Portfolio optimization in the light of factor investment: A bibliometric analysis

Pegah Khazaei[a] and Ahmad Makui[a*]

[a]*Department of Industrial Engineering, School of Engineering, Iran University of Science and Technology, Tehran, Iran*

C H R O N I C L E	A B S T R A C T
	In this study, we attempted to conduct a comprehensive review of the existing and pertinent literature on the topic of factor investment. We performed Scientometric analysis of studies published in reputable finance journals, i.e., The Journal of Portfolio Management, The Financial Analysts Journal, The Journal of Asset Management and others, during the years 2014 to 2023. To obtain the research data for our study, we gathered and examined a collection of 76 bibliographic records sourced from the Web of Science database. This database provided a comprehensive and reliable source of scholarly publications in the field of finance. To analyze the data, we employed Scientometric networks as part of our analytical approach. Scientometric networks allowed us to explore the relationships and connections between different publications, authors, and keywords within the domain of factor investment. To visualize and present the research findings, we utilized the Bibliometrix package for R, a powerful tool specifically designed for bibliometric analysis. This package enabled us to generate insightful visualizations that showcased the key patterns, trends, and interconnections within the literature on factor investment. By employing Scientometric analysis and leveraging the capabilities of the Bibliometrix package, we aimed to provide a comprehensive overview of the existing scholarly research in this field and contribute to the understanding of factor investment.

1. Introduction

Investment stands as a crucial cornerstone for the economic progress and development of nations. It has a substantial influence on the accumulation of capital, expansion of businesses, creation of employment opportunities, and preservation of wealth (Oybek, 2021). Hence, it is crucial to use wise and diverse investing strategies to achieve personal financial objectives and promote economic success on a global scale. Investors employ various strategies to allocate their funds in the capital markets as one of the most powerful drivers of economic growth and wealth creation (Ghanbari et al., 2023). Portfolio optimization is a widely utilized investment strategy that was initially described by (Markowitz, 1952). The theory focuses on rational investors aiming to optimize utility and also has a significant impact on the finance industry. The research conducted by Markowitz on portfolio selection and the mean-variance efficiency principle, established the basis for the creation of the Capital Asset Pricing Model (CAPM) by Sharpe (1964), Lintner (1965), and Black et al. (1972).

The model has played a crucial role in advancing our comprehension of the connection between risk and return. It has made a substantial contribution to enhancing our understanding of how these two concepts are interrelated and how they impact investment decisions and portfolio performance. The model's key proposition is that the expected return of an asset moves

* Corresponding author.
E-mail address: amakui@iust.ac.ir (A. Makui)

in line with the expected return of the overall market portfolio. According to the CAPM, the variations in beta, a measure of an asset's sensitivity to market movements, are enough to explain the differences in stock returns across different assets in the market. In other words, the CAPM suggests that an asset's sensitivity to market movements, as measured by beta, is the primary factor in determining its expected return relative to the overall market. The emergence of the Arbitrage Pricing Theory (APT) by Ross (1976) posed a challenge to the CAPM by introducing a multi-factor model that could more effectively account for the observed empirical irregularities in the market. The APT recognizes that markets may not be perfectly efficient and allows for the existence of arbitrage opportunities. It posits that the expected return of an asset is determined by multiple risk factors rather than just a single factor like beta in the CAPM. Basu (1977) conducted a study with the primary objective of examining the price-earnings (P/E) ratio as a potential indicator of future investment performance. The study examined NYSE listed stocks over a specific time period, from 1956 to 1971 and explored whether the P/E ratio could serve as a useful tool for predicting the future performance of investments. The P/E ratio is calculated by dividing the market price per share of a stock by its earnings per share. It is often considered a valuation metric and can provide insights into market expectations and investor sentiment.

Factor investing can be traced back to the early insights of the APT, which posited that macroeconomic factors are key drivers of security returns. By incorporating these factors into investment strategies, factor-based approaches aim to systematically exploit the risk premiums associated with different factors.

