood & Go, 2023).

Figure 3: Exposure of funds to sustainable-impact solutions



Source: https://www.msci.com/www/blog-posts/biodiversity-funds-br-welcome/04075535373

Biodiversity Indexes

After doing research, we found that there are several indexes focused on conservation finance that pool companies that invest in ESG and specifically in biodiversity. While it is not possible to directly invest in an index, they serve as benchmarks or trackers for the performance of assets related to nature. They are crucial for understanding market trends, comparing fund performance, or even designing index-linked investment vehicles that replicate their movements. Before diving into the most interesting ones, it's worth mentioning the rationale followed, composed by the Morgan Stanley Capital International regarding the thought process for selecting companies that are aligned with conservation efforts. They recommend the following actions:

- Examine the company's operations and its role in deforestation activities.

- Assess income derived from controversial or environmentally damaging products such as palm oil, soybeans, beef, or timber.
- Review whether the company has concrete, specific governance, strategies, or goals related to environmental conservation.
- Determine the company's vulnerability to physical risks stemming from reliance on ecosystem services or operations in areas prone to high water risks.
- Evaluate potential transition risks linked to the company's activities that could lead to legal, reputational, or regulatory challenges.
- Investigate investment opportunities in companies that deal in products which positively influence biodiversity.

After thorough research, some of the most interesting and credible indexes were The MSCI World Select Natural Resources Index, which is composed of 1,169 companies that follow the requisites described above. It is diversified across sectors like energy, materials, industrials, utilities, and real estate, as well as across countries like the United States, Canada, The United Kingdom, Australia, Japan and others. The Solactive Transatlantic Biodiversity Screened 150 CW Decrement 50 Index, Solactive EURO 40 Biodiversity on Land Index 5% AR, Solactive Global Biodiversity Screened 200 CW JP 10 JPY Index. Solactive partners with Iceberg Data Lab to evaluate the biodiversity impact of companies by utilizing metrics that measure ecosystem degradation caused by business activities.

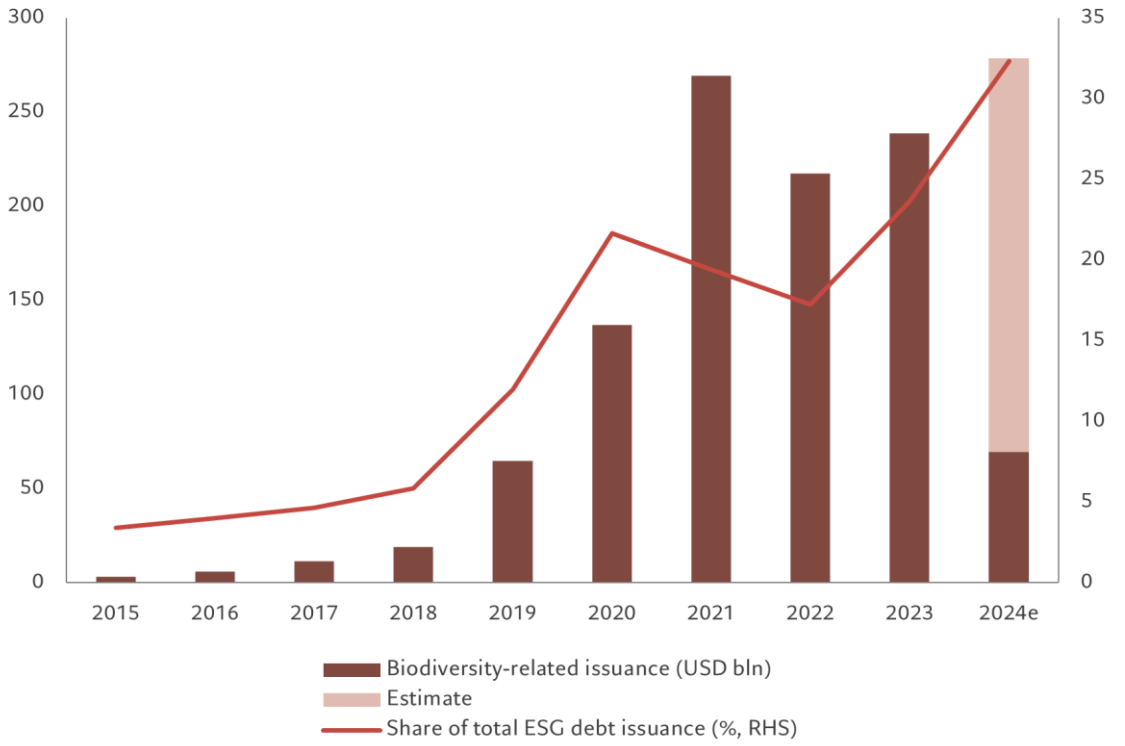
Green and Biodiversity Focused Bonds

Green bonds are specialized financial instruments created to fund projects that have positive environmental and climate outcomes. These bonds are issued by governments, corporations, and financial institutions and function similarly to traditional bonds, with the issuer repaying the principal to the bondholder within a set timeframe. The key distinction of green bonds is that their proceeds are dedicated to supporting specific sustainable initiatives. It is crucial to differentiate Use of Proceeds Bonds, which are essentially the type described above, and Sustainability-Linked Bonds. The latter are corporate issuances where the interest rate may be tied to the issuer's achievement of specific, predetermined sustainability outcomes. Sustainability-Linked Bonds encourage issuers to meet their sustainability targets by linking financial consequences, such as adjusted interest rates, to these goals. All green bonds are encouraged to follow The Green Bond Principles (GBP), to ensure transparent green credentials for the investment opportunity. Transparency leads to a better tracking of sustainable cash inflows and impact (Jacobs & Philip, 2024) (Atwell, Bristsch, & Jia, 2023).

