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Research Article

Sustainability-Cantered Portfolio Management: A BCG Matrix Approach to Climate-Resilient Investments: A Systematic Literature Review

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ABSTRACT

The BCG Matrix, traditionally a business strategy tool, has gained relevance in addressing climate change and sustainability challenges in investment portfolios. This study investigates the integration of the BCG Matrix into sustainability-focused investment strategies, with an emphasis on climate change implications. The research aims to develop a comprehensive model aligning portfolio management practices with long-term sustainability goals by identifying key clusters of sustainable investments and assessing their growth potential and market share within the context of climate-related risks. A systematic literature review was conducted using the Scopus database, following PRISMA guidelines. The final dataset comprised 57 publications from 2010 to 2024, spanning various disciplines. Content analysis and bibliometric techniques were employed to identify trends, key terms, and research clusters. The analysis revealed three distinct clusters: "Investment Portfolios Amid Climate Change and Uncertainty," "Sustainable Portfolios: Market, Stocks, and Risk Management," and "Energy Portfolios: Sustainable Usage and Building Strategies." The research landscape showed a shift from general climate change investment portfolios towards sustainable market approaches and energy-specific strategies. The study's findings led to the development of the Sustainable Investment Portfolio Optimization (SIPO) Framework, which adapts the BCG Matrix to include climate resilience factors. This novel approach provides investors with a tool for strategic resource allocation, balancing short-term returns with long-term sustainability goals. Future research directions include incorporating real-time market data, exploring sector-specific applications, and integrating machine learning techniques for enhanced predictive capabilities. Longitudinal studies tracking the performance of sustainability-focused portfolios are also recommended to assess the long-term efficacy of these strategies in the face of climate change.

Keywords: BCG Matrix, Climate-Resilient Investments, Sustainable Portfolio Management, Climate Change Adaptation, sustainability

INTRODUCTION

The BCG Matrix approach to Climate-Resilient Investments offers a strategic framework for evaluating and balancing investment portfolios in the context of climate change risks and opportunities (Sorrentino, 2023). This adaptation of the traditional Growth-Share Matrix allows investors to categorize climate-related investments based on their market growth potential and relative market share, while incorporating climate resilience factors (Tsvakirai, 2021). For instance, renewable energy technologies like solar and wind power might be classified as "Stars" due to their high growth potential and increasing market share (Jiang et al., 2022). Conversely, certain fossil fuel investments could be

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seen as "Cash Cows" or even "Dogs" depending on their current market position and prospects under climate change scenarios (Sushil & Dhir, 2024). The "Question Marks" quadrant might include emerging climate adaptation technologies or green infrastructure projects with high growth potential but uncertain market share (Litchfield, 2020). This approach enables investors to strategically allocate resources, balancing short-term returns with long-term sustainability and resilience (Peeters, 2021). By integrating climate risk assessments and sustainability metrics into the BCG Matrix framework, investors can make more informed decisions that align financial performance with climate resilience goals ((Khan & Qureshi, 2020; Kurznack et al., 2021), ultimately contributing to a more sustainable and adaptive investment landscape.

In addition, the BCG Matrix approach to Climate-Resilient Investments builds upon several theoretical foundations. Portfolio theory, as pioneered by (Markowitz, 1952), provides the basis for risk diversification and optimal asset allocation (Caldecott, 2018). This theory has been extended to incorporate sustainability factors, as demonstrated by (Gutsche et al., 2016) in their analysis of socially responsible investing. The concept of climate risk integration into investment decisions draws from the work of (Watkiss, 2015), who reviewed economic decision support tools for adaptation assessment. The application of strategic management tools to sustainability challenges is supported by the research of (Grubler et al., 2015a) on modeling approaches for coping with climate change uncertainties. Furthermore, the growing body of literature on ESG investing, exemplified by (Wang et al., 2024), provides empirical evidence for the financial relevance of sustainability factors. These theoretical underpinnings, combined with the practical insights from sector-specific studies like those by (Cucchiella, D'Adamo, et al., 2017) on energy investments, form a robust foundation for adapting the BCG Matrix to climate-resilient investment strategies.

While previous research has made significant strides in exploring the relationship between sustainability practices and financial performance (Cowan & Guzman, 2020; Saeidi et al., 2015), there remains a pressing need for a comprehensive framework that effectively integrates climate risk assessments into traditional portfolio analysis tools like the BCG Matrix. This study directly addresses this gap by proposing to develop such a framework, focusing on the adaptation of the BCG Matrix to sustainability-focused investment strategies (Jain et al., 2021). The challenge of accurately assessing growth potential and market share in the context of long-term climate change impacts, as highlighted by (Mustapha, Khan, Qureshi, Sikandar, Hassan, et al., 2024; Watkiss, 2015), is a key consideration in this research. By identifying key clusters of sustainable investments and assessing their growth potential and market share within the context of climate-related risks, this study aims to provide a more nuanced and forward-looking approach to portfolio management (Kurittu et al., 2023).

Furthermore, while sector-specific studies (Smith, 2018; Sridharan, 2021) offer valuable insights, their limited generalizability across industries has been a significant limitation. This study seeks to overcome this by developing a comprehensive model that can be applied across various sectors, thus providing a more holistic approach to climate-resilient investment strategies. The dynamic and uncertain nature of climate change, emphasized by (Grubler et al., 2015a; Mustapha, Khan, Qureshi, Sikandar, & Nu'man, 2024), poses challenges for static models. This research aims to address this limitation by incorporating flexibility and adaptability into the proposed framework, allowing for the consideration of both mitigation and adaptation strategies in investment portfolio analyses. By addressing these gaps and limitations, this study aims to contribute significantly to the field of sustainable finance and climate-resilient investing. The development of a comprehensive model that aligns portfolio management practices with long-term sustainability goals will provide investors, policymakers, and researchers with a valuable tool for navigating the complex landscape of climate change and sustainable investments.

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1.1. METHODOLOGY

This systematic literature review employs a comprehensive methodology to explore the application of the BCG Matrix in climate change and sustainability contexts. The review follows the PRISMA guidelines to ensure transparency and reproducibility (Moher et al., 2009).

SEARCH STRATEGY

The literature search was conducted using the Scopus database, known for its extensive coverage of peer-reviewed literature (Doğan, 2022). The search string combined BCG Matrix-related terms with climate change and sustainability concepts: ("BCG Matrix" OR "Growth-Share Matrix" OR "Portfolio Analysis") AND ("Climate Change" OR "Global Warming" OR "Sustainability"). This approach aligns with recommendations by (Popay et al., 2006) for comprehensive search strategies in systematic reviews.

The search was limited to publications from 2010 to 2024, reflecting the recent developments in applying business tools to environmental challenges. The initial search yielded 86 results, which was narrowed to 81 after applying the time frame filter. Further refinement to include only articles, book chapters, and reviews resulted in 59 publications.