Fama and French (1992) introduced their three-factor model that expanded upon the single-factor CAPM with two additional factors: size and book-to-market equity. By incorporating these two factors into the CAPM, they demonstrated that the size and book-to-market equity factors were significant determinants of expected stock returns. The three-factor model provided a more comprehensive framework for understanding the cross-sectional variation in stock returns compared to the single-factor CAPM.

Carhart (1997) made an important contribution to the Fama-French three-factor model by adding a fourth factor: momentum. Carhart examined the performance of mutual funds and found that a momentum factor could explain a significant portion of the cross-sectional variation in returns. Through the inclusion of the momentum factor into the Fama-French three-factor model, Carhart expanded the framework's explanatory power, particularly in the context of mutual fund performance analysis. His research highlighted the importance of momentum as an additional factor influencing returns and provided valuable insights into the dynamics of investment performance.

Fama and French (2015) expanded their previous three-factor model by including two additional factors: profitability and investment. The profitability factor captures the difference in returns between firms with high profitability and those with low profitability. Fama and French found that high-profitability firms tend to have higher average returns compared to low-profitability firms.

Hou et al. (2015) conducted a study that introduced the q-factor model which provides a comprehensive framework for understanding the cross-section of average stock returns. This model incorporates the market factor, size factor, investment factor, and profitability factor, which collectively summarize the variations in expected returns for individual stocks. The researchers examined approximately 80 anomalies and found that nearly half of them were not statistically significant when considering the broad cross-section of stocks. This suggests that many previously identified anomalies may not hold up when analyzing a larger sample of stocks. Crucially, the researchers found that the q-factor model's performance was comparable to or better than that of the Fama-French (1993) three-factor model and the Carhart (1997) four-factor model in capturing the significant anomalies that remained. This indicates that the q-factor model provides a robust framework for explaining these anomalies and capturing the cross-sectional variation in stock returns.

Chiah et al. (2016) examined the Australian stock market as a research sample spanning the period from 1982 to 2013. The objective of their research was to assess the effectiveness of the five-factor model in explaining asset pricing dynamics compared to other pricing models. The findings of their study revealed that the five-factor model demonstrated superior explanatory power in the context of the Australian market, surpassing other pricing models under investigation. This suggests that the inclusion of the additional factors in the five-factor model enhanced its ability to capture and explain the variation in asset returns more effectively. Furthermore, they discovered a notable distinction between the performance of the value factor, HML (High Minus Low), in the Australian market compared to its redundancy in the US market. Unlike the US market, where the value factor became redundant after incorporating new factors, the value factor in the Australian market retained its explanatory power even after the addition of the new factors.

Cakici et al. (2016) explored the size, value, and momentum effects in 18 emerging stock markets during the period from 1990 to 2013. Their objective was to examine whether these strategies can generate superior returns in these markets. The findings of the study indicate that size and momentum strategies generally do not lead to significant outperformance in emerging markets. This suggests that the traditional size and momentum factors, which have shown effectiveness in developed markets, may not have the same impact in emerging market settings.

Lin (2017) conducted a study which the applicability of the Fama-French Five-Factor Asset Pricing Model was tested in the Shanghai and Shenzhen Stock Exchanges during the period from 1997 to 2015 and aimed to assess how well the model explained the returns in these stock exchange markets. The findings of Lin's study indicated that the Fama-French Five-Factor Model was significantly more successful than the Fama-French Three-Factor Model in explaining the returns in the Shanghai and Shenzhen Stock Exchange Markets. This suggests that the inclusion of the additional factors of profitability and investment improved the model's ability to explain stock returns in these markets. Contrary to the findings of Fama and French in 2015, Lin's study indicated that the investment factor did not play a significant role in explaining average returns in the selected sample. This discrepancy suggests that the impact of the investment factor may vary depending on the specific market context.

Kubota and Takehara (2018) conducted a study on the stock returns of the Tokyo Stock Exchange from 1978 to 2014. The study aimed to assess the explanatory power of the Fama-French Five-Factor Asset Pricing Model in this particular market and indicated that the profitability and investment factors were not statistically significant in explaining the stock returns in the Tokyo Stock Exchange. This suggests that, within the context of their study, these factors did not have a meaningful impact on explaining the variation in stock returns.