Biodiversity-related bonds represent a specialized niche within the sustainable fixed-income market. Under the Green Bond Principles (GBP), the categories that more accurately address biodiversity as a theme are the preservation of aquatic and terrestrial ecosystems, and water management. The proportion of Environmental, Social, and Governance (ESG) bonds that include aquatic and terrestrial preservation in their potential projects has increased from 5% in 2020 to 16% in 2023, indicating growing interest in these areas. Additionally, a significant larger portion of bonds also focus on related areas such as water management. Most bonds specifically labeled for biodiversity conservation fall under the category of green bonds, with sustainability bonds—those that combine environmental sustainability with social objectives—following closely. However, the issuance of Sustainability-Linked Bonds that feature biodiversity objectives is relatively limited. This limitation is largely due to the challenges associated with defining quantifiable metrics and KPIs to monitor and report (Atwell, Bristsch, & Jia, 2023). The Brazilian pulp and paper company Klabin offers a notable example in the realm of sustainability-linked financing. It has recently issued a Sustainability-Linked Bond (SLB) that matures in 2030, with performance evaluations scheduled for 2025 to potentially adjust interest rates based on the company's achievement of specific biodiversity and environmental targets. Klabin's goals for 2030 are ambitious: reintroducing two species that have been declared extinct in their habitats and enhancing the populations of four more threatened species, with a failure to meet this target resulting in a 6.25 basis point increase in the coupon rate. Additionally, the company aims to keep water consumption at or below 3.68 cubic meters per ton of production, a 16.7% decrease from 2018 figures, with a 12.5 basis point increase in the coupon rate if this target is not met (Jacobs & Philip, 2024).

According to the Institute of International Finance, early issuers of biodiversity-related ESG debt include prominent borrowers like the European Union and the World Bank. Combined, these entities represent approximately two-thirds of all biodiversity-related ESG debt issued so far (Jacobs & Philip, 2024).

Figure 4: Blooming Bonds



Source: *https://am.pictet/en/belgium/global-articles/2024/monthly-markets-views/fixed-income/biodiversity-bonds*

However, corporate borrowers are now starting to participate as well. This movement is a reaction to the increasing implementation of regulations and reporting standards related to nature, all aimed at compelling companies to incorporate biodiversity protection into their net zero strategies. Some examples are, the Chilean pulp and paper company, CMPC, that has issued bonds with Use of Proceeds (UOPs) dedicated to sustainable forest and water management, as well as the restoration of native forests. Similarly, the Finnish forestry company Stora Enso has launched several green bonds, designating UOPs for sustainable forest and water management, along with pollution control among other objectives. China has also played a significant role in this market. The Bank of China recently issued two biodiversity bonds, directing the net proceeds towards biodiversity conservation projects, as well as the environmentally sustainable management of living natural resources and land use projects in mainland China, which are also recognized as eligible UOPs (Jacobs & Philip, 2024).

The increasing interest in biodiversity bonds from investors may also be due to the strong financial performance this asset class has exhibited. According to the Institute of International Finance, the median return for biodiversity fixed income funds was just over 10 percent, surpassing the returns of traditional fixed income funds, which yielded 6.7 percent last year. This finding aligns with an expanding array of academic studies that suggest the presence of a

"biodiversity risk premium" within the fixed income sector. For instance, one study that examined the credit risk structures of infrastructure companies revealed that those managing biodiversity risks benefited from financing conditions up to 93 basis points more favorable than those that did not manage these risks. Additionally, this advantage was found to be more pronounced over longer loan durations, with the discrepancy in terms widening from one to ten years compared to one to five years (Jacobs & Philip, 2024).

Modern Portfolio Theory and Diversification

Introduced in 1952 by Harry Markowitz in his doctoral dissertation and later expanded in his book "Portfolio Selection: Efficient Diversification," Modern Portfolio Theory (MPT) offers a framework for asset selection aimed at constructing a portfolio that maximizes expected returns while minimizing risk. This approach is also referred to as mean-variance analysis, with "mean" denoting average or expected return and "variance" representing a measure of risk (Markowitz, 1952) (CFA Institute).

MPT operates under several key assumptions: investors are rational and seek the highest possible return for the lowest possible risk, willing to take on more risk only if it comes with a higher expected return. It assumes that all market information is instantly and completely available to investors, implying efficient markets (as posited by Fama). Furthermore, it presumes that investors can borrow or lend unlimited amounts at the risk-free rate and do not consider taxes or transaction costs in their investment decisions. Securities within the portfolio are selected based on the expectation that their performances are independent of each other. However, these assumptions have been widely challenged. Despite these criticisms, the core principle of MPT centers on diversification—specifically the strategic use of correlation and covariance to reduce risk. The theory advocates for building a portfolio with assets that have low correlations with each other. This means if one asset performs poorly, another may perform well, thereby balancing the overall portfolio risk. This strategy underscores the well-known investment maxim: "Don't put all your eggs in one basket" (Markowitz, 1952) (CFA Institute).

Risk & Return

Financial risk is typically defined as the deviation from the expected historical returns over a certain period. However, Harry Markowitz's Modern Portfolio Theory posits that the risk associated with any single asset should not be evaluated in isolation but rather in terms of its impact on the overall portfolio risk. There are two primary types of risk: systematic and unsystematic. Systematic risk, also known as market risk, is influenced by macroeconomic factors such as inflation, unemployment, and exchange rates. This type of risk affects all securities to varying degrees and cannot be completely eliminated. Unsystematic risk, on the other hand, is specific to individual companies or a narrow group of assets. While this micro-level risk can be significantly mitigated through diversification within a portfolio, it cannot be entirely eradicated because returns from assets are not perfectly uncorrelated. When

estimating expected returns, which are the returns an investor anticipates, it is common to analyze the historical performance of investments. Typically, this involves calculating the average return of a stock over a specific time period. However, a major limitation of relying on historical returns is the assumption that past performance will mirror future outcomes. While using a sufficiently large historical dataset can provide a useful estimation of how an asset's returns might behave over time, it is important to recognize that future returns are not guaranteed to follow past trends. This method offers a reference point (Markowitz, 1952) (CFA Institute).

After examining risk and return independently, we encounter the concept of the risk-return tradeoff, central to Markowitz's foundational principle. This principle asserts that an investor should expect higher returns as compensation for taking on greater risk. In this context, risk is quantified by standard deviation, where a higher standard deviation indicates increased risk, necessitating a higher risk premium. This premium is defined as the excess return an asset is expected to generate over the risk-free rate. Within the framework of Markowitz's portfolio selection, risk is synonymous with volatility, the higher the volatility of the portfolio, the greater the perceived risk. This relationship underscores the inherent balance investors must manage between potential returns and the level of risk they are willing to accept (Markowitz, 1952) (CFA Institute).