To ensure relevance, the search was focused on key subject areas: Environmental Science (24), Social Sciences (21), Energy (20), Business, Management and Accounting (15), Economics, Econometrics and Finance (15), Engineering (10), and Agricultural and Biological Sciences (5). This interdisciplinary approach is crucial for capturing the diverse applications of the BCG Matrix in sustainability contexts (Schoolman et al., 2012). The final dataset, after filtering for publication stage and English language, comprised 57 publications. The figure 1 below of PRISMA 2020 is illustrating the inclusion and exclusion of documents for the current study (Khan et al., 2020; Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., 2009).

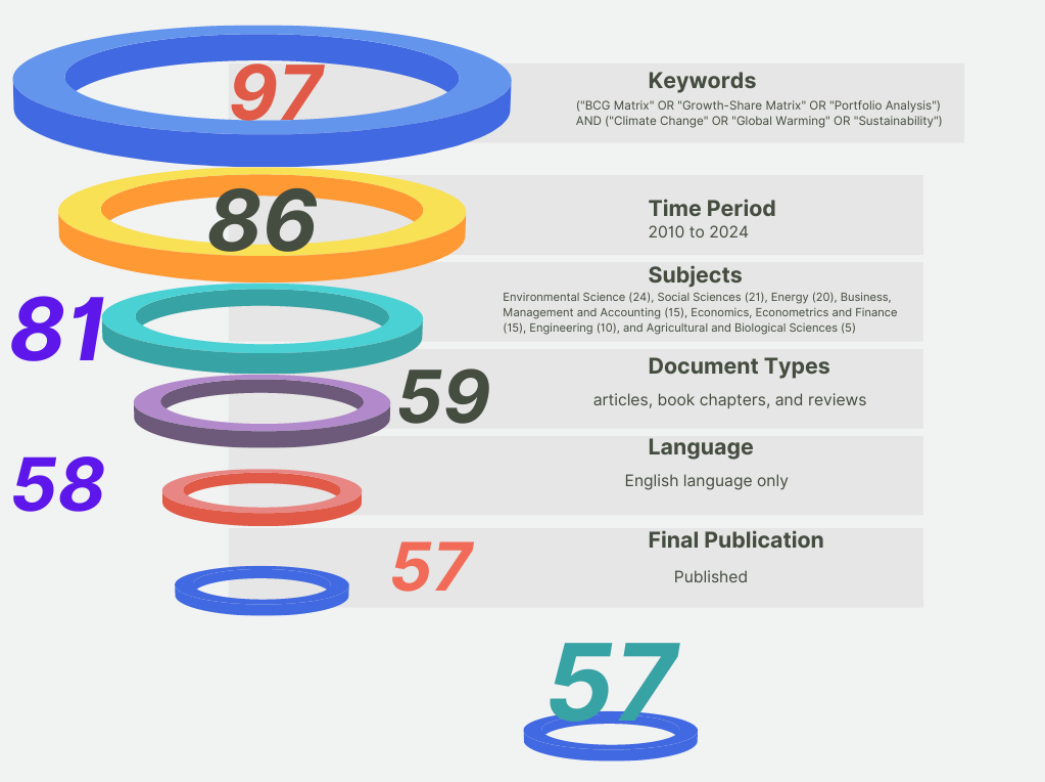

Figure 1: PRISMA statement for inclusion and exclusion of the documents

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INCLUSION AND EXCLUSION CRITERIA

The review includes peer-reviewed articles in English that explicitly discuss or apply the BCG Matrix in relation to climate change or sustainability. This criterion ensures the relevance and academic rigor of the included studies. Studies that only mention the BCG Matrix without substantial discussion or application are excluded, as are non-academic sources, to maintain the scholarly focus of the review.

DATA EXTRACTION AND QUALITY ASSESSMENT

Data extraction follows a structured approach, capturing key elements such as author(s), publication year, study objectives, methodology, key findings, BCG Matrix application, and identified strengths and limitations. This comprehensive data extraction allows for a thorough analysis of the literature.

The quality of included studies will be assessed using an adapted version of the Critical Appraisal Skills Programme (CASP) checklist. This tool provides a systematic method for evaluating the methodological quality and relevance of studies in systematic reviews.

This methodology ensures a rigorous and transparent approach to reviewing the literature on the BCG Matrix's application in climate change and sustainability contexts, providing a solid foundation for synthesis and analysis.

1.2.RESULTS
DESCRIPTIVE ANALYSIS OF INCLUDED STUDIES

The bibliometric analysis of literature on the BCG Matrix's application to climate change and sustainability from 2010 to 2024 reveals a dynamic and rapidly evolving field of study. With 57 documents published across 44 sources, the research area demonstrates significant diversity and interdisciplinarity. The annual growth rate of 6.76% indicates increasing scholarly interest, while the average of 20.61 citations per document suggests that this research is making a substantial impact. The predominance of articles (50 out of 57 documents) points to a focus on primary research, though the presence of book chapters and reviews indicates the field is mature enough for synthesizing works. The research landscape is characterized by collaborative efforts, with an average of 3.44 co-authors per document and 26.32% international co-authorships, reflecting the complex, multifaceted nature of climate change and sustainability issues that often require diverse expertise. The rich keyword data, with 475 Keywords Plus and 226 Author's Keywords, underscores the breadth of topics and applications being explored. This variety suggests that researchers are adapting the BCG Matrix, traditionally a business strategy tool, to a wide range of sustainability contexts. The relatively young average age of documents (5.7 years) further emphasizes the field's currency and rapid development. Collectively, these bibliometric indicators paint a picture of a vibrant, collaborative, and impactful research area that is bridging business strategy with environmental concerns, potentially offering novel approaches to addressing climate change and sustainability challenges. Table 1 below show the information of the documents from 2010 to 2024.

Table 1: Main information of the documents extracted

Description	**Results**
Timespan	2010:2024
Sources (Journals, Books, etc)	44
Documents	57
Annual Growth Rate %	6.76
Document Average Age	5.7
Average citations per doc	20.61

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References	2803
Keywords Plus (ID)	475
Author's Keywords (DE)	226
Authors	171
Authors of single-authored docs	3
Single-authored docs	3
Co-Authors per Doc	3.44
International co-authorships %	26.32
article	50
book chapter	4
review	3

In addition, the annual production of documents on the application of the BCG Matrix to climate change and sustainability issues from 2010 to 2024 exhibits a general upward trend, albeit with notable fluctuations. The field saw a modest start with 2 articles published in both 2010 and 2011, followed by a slight increase to 3 in 2012. A dip occurred in 2013 with only 1 publication, but this was followed by a rebound to 4 articles in both 2014 and 2015. After a brief decline to 2 publications in 2016, the field experienced its first significant spike in 2017 with 7 articles. The following years showed some variability: 3 articles in 2018, a decrease to 2 in 2019, and then another notable increase to 6 publications in 2020. The year 2021 saw a slight dip to 3 articles, but this was followed by the most productive year in the dataset, with 9 articles published in 2022. The field maintained strong output in the final two years of the period, with 4 articles in 2023 and 5 in 2024. Figure 2 below showing the annual production of documents from 2010-2024.