Barillas and Shanken (2018) compared different pricing models based on a set of candidates traded factors. They developed a test procedure that allows for model comparison and the computation of model probabilities for all possible pricing models that are constructed using subsets of the given factors. The findings of the study suggest that the models proposed by Hou et al. (2015, 2017) and Fama and French (2015, 2016) are dominated by a variety of alternative models. These alternative models include a momentum factor, as well as value and profitability factors that are updated on a monthly basis. This implies that the inclusion of a momentum factor, along with value and profitability factors that are frequently updated, provides a better explanation for asset pricing and the cross-section of stock returns compared to the models proposed by Hou et al. (2015, 2017) and Fama and French (2015, 2016).

Ahmed et al. (2019) conducted a comprehensive comparison of major factor models revealed that the Stambaugh and Yuan (2016) 4-factor model performed the best overall in the time-series domain. Taking second place was the Hou, Xue, and Zhang (2015) q-factor model. The Fama and French (2015) 5-factor model and the Barillas and Shanken (2018) 6-factor model jointly occupied the third-place ranking.

Aït-Sahalia et al. (2020) utilized data from all traded stocks on the NYSE, AMEX, and NASDAQ stock markets spanning the period of 1996 to 2017. They constructed the five Fama-French factors along with the momentum factor at a high-frequency level, specifically at a 5-minute interval. The authors then examined the empirical properties of both the stocks and the newly constructed factors. They employed a nonparametric time series regression model using the high-frequency Fama-French factors. The objective was to evaluate the effectiveness of this factor model in explaining the systematic risk component of individual stocks. The findings of the study revealed that the proposed factor model, which incorporated the high-frequency Fama-French factors, was successful in capturing the systematic risk associated with individual stocks. In other words, the factors derived from the Fama-French framework, along with the momentum factor at a high-frequency level, significantly contributed to explaining the variation in stock returns. (Altinay et al., 2023)

Zhu et al. (2021) aimed to test a multi-factor asset pricing model that allows for time-varying beta coefficients. This approach differs from traditional models that assume constant beta coefficients. To achieve this, they utilized the Generalized Arbitrage Pricing Theory (GAPT) and estimated it using price differences instead of returns. One inference from the GAPT is that when utilizing price differentials, the beta coefficients remain stable. To test the GAPT, the authors employed the adaptive multi-factor (AMF) model, which accommodates time-varying beta coefficients. They utilized a Groupwise Interpretable Basis Selection (GIBS) algorithm to discern pertinent factors from a pool of all traded exchange-traded funds. The authors conducted a performance comparison between the AMF model and the Fama-French 5-factor (FF5) model. The key finding of the study was that for nearly all time spans shorter than six years, the beta coefficients remained time-invariant in the AMF model, while this was not the case for the FF5 model. This suggests that the AMF model, particularly when using a rolling window of, for example, five years, aligns more consistently with realized asset returns compared to the FF5 model.

Meng and Zhang (2022) conducted a study analyzing the impact of corporate environmental information disclosure on investor response. In their research, they gathered data on environmental information disclosure from all publicly listed Chinese companies spanning the years 2004 to 2020, while also controlling for the effects of annual reports on investor response. To measure the impact of environmental information disclosure, the authors applied the Fama-French five-factor model. This model incorporates market, size, value, profitability, and investment factors to compute the cumulative abnormal returns of stocks throughout the event window period. The event window period is likely associated with the release of environmental information by the companies. Based on their analysis, the results of the study imply that environmental information disclosure holds substantial influence on investor response. However, without further details, it is not possible to provide a more specific explanation of the findings or the nature of the impact observed.