Diversification

Diversification is achieved by creating a portfolio composed of assets that do not move in tandem. This strategy aims to reduce short-term volatility while ensuring steady long-term growth, enhancing the portfolio's resilience to fluctuations in financial markets. There are several strategies to achieve diversification (Markowitz, 1952) (CFA Institute):

- Diversify with asset classes: Typically, correlations among major asset classes are not very high, which helps in reducing portfolio risk. Diversifying across different asset classes and geographies can also produce lower correlations, thereby spreading risk. Key asset classes to consider include domestic large caps, domestic small caps, growth stocks, value stocks, domestic corporate bonds, long-term domestic government bonds, domestic T-bills (cash), emerging market stocks, emerging market bonds, and developed market stocks and bonds. The specific mix of these asset classes in a portfolio should be determined based on the risk tolerance, expected returns, and correlation of each asset

class, as well as the investor's country of residence. This tailored approach ensures that the portfolio is well-suited to meet the investor's personal financial goals and risk profile (CFA Institute).

- Diversification among different countries: Diversifying investments across various countries allows investors to leverage distinct industry focuses, economic policies, and political climates, enhancing potential financial returns. For instance, the U.S. economy is heavily oriented towards financial and technical services with substantial investments in innovation, while China and India predominantly emphasize manufacturing. In contrast, the European Union boasts established, vibrant democracies, whereas East Asia continues to evolve in its democratic practices. These differences mean that financial returns from one country are likely not to be highly correlated with those from another. Additionally, currency fluctuations also influence returns, as the value of foreign investments may change when converted back to an investor's domestic currency. Since currency returns generally do not correlate with stock returns, they can help mitigate risks associated with equity investments in volatile emerging markets. Thus, investing internationally is a crucial strategy for achieving a well-rounded, diversified portfolio, providing both risk management and access to a broader range of growth opportunities (CFA Institute).
- Diversification among index funds: Diversifying among multiple asset classes can be cost-prohibitive for smaller investors due to the extensive number of securities needed. For example, gaining exposure to 10 asset classes might necessitate owning at least 300 different securities, which can be expensive and complex to manage. An effective alternative is to use exchange-traded funds (ETFs) or mutual funds that track specific indexes. These funds offer the advantage of diversification across various asset classes while significantly reducing trading and tracking costs. This approach not only simplifies the investment process but also enhances accessibility, making it easier for investors to achieve a diversified portfolio without the need for substantial capital outlays (CFA Institute).
- Insurance for risky portfolios: Insurance-like investment strategies provide a unique counterbalance to traditional portfolios. They tend to yield positive returns when the rest of the portfolio suffers losses but offer no returns when the portfolio's value is stable. Although these strategies generally produce a negative average return over time, some investors find them appealing for their ability to mitigate severe losses. Alternatively, certain assets exhibit negative correlations with traditional stocks. For instance, gold historically shows a negative correlation with equities, although its

expected returns are typically low and can even be negative. Despite this, investors often incorporate gold and other commodities into their portfolios as a hedge against overall risks, including those related to currency and inflation. Another method for risk reduction is purchasing put options, which can provide returns when the underlying asset declines in value. However, these options come with costs, and their expected returns are zero or slightly negative, which means they are primarily used as a protective measure rather than for generating returns (CFA Institute).

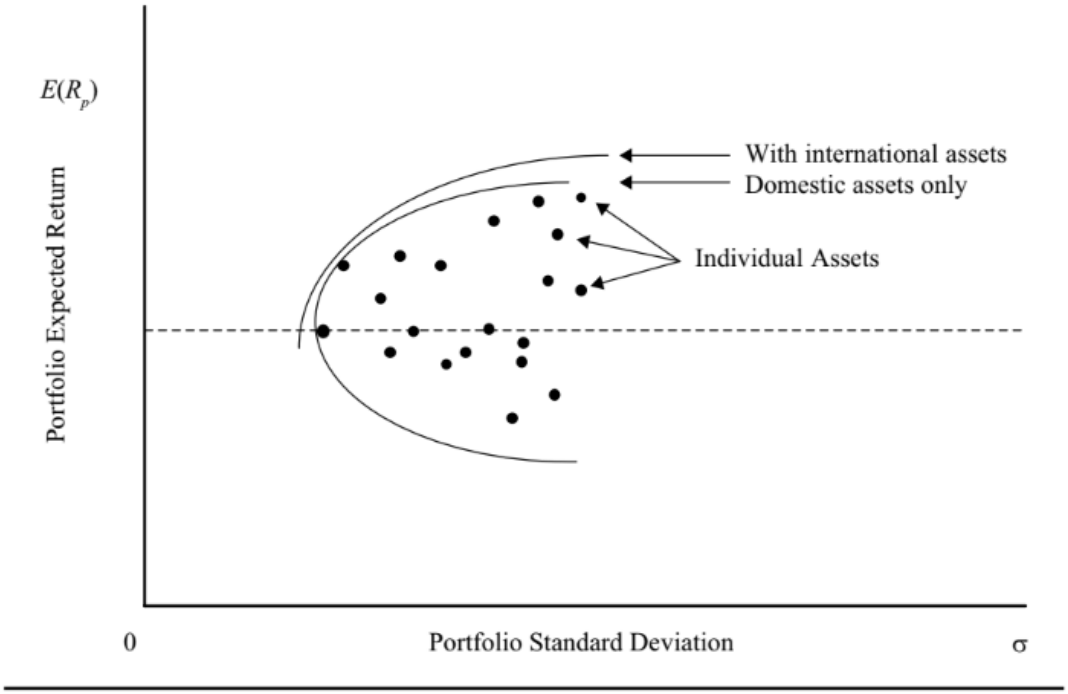
Efficient Frontier

In the mean-variance framework, we consider all available risky assets when constructing a set of potential investments. Starting with individual investable assets, we methodically create portfolios that, when graphed, form a continuous curve. This curve, along with any points to its right, represents the investment opportunity set, which initially might only include domestic assets. However, by incorporating international assets and other asset classes, this set broadens significantly, as illustrated in the accompanying figures. The expanded investment opportunity set provides a wider array of choices, enhancing the potential for diversification and optimizing the risk-return trade-off. Ultimately, the goal is to continue adding asset classes until they no longer contribute to improving this trade-off, thereby maximizing the benefits of diversification. With the comprehensive investment opportunity set defined, including all risky assets, the next step involves identifying the optimal portfolio (Markowitz, 1952) (CFA Institute).