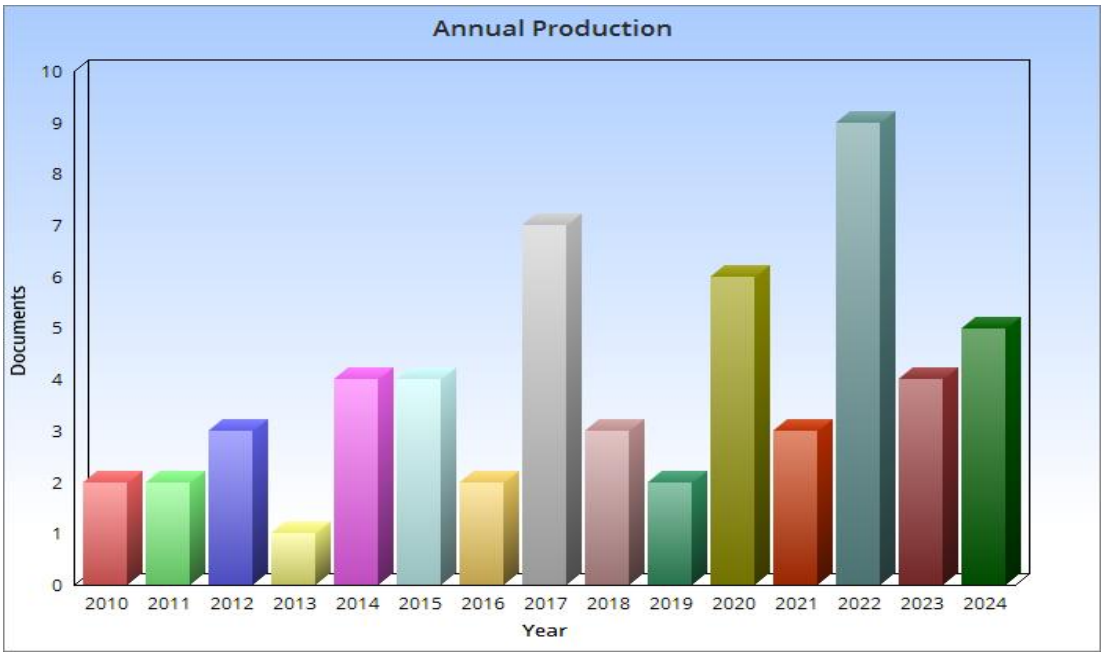

Figure 2: Annual production of the articles

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Furthermore, the distribution of articles across major sources, as depicted in Figure 3, provides valuable insights into the interdisciplinary nature of research applying the BCG Matrix to climate change and sustainability issues. "Sustainability (Switzerland)" emerges as the leading publication venue with 5 articles, highlighting its significant role in disseminating research in this field. The "Journal of Cleaner Production" and the "Journal of Sustainable Finance and Investment" follow closely, each contributing 3 articles, which underscores the relevance of the BCG Matrix in both production processes and financial aspects of sustainability. A cluster of journals, including the "African Journal of Food, Agriculture, Nutrition and Development," "Energy Economics," "Energy Policy," and "Renewable and Sustainable Energy Reviews," each published 2 articles, demonstrating the wide-ranging applications of the BCG Matrix across sectors such as agriculture, energy, and policy. The inclusion of "Sustainable Cities and Society" with 2 articles indicates the tool's relevance to urban sustainability challenges. "Buildings," with 1 publication, rounds out the list, suggesting potential applications in sustainable architecture or urban planning.

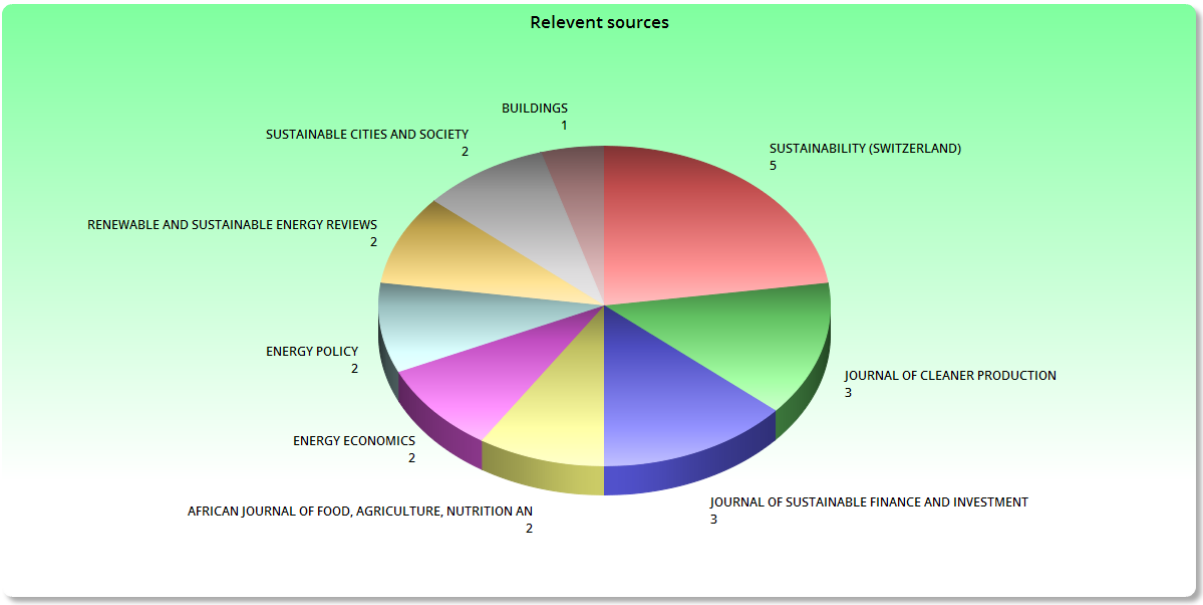

Figure 3: relevant sources

Moreover, Figure 4 presents a compelling overview of the most cited papers in the field of BCG Matrix application to climate change and sustainability, offering insights into the most influential works and their impact over time. The data encompasses total citations, citations per year, and normalized citation counts, providing a multifaceted view of each paper's influence. (Yeh et al., 2010) paper stands out as the most cited overall with 151 citations, indicating its seminal role in the field, though its normalized citation count suggests its influence may be waning relative to newer publications. (Watkiss et al., 2015; Ziegler et al., 2011) paper follow with 99 and 93 citations respectively, demonstrating sustained impact. Notably, (Ando & Mallory, 2012) paper shows remarkable recent influence with the highest citations per year (16.60), despite its relatively recent publication. (Zhang et al., 2022) paper exhibits a similar trend with 15.67 citations per year and the highest normalized citation count (4.23), suggesting it may be setting a new direction in the field. The presence of papers from various years (2010 to 2022) in this top-cited list indicates that both foundational works and recent contributions are shaping the discourse. The range of normalized citation counts (from 1.30 to 4.23) further illustrates the dynamic nature of the field, with newer papers often showing higher relative impact.