Ahmed et al. (2023) aimed to determine which factor model is most effective in capturing systematic return covariation and its economic implications for portfolio risk control. They employed the pairwise variance equality test and the model confidence set procedure to compare various factor models. The findings of the study suggest that the Fama and French (2015) five-factor model, the Barillas and Shanken (2018) six-factor model, and the Fama and French (2018) six-factor model performed exceptionally well in terms of factor model-implied minimum risk portfolios during the out-of-sample period. These models demonstrated superior performance in capturing the covariation of systematic returns, indicating their effectiveness in managing portfolio risk. Additionally, when considering the construction of minimum tracking error portfolios, the Barillas and Shanken (2018) six-factor model and the Fama and French (2018) six-factor model emerged as the top performers in the study. These models proved to be particularly effective in minimizing the tracking error, further highlighting their suitability for portfolio management purposes.

Kabir et al. (2023) aimed to examine the explanatory power of the Carhart four-factor model, Fama-French three-factor model, and a single-factor model in the context of the Bangladeshi stock market. The researchers focused on several objectives, including assessing risk-adjusted returns, testing the valuation capabilities of multi-factor models, and estimating optimal portfolio weights for stocks listed in the Dhaka Stock Exchange (DSE) under the DSE30 index. The findings of the study suggest that large-cap firms with low or medium book-to-market (B/M) ratios tend to exhibit more focused returns compared to their counterparts. This concentration of returns results in higher earnings per unit of total, systematic, and downside risks. Moreover, the study reveals that each factor in the multi-factor models has significant explanatory power for market excess returns. Nevertheless, the impact of factor values on the cross-section of stock returns seems to exhibit a certain degree of inconsistency. Specifically, the momentum factor was ineffective in elucidating cross-section excess returns, whereas the risk premium, size, and value factors exhibited a noteworthy impact.

The main aim of this study is to extensively review and perform bibliometric analysis of the previous empirical research on the theme of factor investment for portfolio optimization, in order to provide a clear theoretical understanding. To achieve this goal, we search for factor investment in portfolio optimization in Web of Science (WoS).

Our review study carries significant implications and contributes to the literature in several ways. Firstly, it conducts a comprehensive review of numerous studies published in reputable journals, offering clear insights into the major determinants of investment decisions. Secondly, the study enriches theoretical perspectives on relevant factors that hold the potential to influence investment decisions. Thirdly, the study serves as a valuable outline document for investors, providing a condensed review of a substantial body of literature.

The structure of this study is outlined as follows. Section 2 provides an explanation of the employed research approach and literature search strategy. In Section 3, the results obtained from various Scientometric methods are presented. This includes the generation of knowledge maps depicting links between different concepts, as well as tables that display relevant data. Finally, in Section 4, the study concludes by summarizing the main findings and drawing conclusions based on the research outcomes.

2. Methodological approach

Bibliometric analysis, initially introduced by Bradford (1934), has undergone significant evolution over the years. Price (1965) contributed by presenting bibliometric methods aimed at evaluating and mapping scholarly articles, with a focus on the number of citations each article receives (Kim & McMillan, 2008). This approach utilizes articles as the fundamental unit of analysis, as highlighted by Alon et al. (2018). The evolution of bibliometric analysis has allowed researchers to quantitatively assess the impact and influence of scholarly work, offering valuable insights into citation patterns and the dissemination of knowledge within various academic fields (Patel et al., 2022).

We perform bibliometric analysis based upon the review of 10 years of factor investment literature during the period 2014 to 2023 published in top three journals including The Journal of Portfolio Management, The Financial Analysts Journal, The Journal of Asset Management.

We use WoS as an academic database for publication search and selection. The search equation is: ("Portfolio optimization" OR "Portfolio selection" OR "Portfolio allocation" OR "Portfolio Construction" OR "Portfolio management" OR "Portfolio Rebalancing") AND ("Factor investing" OR "Factor investment"). 76 documents were obtained from WoS. The research results were visualized using the Bibliometrix package for R, which was created by Aria and Cuccurullo (2017).