Risk-averse investors prioritize minimizing risk for a specified level of return. Consider points X, A, and B, all of which lie on the same horizontal line on the graph, indicating they offer the same expected return but vary in risk levels. Among these, an investor would ideally prefer point X for its lower risk, but X is unattainable, therefore point A becomes the next best choice as it represents the minimum achievable risk. Point B and any points to its right are also possible options but entail greater risk. The set of portfolios, each representing the lowest possible risk for their respective returns, forms what is known as the minimum variance frontier. This frontier outlines a subset of portfolios that are more desirable for risk-averse investors compared to other portfolios offering the same return but at higher risks. The portfolio at the far left of this frontier, the global minimum variance portfolio, is the one with the least risk among all portfolios consisting solely of risky assets. The introduction of a risk-free asset alters this dynamic slightly by providing new, lower-risk investment opportunities, thereby expanding the choices available

to investors, and easing the constraints on achieving lower risk levels (Markowitz, 1952) (CFA Institute).

Figure 5: Investment Opportunity Set

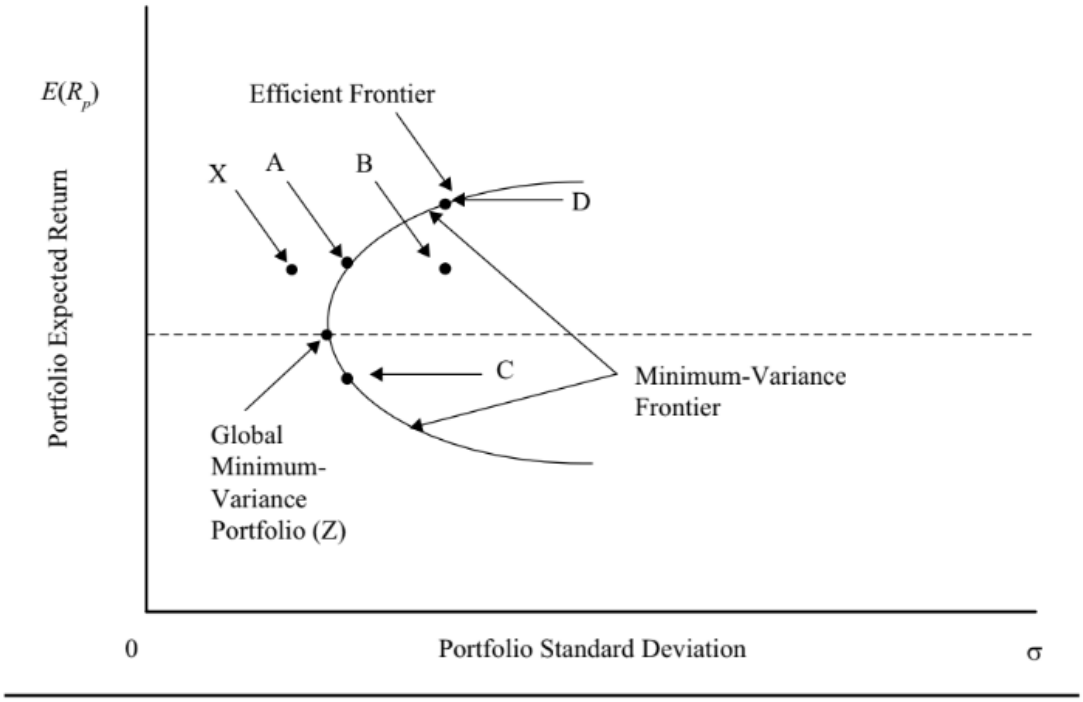


Source: CFA Institute, Refresher Reading 52, Portfolio Management: Portfolio Risk and Return

Investors also aim to maximize returns for a given level of risk. Consider points A and C on a risk-return graph, where both points share the same level of risk, but point A offers a higher return. Rational investors will invariably choose point A over point C. Similarly, any portfolios located below the global minimum variance portfolio are deemed inefficient as they provide lower returns for the same or higher risk (Markowitz, 1952) (CFA Institute).

The portion of the curve that rises above the global minimum variance portfolio is known as the Markowitz Efficient Frontier. This frontier comprises all portfolios of risky assets that rational, risk-averse investors would select. It's important to note that as you move from left to right along this frontier, the slope of the curve decreases, indicating that the additional return gained per unit of additional risk taken diminishes. This demonstrates the principle of diminishing marginal returns in the context of portfolio risk management (Markowitz, 1952) (CFA Institute).

Figure 6: Minimum-Variance Portfolio



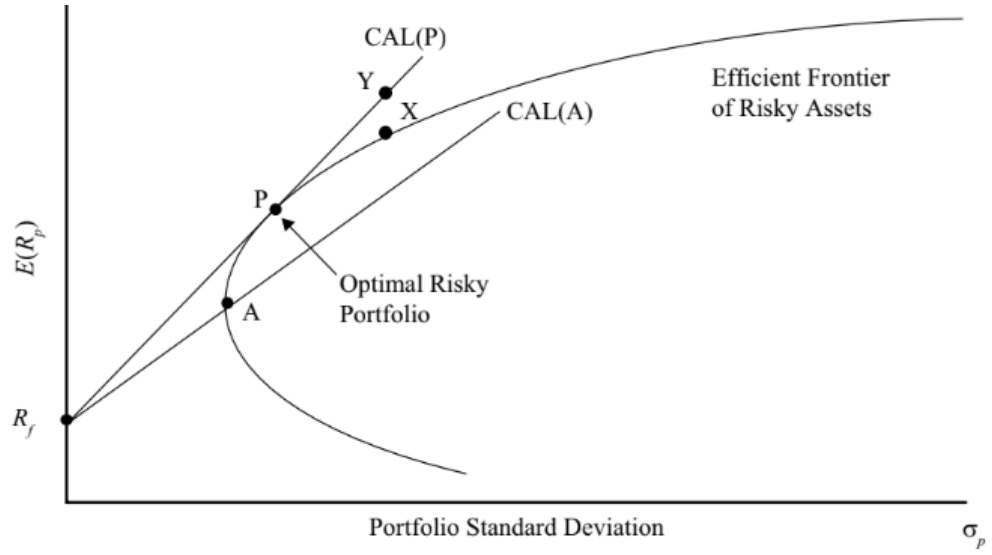
Source: CFA Institute, Refresher Reading 52, Portfolio Management: Portfolio Risk and Return