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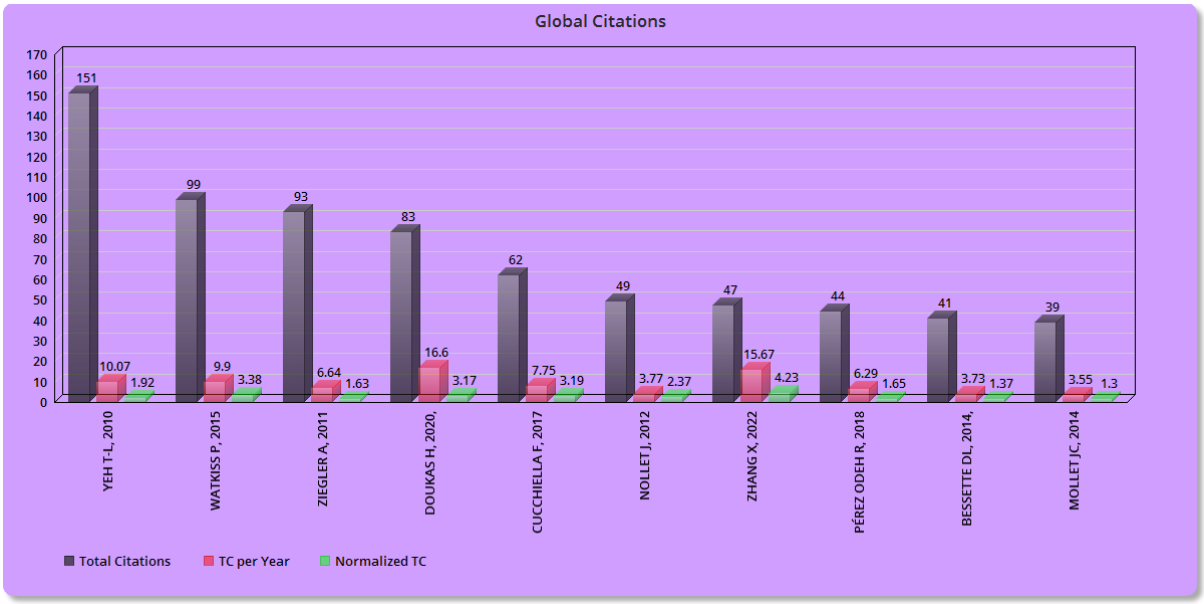

Figure 4: major global citations

1.3.CONTENT ANALYSIS

RStudio has emerged as a powerful tool for conducting content analysis, offering researchers a versatile environment for text mining, topic modeling, and advanced linguistic analysis (Welbers et al., 2017). Its integration with R's extensive ecosystem of packages makes it particularly suitable for handling large-scale textual data (Hvitfeldt & Silge, 2021). The analysis of key terms in the literature on applying the BCG Matrix to climate change and sustainability issues reveals significant trends in research focus is showing in Table 2. "Climate change" emerges as the dominant theme, appearing 27 times and constituting 14.21% of all key terms, underscoring its central role in this research area. The prominence of "risk assessment" and "uncertainty analysis," each occurring 13 times (6.84%), highlights the emphasis on evaluating and managing climate-related risks and uncertainties. "Portfolio analysis," appearing 12 times (6.32%), reflects the core application of the BCG Matrix in this context. Terms like "sustainable development" (4.74%), "decision making" (4.21%), and "sustainability" (4.21%) indicate the broader goals and contexts of these studies. The frequent occurrence of economic terms such as "investments" (3.68%) and "economic analysis" (3.16%) suggests a strong focus on the financial aspects of climate change mitigation and adaptation. Energy-related terms, including "energy efficiency" and "energy utilization" (each 3.16%), point to a significant focus on the energy sector. The presence of terms like "cost benefit analysis" (2.63%) and "optimization" (2.11%) indicates that researchers are employing the BCG Matrix within broader analytical frameworks for decision-making in sustainability contexts

Table 2: Frequency and Percentage of Key Terms in Literature

Terms	**Frequency**	**Percentage**
climate change	27	14.21%
risk assessment	13	6.84%
uncertainty analysis	13	6.84%
portfolio analysis	12	6.32%
sustainable development	9	4.74%
decision making	8	4.21%

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sustainability	8	4.21%
investments	7	3.68%
united states	7	3.68%
commerce	6	3.16%
economic analysis	6	3.16%
energy efficiency	6	3.16%
energy utilization	6	3.16%
global warming	6	3.16%
investment	6	3.16%
cost benefit analysis	5	2.63%
costs	5	2.63%
economic and social effects	5	2.63%
environmental policy	5	2.63%
greenhouse gases	5	2.63%
decision support system	4	2.11%
energy conservation	4	2.11%
optimization	4	2.11%
uncertainty	4	2.11%
climate models	3	1.58%

In addition, the co-occurrence network in Figure 5 provides a visual representation of the key terms and their relationships in the literature applying the BCG Matrix to climate change and sustainability issues, closely aligning with the frequency data presented in Table 4. The network's central and largest nodes – "climate change," "portfolio analysis," "uncertainty analysis," and "risk assessment" – correspond to the most frequent terms in Table 4, highlighting the core focus of the research. The strong interconnections between these nodes illustrate how the BCG Matrix (represented by "portfolio analysis") is being applied to assess and manage climate-related risks and uncertainties. The prominence of "sustainable development" in both the network and Table 4 underscores its significance in this context. Economic and energy-related terms such as "investments," "energy efficiency," and "cost benefit analysis" feature noticeably in both representations, reflecting the research's practical implications. Policy and decision-making aspects are also evident, with terms like "environmental policy" and "decision making" appearing in both the network and frequency table. Geographical references, particularly to the United States, and specific climate-related terms like "global warming" and "greenhouse gases" further contextualize the research focus