The study at hand draws inspiration from the research conducted by Marín-Rodríguez et al. (2022) and Farooq et al. (2022). Their work has influenced the current study and provided valuable insights and ideas that have shaped the research direction and methodology.
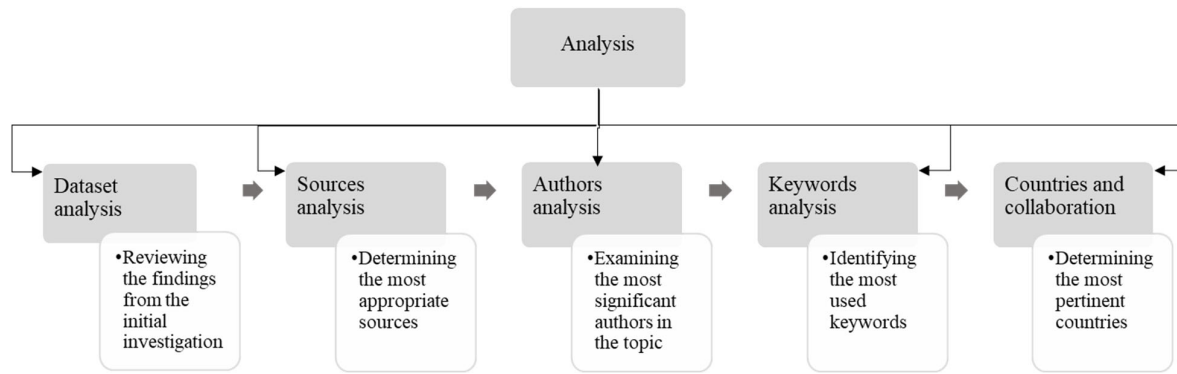
Fig. 1. Literature search approach

3. Scientometric analysis

Scientometric analysis, also known as bibliometric analysis, is a quantitative approach used to study scientific literature and its characteristics. It involves analyzing patterns, trends, and relationships within scholarly publications, authors, journals, and keywords to gain insights into the structure and development of research fields. In our study, out of the 76 documents that were selected, we identified a total of 158 authors. The average number of citations per document in this study is 3.75. The annual growth rate experienced a substantial increase of 25.09% per year. This indicates significant growth and suggests a positive trend in the subject area being studied. The primary document type in this study is articles, consisting of 62 documents. Throughout the analysis, 96 keywords labeled as "Plus" and 129 author keywords were discovered. In Table.1 a comprehensive overview of the description details pertaining to the reviewed papers in this investigation is presented.

Table 1
Overview of the descriptive information

Main information of data	
Descriptions	Results
Timespan	2014:2023
Secondary Sources	24
Documents	76
Annual Growth Rate %	25.09
Document Average Age	3.67
Average Citation per Doc	3.75
References	1637
Information of Documents & Authors	
Descriptions	Results
Article	62
Article; early access	1
Article; proceedings paper	1
Book review	1
Review	2
Keywords Plus (ID)	96
Author's Keywords (DE)	129
Authors of single-authored docs	11
Single-authored docs	15
Co-Authors per Doc	2.53
International co-authorships %	31.58

Source: The researcher's original investigation conducted using the Biblio-metrix tool and the WoS databases.

3.1. Publication output

Publication output in bibliometrics refers to the quantitative measurement of the number of publications produced by researchers or institutions within a specific field or over a certain period of time. It is a commonly used metric to assess research productivity and scholarly activity.

Fig.2a illustrates an upward trend in the quantity of published studies in recent years, particularly since 2018. This observation implies a growing level of interest among the academic community.

According to Fig.2b the average number of citations per paper in 2016 was 0.5, while in 2018, it increased to 1.5. This indicates a rise in the average number of citations received by papers between the two years. The increase suggests that the research conducted during this period gained more attention and recognition within the academic community, leading to a