A Risk-Free Asset and Many Risky Assets

Up to this point, our discussion has focused exclusively on portfolios composed of risky assets. However, most investors have access to risk-free assets that carry virtually no risk. Integrating a risk-free asset with a portfolio of risky assets can be graphically represented by a straight line known as the Capital Allocation Line (CAL). While there are numerous risky portfolios to consider, all of which are positioned along the efficient frontier, the optimal risky portfolio is identified at the point where the CAL is tangent to the efficient frontier of risky assets (Markowitz, 1952) (CFA Institute).

The significance of this tangent point lies in its maximization of the Sharpe Ratio, which measures the excess return per unit of risk, and is a crucial metric for comparing the performance of investment portfolios. The introduction of a risk-free asset allows investors to adjust their portfolio allocation between the risk-free asset and the optimal mix of risky assets to achieve their desired level of risk, thereby enhancing potential returns without disproportionately increasing risk (Markowitz, 1952) (CFA Institute).

Figure 7: Optimal Risky Portfolio



Source: CFA Institute, Refresher Reading 52, Portfolio Management: Portfolio Risk and Return

Furthermore, the use of the CAL enables more precise and flexible investment strategies. Investors can leverage this by shifting capital between the risk-free asset and the optimal risky portfolio along the CAL, adjusting their exposure based on risk tolerance, market conditions, or personal financial goals. This dynamic shifts the portfolio's position along the CAL, allowing for strategic risk management while pursuing the best possible returns (Markowitz, 1952) (CFA Institute) (Cesarone,, Giacometti, & Lui, 2023).

Constructing a Diversified Portfolio with a Focus on Biodiversity Investments

This study focuses on the significance of investing in nature, emphasizing its importance, and exploring the various options available. Central to this investigation, as seen above, is the application of Modern Portfolio Theory (MPT), particularly its focus on diversification. This study aims to use the robust framework provided by diversification to integrate biodiversity-focused investments into a broader portfolio. While numerous articles discuss the importance of biodiversity and the various asset types available for investment, there is a notable gap in providing tangible options for the average investor to construct a nature-conscious portfolio. This gap presents a unique opportunity to explore and propose actionable strategies that align with both financial goals and environmental sustainability.

To address this gap, I will propose two different portfolios that include the biodiversity focused index. When selecting a biodiversity-focused index for the portfolio, the MSCI World Select Natural Resources Index was chosen. Extensive research into its composition, efficiency, and adherence to high standards determined that this index perfectly embodies a commitment to nature. The MSCI World Select Natural Resources Index includes companies from developed markets that conduct tangible, extensive sustainable initiatives, with a strong emphasis on biodiversity conservation and efficient resource management. For more detailed information about the index's composition, sector, and regional distribution, please refer to the Index Factsheet.

Th first portfolio will diversify geographically, taking into consideration the main equity indexes for the United States, Europe and Asia. One of the chosen indexes was the S&P 500 which provides comprehensive exposure to 500 of the largest publicly traded companies in the United States, spanning a broad range of sectors. The index undergoes rebalancing on a quarterly basis, maintaining alignment with its sector weightings and market-cap criteria. By including this index, the portfolio benefits from the stability and growth potential of well-established U.S. companies, enhancing the overall risk-return profile through geographic and sectoral diversification (FactSet, 2024). The next selection for the portfolio was the EURO STOXX 50, a leading stock index that represents the performance of 50 large, blue-chip companies from 11 Eurozone countries. It is designed to provide a blue-chip representation of super sector leaders in the Eurozone. The index is widely used as a benchmark for European equity markets and includes major companies across diverse sectors such as financials, industrials, consumer goods, and

technology. Its constituents are selected based on free-float market capitalization, ensuring that the index reflects the economic performance and market sentiment of the Eurozone's most prominent companies (FactSet, 2024). To complete the geographic diversification, the S&P Asia 50 (SASIA50X) Index includes 50 leading companies from Hong Kong, South Korea, Taiwan, and Singapore, providing a tradable and easily replicable benchmark that represents the investable markets of Asia, excluding Japan. This index covers major sectors such as technology, finance, consumer goods, and industrials, and is weighted by market capitalization. It is rebalanced quarterly to reflect market changes and ensure accurate representation. Designed for liquidity and tradability, the S&P Asia 50 offers investors comprehensive exposure to the largest and most dynamic companies in these regions.

On the other hand, for the study we selected a few sectors that we thought might be interesting to explore how they merge with the biodiversity focused index. There are compelling reasons to invest specifically in the semiconductor, transportation, industrial, and nuclear energy sectors. These investments not only offer potential for high returns but also contribute to the concept hedging within the portfolio. The semiconductor industry is a cornerstone of modern technology, essential to produce electronic devices, including computers, smartphones, and various IoT devices. Investing in semiconductors provides exposure to a sector characterized by rapid innovation and high growth potential (Burkacky, Dragon, & Lehmann, McKinsey & Company, 2022). With the increasing demand for advanced technology and the expansion of AI and machine learning applications, the semiconductor market is poised for sustained growth. This sector's performance is typically less correlated with traditional equity markets, offering a hedge against market volatility (Burkacky, Mancini, Patel, Poltronieri, & Roundtree, 2024). To represent the semiconductor industry within the portfolio, the VanEck Vectors Semiconductor ETF (SMH) was chosen. This ETF tracks a market-cap-weighted index of 25 of the largest U.S.-listed semiconductor companies. SMH is highly concentrated, investing in common stocks and depositary receipts of semiconductor firms. It includes mid-cap companies and foreign companies listed in the U.S., provided that 50% of their revenues come from semiconductor production and equipment. Eligibility is determined by two key factors: free-float market capitalization and three-month average daily trading volume. The top 50 eligible companies by market cap are ranked based on these criteria. The highest-ranked 25 companies are then selected, with a capping scheme applied to ensure diversification and a greater weight assigned to larger companies. This methodology ensures that SMH provides focused yet diversified exposure to the leading players in the semiconductor industry (FactSet, 2024).