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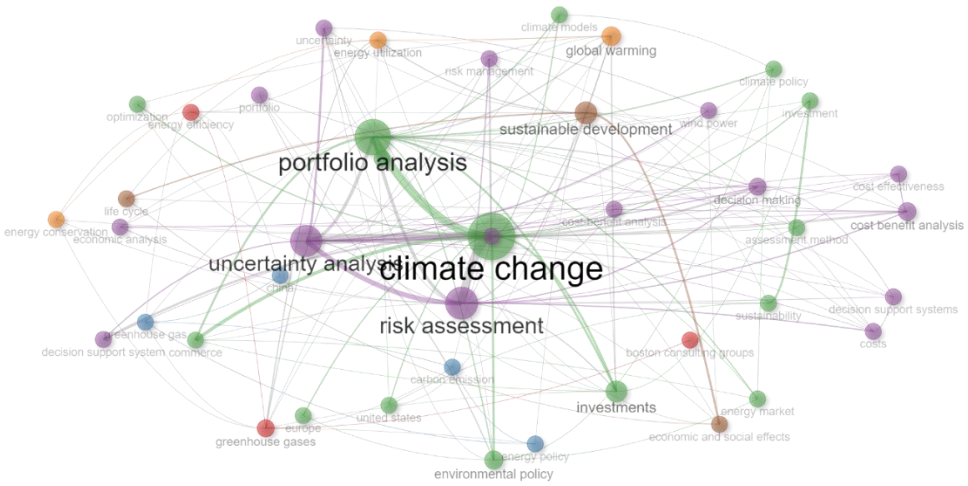

Figure 5: co-occurrence Network

Furthermore, Figure 6 presents a word cloud that visually represents the key terms and concepts prevalent in the literature applying the BCG Matrix to climate change and sustainability issues. The size of each word corresponds to its frequency of occurrence in the analyzed texts. "Climate change" dominates the cloud, indicating its central role in this research area. Other prominent terms include "uncertainty analysis," "portfolio analysis," "sustainable development," and "risk assessment," which align with the core themes of applying the BCG Matrix in this context. The cloud also highlights the multifaceted nature of the research, encompassing economic aspects ("investments," "economic analysis," "cost benefit analysis"), energy-related terms ("energy efficiency," "energy utilization"), policy considerations ("environmental policy," "climate policy"), and methodological approaches ("decision making," "decision support systems"). Geographical references like "United States" and "China" suggest a focus on these regions. The presence of terms such as "global warming," "greenhouse gases," and "carbon emission" underscores the specific climate-related issues being addressed. Additionally, the inclusion of industry-specific terms like "electric power transmission" and "photovoltaic system" indicates the application of these concepts across various sectors.

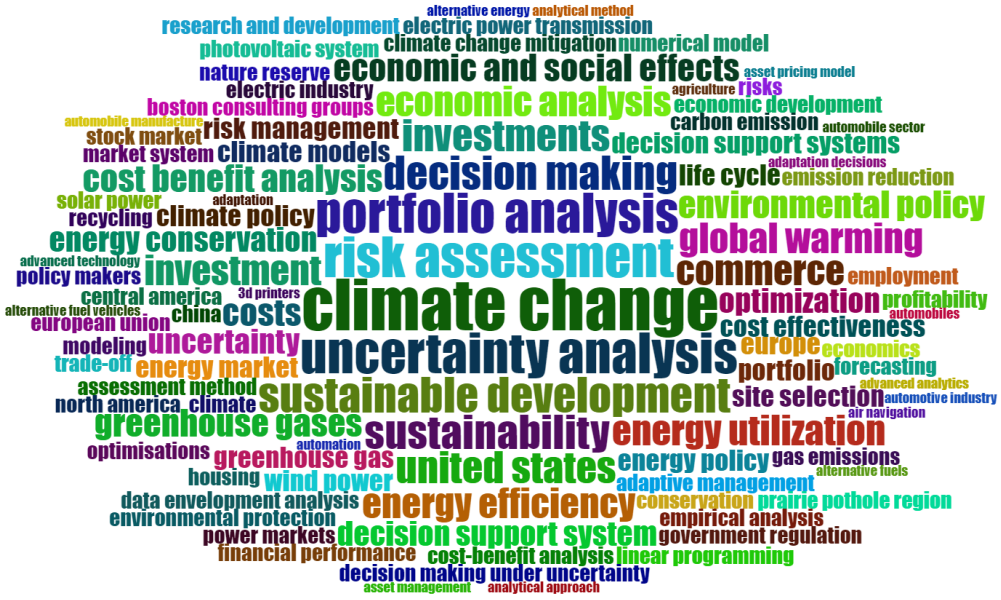

Figure 6: word cloud the key terms and concepts prevalent

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1.4.FACTORIAL ANALYSIS

This figure 7 presents a Conceptual Structure Map using Multidimensional Scaling (MDS) to visualize the relationships between various concepts in the field of climate change, sustainability, and portfolio analysis. The map is plotted on two dimensions, with each point representing a key term or concept from the literature.

The distribution of terms reveals several clusters and patterns:

1. Economic and analytical concepts (e.g., "cost-benefit analysis," "optimization," "linear programming") are scattered across the upper half of the map.

2. Energy-related terms (e.g., "energy conservation," "energy efficiency," "power markets") are concentrated in the central-right area.

3. Environmental and policy-related concepts (e.g., "environmental protection," "climate policy," "greenhouse gases") are spread around the periphery.

4. Investment and market-related terms (e.g., "portfolio analysis," "stock market," "financial performance") are mostly located in the lower half.

5. Geographical references ("United States," "China," "European Union") are dispersed, indicating global relevance.

The proximity of terms suggests thematic relationships. For instance, "portfolio analysis" is near "sustainability" and "investment," indicating their close association in the literature. The central position of terms like "decision making" and "uncertainty" suggests their cross-cutting importance across different aspects of the field.