higher number of citations. Higher citation counts can be indicative of the significance and impact of the research conducted in a particular field.
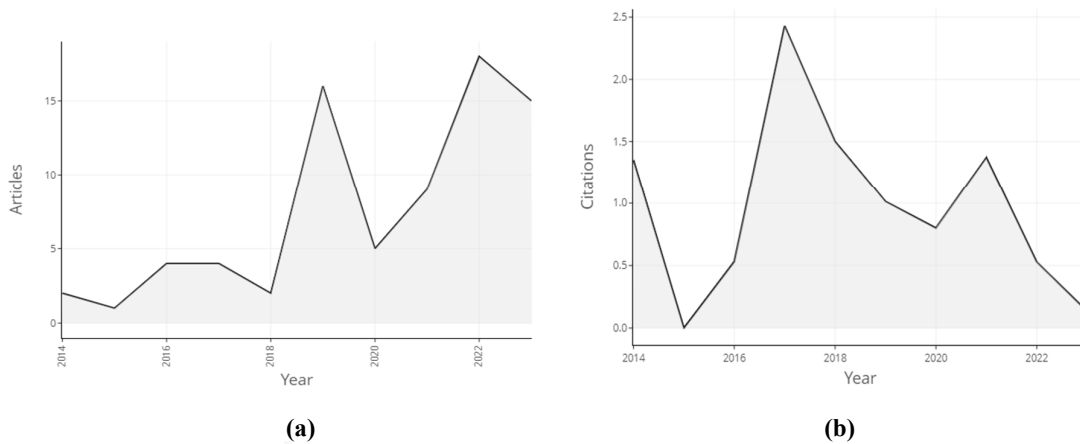

(a)   (b)

Fig. 2. Publication output. (a): The annual scientific production. (b): Average number of citations per year.   Source: The researcher's original investigation conducted using the Biblio-metrix tool and the WoS

3.2. Discipline-Wise analysis

Discipline-wise analysis in bibliometrics involves examining and analyzing research publications within specific academic disciplines or fields of study. Fig. 3 presents a ranking of articles published by various sources based on their significance, regarding the study of factor investment in portfolio optimization. The figure provides insights into the sources that have contributed significantly to research in this area. The analysis revealed that the topic of factor investment in portfolio optimization has been studied, with a notable number of articles published in the "Journal of Portfolio Management" (41 occurrences). Both the "Journal of Financial Analysts" and "Financial Markets and Portfolio Management" were found to have 4 occurrences in the analysis of articles related to the topic of our study. While they have a lower number of occurrences compared to other journals mentioned, they still contribute to the body of research in this area. These findings indicate that researchers in this field can consider these three journals as important references and platforms for accessing relevant studies and contributing to the existing body of knowledge.
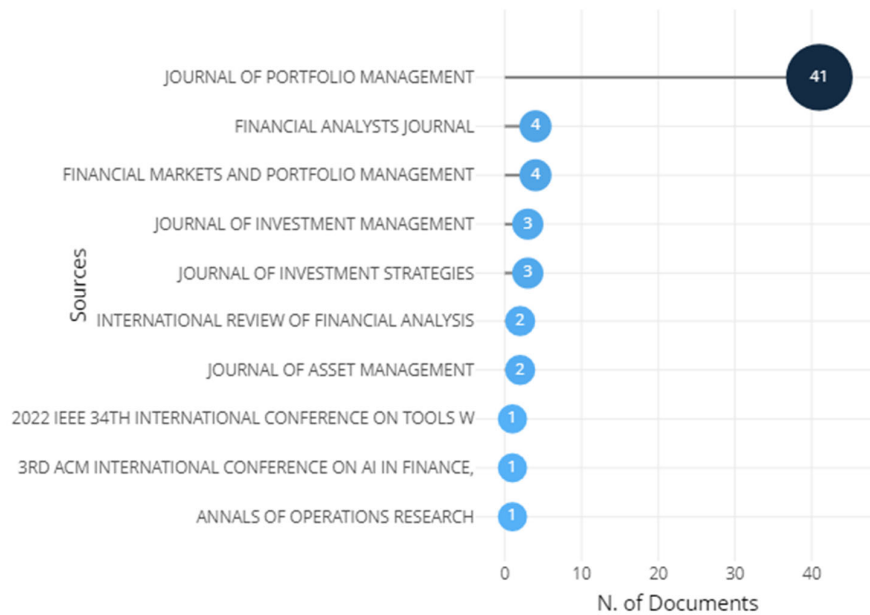

Fig. 3. Document distribution among sources
Source: The researcher's original investigation conducted using the Biblio-metrix tool and the WoS.