The industrial sector includes companies involved in manufacturing, construction, and infrastructure development. Investing in infrastructure offers several strategic advantages that complement a diversified portfolio. The unique return drivers of infrastructure projects mean that they are less influenced by market volatility and more by the specific economic and regulatory conditions governing them. This characteristic provides a stable return profile that is not reliant on market beta, making infrastructure investments a reliable source of income and growth. Moreover, the low correlation of infrastructure assets with other asset classes, such as equities and bonds, enhances portfolio diversification. By including infrastructure investments, investors can achieve a more balanced risk-return profile, reducing the overall volatility of their portfolios. This diversification is particularly valuable during periods of market instability, as infrastructure assets can provide a hedge against market fluctuations. For instance, a study by J.P. Morgan found that from 2008 to 2020, the correlation coefficient of private market infrastructure to both global bonds and global equities was -0.1. This low correlation makes infrastructure an attractive addition to a diversified portfolio, as it can provide stability and reduce overall portfolio volatility (Mercer, 2021). To represent this asset class we have chosen the iShares Global Industrials ETF (EXI) tracks a market-cap-weighted index of global industrial stocks. This fund provides exposure to a broad range of large-cap industrial firms worldwide, offering reasonably market-like coverage in a stable and accessible format. By focusing on larger companies, EXI excludes smaller firms and slightly overweight those that already have significant market dominance due to its market-cap weighting. Despite this, the fund avoids geographic biases and maintains a global perspective (FactSet, 2024).

Nuclear energy is a critical component of the global transition to clean energy. It offers a stable and substantial source of low-carbon electricity, essential for meeting climate goals and reducing greenhouse gas emissions. Investing in nuclear energy companies provides exposure to a sector that is likely to grow as countries strive to diversify their energy sources and reduce reliance on fossil fuels. The relatively stable and regulated nature of nuclear energy investments can also provide a steady income stream, contributing to the overall stability of the portfolio. I chose the following fund (IEA, 2019). The Global X Uranium ETF (URA) tracks a market-cap-weighted index of companies involved in uranium mining and the production of nuclear components. This fund provides investors with exposure to a diverse range of firms that are either exclusively engaged in the uranium industry or generate significant revenues from uranium-related activities. These activities include the extraction, refining, exploration, and manufacturing of equipment for the uranium and nuclear sectors. The fund's underlying index is reconstituted semi-annually to ensure it accurately reflects the current market landscape.

Prior to May 1, 2018, URA tracked the Solactive Global Uranium Index but has since transitioned to the Solactive Global Uranium & Nuclear Components Index, broadening its scope to include nuclear component production. This adjustment aims to better capture the performance of the uranium and nuclear industries on a global scale (FacSet).

Investing in the transportation sector offers notable advantages due to its critical role in facilitating economic growth and supporting infrastructure. Transportation companies are vital for the movement of goods and people, serving as a backbone for supply chains and benefiting significantly from periods of economic expansion, increased trade, and consumer spending. Additionally, this sector provides diversification benefits with its unique risk and return profiles, distinct from other sectors. (Fejfer & Wiggins, 2021). The fund chosen to represent this sector is the iShares US Transportation ETF (IYT), which follows a broad-based, modified market-cap-weighted index of U.S. transportation industry stocks. This index exclusively invests in companies classified by the Global Industry Classification Standard (GICS) as part of the transportation sector. It includes sub-industries such as air freight and logistics, airlines, airport services, highways and rail tracks, marine transport, marine ports and services, railroads, and trucking. To be eligible, securities must be part of the S&P Total Market Index and meet specific liquidity and capitalization requirements (FacSet, 2024).

The biodiversity-focused index, represented by the MSCI World Select Natural Resources Index, plays a crucial role in this diversified portfolio. While the chosen sectors (semiconductors, industrials, transportation and nuclear energy) offer high returns and hedging benefits, they might not be as proactive in promoting environmental sustainability. The biodiversity index offsets any potential negative impacts by ensuring that part of the portfolio is dedicated to companies with strong commitments to sustainable practices and biodiversity conservation. This integration of the biodiversity index ensures that the portfolio not only aims for optimal risk-adjusted returns but also supports environmental sustainability. By balancing investments in high-growth sectors with a commitment to biodiversity, the portfolio achieves a comprehensive and responsible investment strategy. This approach aligns with the broader goal of achieving financial stability while proactively contributing to the preservation of our natural environment.

Data & Methodology

In the methodology section of my academic essay, I will describe the process of determining the optimal portfolio composition through the application of a Python-based computational approach. This methodology will involve the calculation of daily returns (% change of the prices), expected returns, volatility, and the covariance and correlation matrix for the dataset in question. Subsequently, I will utilize Python's scipy.optimize.minimize function to optimize the portfolio by maximizing the Sharpe ratio, a measure of risk-adjusted return. Given that the minimize function inherently seeks to minimize a value, the optimization will be performed on the negative of the Sharpe ratio, effectively transforming the problem into one of minimization.