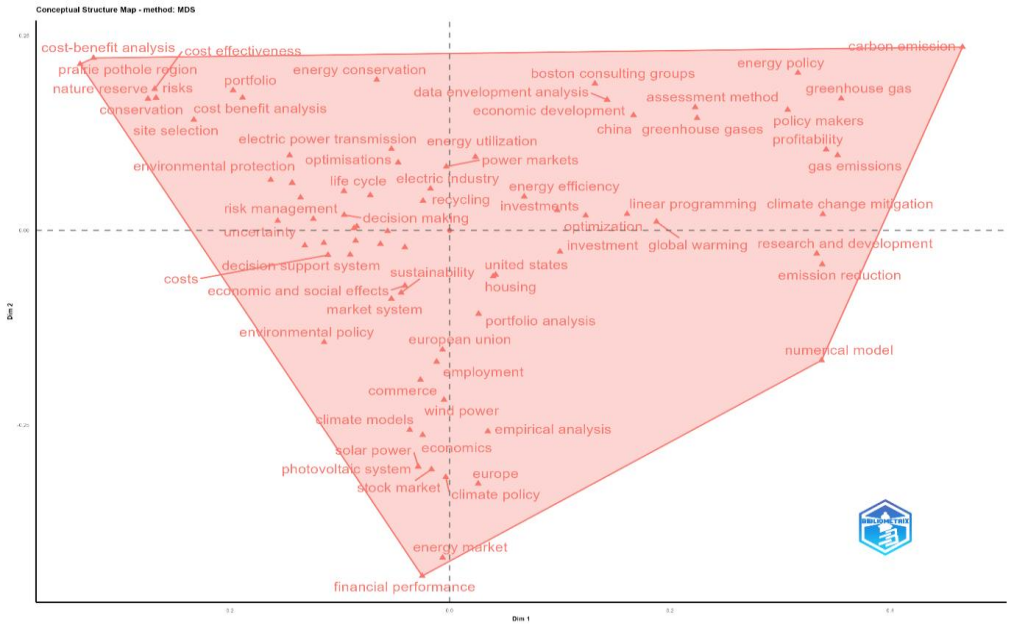

Figure 7: Factorial analysis

1.5.CLUSTER IDENTIFICATION

The study also identified the major research clusters, Table 3 presents a cluster analysis of the research topics related to the application of the BCG Matrix in climate change and sustainability contexts. The table identifies three distinct clusters, each representing a major theme in the literature. The first cluster, "Investment Portfolios Amid Climate Change and Uncertainty," has the highest Callon Centrality (11.317), indicating its strong connections to other research areas, and a high Cluster Frequency (95),

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suggesting it's a dominant theme. The second cluster, "Sustainable Portfolios: Market, Stocks, and Risk Management," has the lowest Callon Centrality (6.097) and Cluster Frequency (31), but ranks first in both Centrality and Density, implying it's a well-defined, cohesive research area. The third cluster, "Energy Portfolios: Sustainable Usage and Building Strategies," shows a balance between centrality (8.431) and the highest density (155.602), with a relatively high frequency (70), suggesting it's a distinct, well-developed research area with strong internal connections. These clusters highlight the multifaceted nature of the research, spanning investment strategies, sustainable market approaches, and energy-focused portfolios, all within the context of climate change and sustainability.

Table 3: clusters identification

Cluster	Callon Centrality	Callon Density	Rank Centrality	Rank Density	Cluster Frequency
Investment Portfolios Amid Climate Change and Uncertainty	11.317	98.73	4	3	95
Sustainable Portfolios: Market, Stocks, and Risk Management	6.097	67.833	1	1	31
Energy Portfolios: Sustainable Usage and Building Strategies	8.431	155.602	3	4	70

In addition, this figure 8 illustrates the trend of cluster 1: "Investment Portfolios Amid Climate Change and Uncertainty" over the period from 2010 to 2024. The y-axis represents the expected topic prevalence, while the x-axis shows the years. The solid red line in the middle represents the mean trend, with the dotted lines above and below indicating the 95% confidence interval. The trend shows a gradual decline in the prevalence of this topic over time. Starting from a higher prevalence in 2010, there is a consistent downward slope until about 2020. After 2020, the trend line appears to flatten slightly, suggesting a possible stabilization of interest in this topic. However, the overall trajectory remains downward. The widening confidence interval, particularly noticeable from 2020 onwards, suggests increasing uncertainty in the topic's prevalence in more recent years. This could indicate a diversification of research focus within this area or less consensus among researchers about its importance. Despite the declining trend, the topic remains relatively prevalent throughout the entire period, never dropping below an expected prevalence of 0.3.

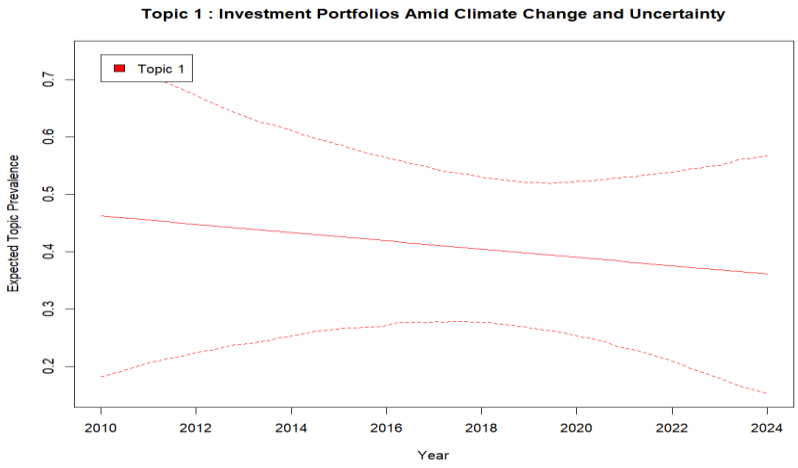

Figure 8: Trends of the Investment Portfolios Amid Climate Change and Uncertainty

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Furthermore, Figure 9 illustrate the cluster 2, "Sustainable Portfolios: Market, Stocks, and Risk Management," shows a markedly different trend compared to Cluster 1. While cluster 1 exhibited a declining trend, cluster 2 demonstrates a steady increase in expected topic prevalence from 2010 to 2024. The solid red line, representing the mean trend, shows a consistent upward trajectory, starting from around 0.27 in 2010 and reaching approximately 0.35 by 2024. This suggests a growing interest and research focus on sustainable portfolios, market dynamics, stocks, and risk management in the context of climate change and sustainability. Unlike cluster 1's narrowing confidence interval, Topic 2's confidence interval (represented by the dotted lines) widens significantly over time, particularly from 2020 onwards. This widening indicates increasing uncertainty or variability in the topic's prevalence in recent years, possibly reflecting a diversification of research approaches or a broadening of the subject matter within this area.