The optimization will proceed with the following parameters:

1. **Objective Function**: The negative Sharpe ratio, implemented in the function **_neg_sharpe_ratio(...)**.
2. **Initial Guess**: Capital allocation will start with an even distribution across all assets within the portfolio.
3. **Arguments**: These will be passed to the **_neg_sharpe_ratio(...)** function to calculate the necessary financial metrics.
4. **Optimization Method**: A method suitable for this type of financial optimization, as supported by **scipy**.
5. **Variable Boundaries**: Each weight $wiwi$ in the portfolio must satisfy $0 \leq wi \leq 10 \leq wi \leq 1$.
6. **Constraints**: Ensuring that the sum of all portfolio weights $\sum wi \sum wi$ equals 1, maintaining a fully invested portfolio.

This approach leverages modern computational tools to refine traditional portfolio theory applications, allowing for precise and dynamic portfolio management. As for the the data in this study, it spans across the last ten years, focusing on daily closing prices, or LEVEL EOD in the case of the indexes. This comprehensive dataset has been sourced from MSCI and FactSet, ensuring accuracy and reliability. By analyzing a decade's worth of daily closing prices, the study aims to provide in-depth insights into market trends, volatility, and the long-term performance of selected indexes and securities.

Results

Portfolio 1: Geographical Diversification

For the initial portfolio, which includes the S&P 500, EURO STOXX 50, S&P ASIA 50, and MSCI Global Select Natural Resources Index, the results were the following:

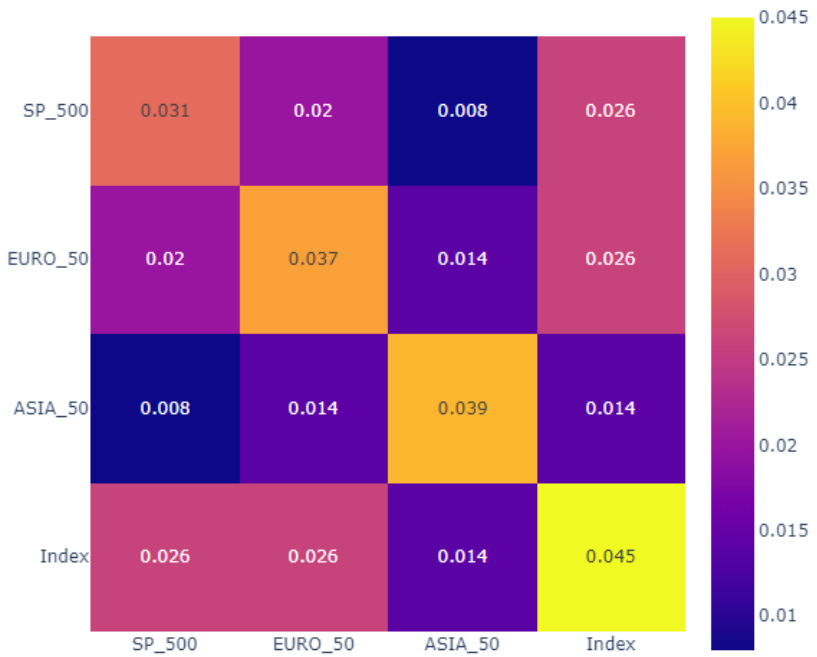
Table 1: Metrics

Asset	Expected Returns	Volatility
S&P 500	11.06%	17.68%
EURO STOXX 50	5.54%	19.35%
S&P ASIA 50	3.49%	19.72%
MSCI WORLD SECLECT NATURAL RESOURCES	4.93%	21.19%

Source: author's elaboration

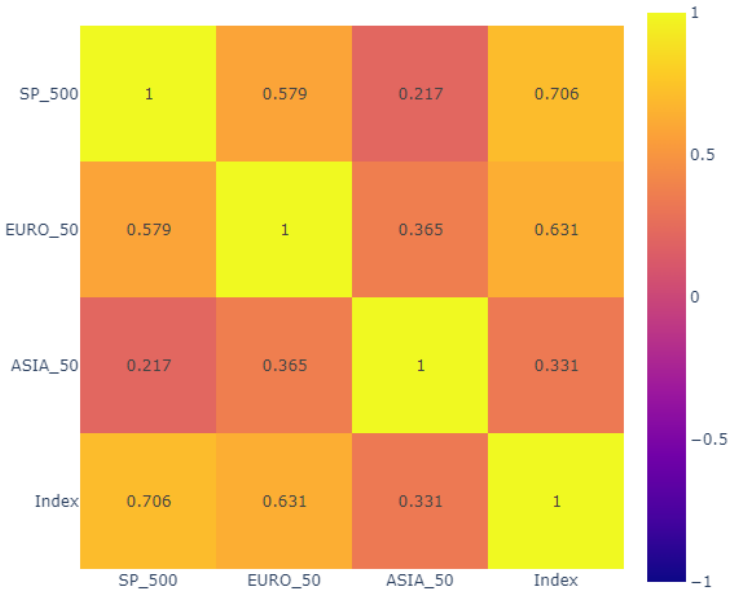
Next, we calculated the covariance matrix and the correlation matrix.

Figure 1: Covariance Matrix



Source: author's elaboration

Figure 2: Correlation Matrix



Source: author's elaboration

The correlation matrix indicates the degree of correlation between the different indexes.

- The S&P 500 has a moderate to high positive correlation with the EURO STOXX 50 (0.579) and the MSCI World Select Natural Resources Index (0.706), but a lower correlation with the S&P ASIA 50 (0.217).
- The EURO STOXX 50 has a lower correlation with the S&P ASIA 50 (0.365) and a moderate correlation with the MSCI World Select Natural Resources Index (0.631).
- The S&P ASIA 50 has a lower correlation with both the S&P 500 (0.217) and the MSCI World Select Natural Resources Index (0.331).

The tangent portfolio, with the constraint that all assets must be included, has the following asset weights:

Table 2: Tangent Portfolio Composition

Asset	Weight
SP_500	94.6%
ASIA_50	3.4%
EURO_50	1.0%
MSCI GLOBAL SELECT WORLD NATURAL RESOURCES	1.0%

Source: author's elaboration

This portfolio achieves an expected return of 10.7% with a volatility of 17.1%. The high weight of the S&P 500 (94.6%) indicates that the optimization heavily favors this index due to its higher

expected return and moderate volatility compared to the other indexes. The low weights assigned to the S&P ASIA 50, EURO STOXX 50, and MSCI World Select Natural Resources Index suggest that these assets provide less contribution to the overall portfolio's return per unit of risk.