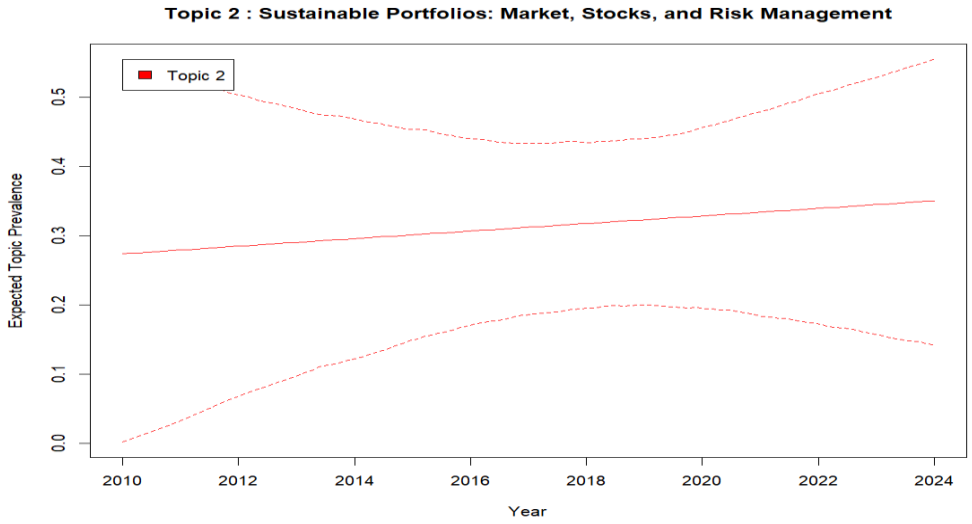

Figure 9: Trends in Sustainable Portfolios: Market, Stocks, and Risk Management

Moreover, Figure 10 illustrate the cluster 3, "Energy Portfolios: Sustainable Usage and Building Strategies," exhibits a trend that combines elements from both cluster 1 and cluster 2, while also showing its own unique characteristics. Similar to cluster 2, cluster 3 demonstrates an overall upward trend in expected topic prevalence from 2010 to 2024, but the increase is more gradual. The mean trend line (solid red) shows a steady, modest rise from about 0.26 in 2010 to approximately 0.29 by 2024. This suggests a growing, albeit slower, interest in energy portfolios and sustainable building strategies compared to the more rapid rise of sustainable market portfolios in Topic 2.

Unlike the declining trend of cluster 1 and the steeper rise of cluster 2, cluster 3's growth is more moderate, indicating a consistent but measured increase in research focus on energy-related sustainability issues. The confidence interval for cluster 3 is notably wider than both cluster 1 and cluster 2, particularly in the later years. This wide interval suggests a high degree of variability or uncertainty in the topic's prevalence, possibly reflecting the diverse and evolving nature of energy portfolio research and sustainable building strategies. The trends across all three topics suggest a shifting landscape in climate change and sustainability research related to the BCG Matrix.

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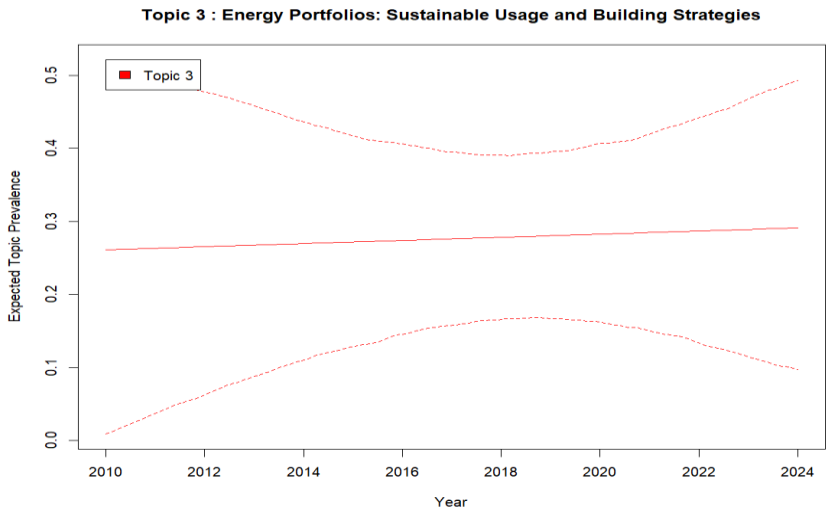

Figure 10: trends in Energy Portfolios: Sustainable Usage and Building Strategies

1.6.DISCUSSION

The integration of portfolio analysis frameworks, particularly the BCG Matrix, into sustainability-focused investment strategies is a complex endeavor that requires a multifaceted approach. The first cluster, "Investment Portfolios Amid Climate Change and Uncertainty," directly addresses the core challenge of integrating climate change considerations into investment decisions. This cluster emphasizes the need for adaptive and resilient investment strategies in the face of climate-related uncertainties, which is crucial for developing a comprehensive model that aligns portfolio management with long-term sustainability goals. For instance, (Zakari et al., 2022) discussed the importance of considering climate change impacts on renewable energy investments, demonstrating how climate uncertainties can affect the growth potential of sustainable energy portfolios. Similarly, (Forouli et al., 2019) provide insights into optimizing technological portfolios for power generation in the context of climate change mitigation, which is essential for identifying key clusters of sustainable investments within the energy sector.

In addition, the work of (Ziegler et al., 2011) and (Ferrat et al., 2022) in this cluster explores the relationship between corporate sustainability practices and stock performance, offering valuable insights into how markets value climate-related actions. This research is particularly relevant to the application of the BCG Matrix in sustainability contexts, as it helps in assessing the market share and growth potential of companies based on their sustainability practices. Furthermore, the decision-making frameworks proposed by (Grubler et al., 2015b) and (Watkiss et al., 2015) provide tools for evaluating investments under uncertainty, which can be adapted to incorporate the BCG Matrix's dimensions of market share and growth rate in the context of climate-related risks.

Furthermore, the second cluster, "Sustainable Portfolios: Market, Stocks, and Risk Management," builds upon the insights from the first cluster by focusing on the practical aspects of constructing and managing sustainable investment portfolios. This cluster is crucial for developing a comprehensive model that aligns portfolio management practices with sustainability goals. For example, (Mollet & Ziegler, 2014) examine the performance of socially responsible investing (SRI) in stock markets, providing evidence on how sustainability criteria affect portfolio performance. This research is essential for assessing the "market share" dimension of the BCG Matrix in the context of sustainable investments.

Additionally, (Sun & Small, 2022) further contribute to this cluster by analyzing the impact of sustainability on the financial performance of exchange-traded funds (ETFs) during the COVID-19 pandemic. Their findings on the resilience of sustainable investing during crisis periods are valuable for

assessing the growth potential of sustainable investment clusters, a key component of the BCG Matrix framework. Additionally, the work of (Zhang et al., 2022) on ESG investing in China offers insights into how sustainability factors can be integrated into portfolio management in emerging markets, expanding the applicability of the proposed comprehensive model to diverse market contexts.

Moreover, the third cluster, "Energy Portfolios: Sustainable Usage and Building Strategies," focuses on the critical sector of energy, which is central to both climate change mitigation efforts and sustainable development. This cluster provides sector-specific insights that are essential for applying the BCG Matrix to sustainability-focused investments in the energy sector. For instance, (Romejko & Nakano, 2017) analyze alternative fuel vehicle portfolios, considering technological advancements, energy security, and policy. Their approach demonstrates how sector-specific factors can be incorporated into portfolio analysis, which is crucial for accurately assessing the market share and growth potential of different energy technologies within the BCG Matrix framework. Table 4 illustrate the major authors contributing to BCG Matrix framework.

Table 4: Portfolio Analysis in Sustainability and Climate Change Contexts

Author(s) & Year	Research Setting	Research Focus
Zakari et al. (2022)	India	Climate change impact on wind and solar energy installations
Forouli et al. (2019)	European Union	Optimal technological portfolios for European power generation towards climate change mitigation
Ziegler et al. (2011)	European and US stock markets	Corporate responses to climate change and stock performance
Ferrat et al. (2022)	Developed and emerging markets	Sustainability risk premium in emerging markets
Grubler et al. (2015)	International Institute for Applied Systems Analysis	Modeling approaches for coping with uncertainties in climate change
Watkiss et al. (2015)	Various (Review study)	Review of economic decision support tools for adaptation assessment
Mollet & Ziegler (2014)	US and European stock markets	Socially responsible investing and stock performance
Sun & Small (2022)	Australian exchange traded funds	Impact of sustainability on financial performance during COVID-19
Zhang et al. (2022)	Chinese stock market	Performance of ESG investing in China
Romejko & Nakano (2017)	Polish market (case study)	Portfolio analysis of alternative fuel vehicles considering technological advancement, energy security and policy

Similarly, (Cucchiella, Gastaldi, et al., 2017)) further contribute to this cluster by examining investments in cleaner energy production through portfolio analysis in the Italian electricity market. Their research provides a practical example of how portfolio theory can be applied to select an optimal mix of renewable energy sources, which is directly relevant to the research objective of developing a comprehensive model for sustainable investment strategies.

In conclusion, these three research clusters collectively provide a robust foundation for integrating the BCG Matrix into sustainability-focused investment strategies. They offer insights into managing climate-related uncertainties, constructing sustainable portfolios, and optimizing investments in key sectors like energy. By synthesizing the approaches and findings from these clusters, researchers can develop a more comprehensive and nuanced model that aligns portfolio management practices with long-term sustainability goals while effectively accounting for climate-related risks and opportunities. This integrated approach will enable investors and policy makers to make more informed decisions that

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balance financial performance with sustainability objectives in an increasingly complex and uncertain climate future.

1.7. FINDINGS

Based on the comprehensive analysis presented in this research article, the integration of the BCG Matrix into sustainability-focused investment strategies offers a promising approach for navigating the complex landscape of climate change and sustainable investments. The current study's findings reveal significant trends in the application of the BCG Matrix to climate change and sustainability contexts. Content analysis identified "climate change" as the dominant theme, appearing in 14.21% of key terms, followed by "risk assessment" and "uncertainty analysis" (6.84% each). The research landscape is characterized by high collaboration, with an average of 3.44 co-authors per document and 26.32% international co-authorships. In addition, the study identified three key clusters: Investment Portfolios Amid Climate Change and Uncertainty, Sustainable Portfolios: Market, Stocks, and Risk Management, and Energy Portfolios: Sustainable Usage and Building Strategies. These clusters highlight the multifaceted nature of sustainable investing, encompassing risk assessment, market dynamics, and sector-specific strategies, particularly in energy. The research demonstrates a shifting focus in the field, with a declining trend in general climate change investment portfolios and an increasing emphasis on sustainable market approaches and energy-specific strategies. This evolution reflects the maturing of the field and the growing sophistication of sustainable investment practices. The adaptation of the BCG Matrix to include climate resilience factors provides investors with a valuable tool for strategic resource allocation, balancing short-term returns with long-term sustainability goals. However, the study also reveals ongoing challenges, particularly in accurately assessing long-term climate impacts on investment portfolios. Future research should focus on developing more dynamic models that can adapt to the evolving nature of climate change and sustainability challenges, potentially incorporating advanced data analytics and machine learning techniques to enhance predictive capabilities. In addition, this study significantly addresses the research gap in sustainable investing and climate change adaptation by developing a comprehensive framework that integrates climate risk assessments into the traditional BCG Matrix. Unlike existing literature, this framework applies across multiple sectors and adapts to the dynamic nature of climate change. It overcomes the limitations of static, sector-specific models, offering a more flexible, climate-resilient investment approach. The figure 10 below illustrate the Sustainable Investment Portfolio Optimization (SIPO) Framework suggested by this study outcomes.

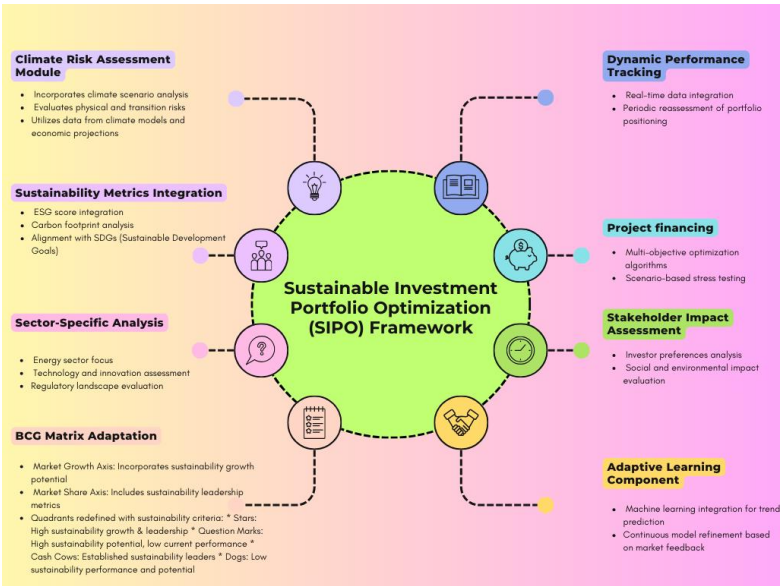

Figure 10: Sustainable Investment Portfolio Optimization (SIPO) Framework

Key contributions include the identification and analysis of three distinct research clusters, providing insights into the evolving landscape of sustainable investing. The study also introduces a novel adaptation of the BCG Matrix, incorporating sustainability metrics like climate resilience, enhancing strategic resource allocation. Additionally, a temporal analysis of investment trends offers unique insights into shifting research and practice in the field. By synthesizing insights from environmental science, finance, energy, and policy, the study provides actionable recommendations for investors and policymakers, bridging the gap between theory and practical implementation. This multidisciplinary approach creates a new paradigm for investment strategies amid climate uncertainty.

1.8. FUTURE RESEARCH

This study provides valuable insights into the application of the BCG Matrix in sustainability-focused investment strategies, it also has limitations that suggest directions for future research. One key limitation is the reliance on published literature, which may not fully capture the most recent developments in rapidly evolving fields like sustainable finance and climate change adaptation. Future studies could incorporate real-time market data and practitioner insights to provide more current analyses. Additionally, the study's focus on the BCG Matrix, while novel, could be expanded to include other portfolio analysis tools for a more comprehensive comparison. Future research could also delve deeper into sector-specific applications, particularly in emerging sustainable industries. Moreover, the integration of machine learning and AI techniques in portfolio optimization for sustainability could be a fruitful area for further investigation. Lastly, longitudinal studies tracking the performance of sustainability-focused portfolios over extended periods would provide valuable insights into the long-term efficacy of these strategies in the face of climate change.

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