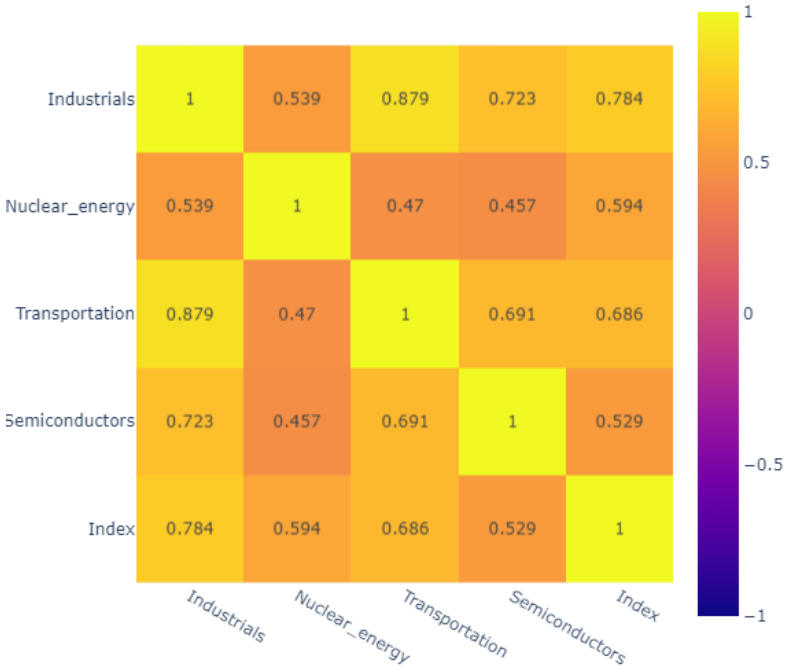
The correlations among the indexes play a crucial role in diversification. Despite the lower expected returns, the inclusion of the EURO STOXX 50 and the S&P ASIA 50 helps to diversify the portfolio due to their lower correlations with the S&P 500. The MSCI World Select Natural Resources Index, while having the highest volatility, is included in the portfolio likely due to its lower correlation with the S&P ASIA 50, thus providing some diversification benefit.

The expected return of the portfolio (10.7%) is slightly lower than the S&P 500 alone, but the volatility (17.1%) is also slightly reduced. This demonstrates the effect of diversification in reducing risk while maintaining a relatively high return. Including the MSCI World Select Natural Resources Index aligns with the goal of incorporating ESG principles, particularly focusing on biodiversity. Although it has a small weight, its inclusion reflects a commitment to sustainable investing.

Portfolio 2: Sectorial Diversification

After careful consideration for the behavior of the sectors discussed above and how they may behave when studied together. The correlation matrix revealed significant correlations among these sectors and the biodiversity-focused index which suggests that the proposed sectorial diversification does not provide sufficient diversification benefits. Instead, the portfolio exhibits high volatility with relatively little return, as the assets tend to move together. This high correlation undermines the intended effect of diversification, leading to a portfolio that is more volatile and less effective in achieving a balanced risk-return profile. To achieve better diversification, it is essential to include sectors or assets that have lower correlations with each other and with the biodiversity index.

Figure 3: Correlation Matrix



Source: author's elaboration

Conclusion

This study highlights the critical need for integrating biodiversity-focused investments into modern portfolio strategies, especially considering recent developments such as the UN's COP 15 and the Taskforce on Nature-related Financial Disclosures (TNFD). Biodiversity has emerged as a significant theme in the investment community, with several funds specifically dedicated to this area. Despite the awareness of these issues, there remains a significant gap in funding for biodiversity conservation. An estimated $824 billion is required to adequately protect and restore nature, yet current expenditures are only a fraction of this amount. The financial sector has historically prioritized climate change due to its more straightforward metrics, while biodiversity's complex value metrics have lagged. According to MSCI Research, as of Q3 2023, approximately USD 1 billion is managed across 15 biodiversity-labeled funds, with a broader range of biodiversity-related funds managing around USD 59 billion. Despite the growing interest, biodiversity-focused funds still face challenges, particularly in terms of risk-adjusted returns and sector diversification. Many of these funds are heavily invested in cyclical sectors like industrials and information technology, which can lead to increased volatility. Additionally, a significant portion of the assets under management in these funds is concentrated in equity from developed markets, indicating a need for greater asset-class diversification.

The analysis conducted in this study demonstrates the potential for creating a well-balanced portfolio that incorporates biodiversity-focused investments while achieving competitive financial returns. By utilizing indices such as the S&P 500, EURO STOXX 50, S&P ASIA 50, and MSCI World Select Natural Resources Index, the constructed portfolio achieves an expected return of 10.7% with a volatility of 17.1%. This balance between risk and return highlights the feasibility of integrating environmental sustainability into profitable investment strategies. Guided by Modern Portfolio Theory (MPT), which advocates for diversification to minimize risk and maximize returns, the portfolio allocation was designed to meet the needs of the average investor. While the allocation to the biodiversity-focused index is relatively low to maintain a return-driven portfolio suitable for the average investor, it nonetheless provides a practical means for everyday investors to contribute to biodiversity conservation within their financial capabilities.

Green and biodiversity-focused bonds represent another promising area within the sustainable finance market. These bonds, particularly those adhering to the Green Bond Principles, are designed to fund projects with positive environmental outcomes. The growing issuance of

biodiversity-related bonds, including innovative instruments like Sustainability-Linked Bonds, reflects increasing investor interest and the potential for substantial financial returns.

In conclusion, this research contributes to the ongoing dialogue on sustainable investing by providing a practical example of how biodiversity can be integrated into investment portfolios. By continuing to develop innovative financial instruments and frameworks that support biodiversity, the financial sector can play a pivotal role in addressing ecological risks and promoting long-term economic stability. This approach not only supports environmental goals but also aligns with the broader agenda of sustainable development, ensuring that investments today contribute to a healthier and more resilient planet for future generations.

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Fecha: 05/06/2024

Firma: ___Lucía Grau Torres_____

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