3.3. Most relevant sources

In this segment, we delve into the key and influential resources in the field of factor investment research. The distribution of the most cited publications is depicted in Fig.4 shedding light on the prominence and impact of specific journals in this area. Fig. 4 reveals that the "Journal of Finance" emerges as the most cited publication, with a remarkable 322 citations. This prestigious journal has consistently attracted high-quality research in the field of finance and has become a primary source for scholars and practitioners alike. Following closely behind is the "Journal of Portfolio Management", which boasts 288 citations.

This journal focuses specifically on portfolio management strategies, including factor-based approaches. The significant number of citations indicates its relevance and the valuable insights it provides to researchers and practitioners engaged in factor investment analysis and decision-making. "The Journal of Financial Economics", with 256 citations, secures a notable position in the list of most cited publications. This journal focuses on the intersection of finance and economics, exploring various topics including factor investing.

The substantial citation count underscores its influence and the recognition it receives within the academic community. These top-ranking journals and their respective citation counts highlight their significance as primary resources for researchers in the field of factor investment. They serve as reputable platforms for the publication and dissemination of impactful research, shaping the discourse and advancements in this domain. Researchers and practitioners seeking comprehensive and influential resources in factor investment would benefit from exploring the valuable insights presented in these journals.
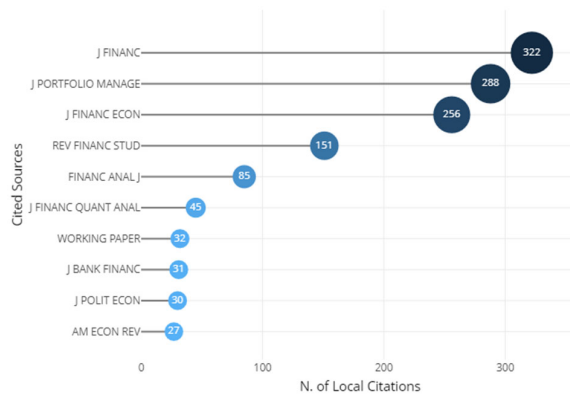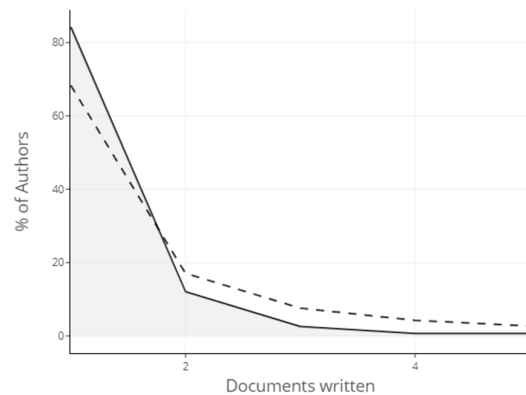

Fig. 4. Most Cited Sources

Fig. 5. Productivity of authors based on Lotka's Law: research on factor investment in portfolio optimization

Source: The researcher's original investigation conducted using the Biblio-metrix tool and the WoS.

3.4. Authors' productivity

Lotka's Law is a bibliometric principle that outlines how scientific output is distributed among researchers within a specific field or knowledge area (Lotka, 1926). It states that a minority of researchers will contribute the majority of publications in a given field, while the majority of researchers will have a lower level of productivity. Fig.5 displays the findings related to papers examining factor investment in portfolio optimization and the predicted distribution based on Lotka's law is presented alongside these results. According to the results, approximately 50% of authors have written only one article. Around 10% of authors have written 2 articles and no one has authored more than five articles in the studied field. The finding implies that there is a potential for more contributions and opportunities for researchers to make significant contributions to the field by publishing additional articles.

3.5. Authors of utmost relevance and considerable impact.

In this section, we explore the authors who have made significant impacts in our study field. These individuals have likely made substantial contributions to the study, and their work is often cited and recognized by other researchers. Identifying authors of utmost relevance in bibliometrics is crucial for understanding the key figures shaping the field and for recognizing the thought leaders whose work has had a significant impact on the study of scholarly communication and information science. Based on the information provided, Fig.6a indicates that Fabozzi is the most prominent author in terms of the number of published articles with a total of 5 articles. Following Fabozzi, Lohreh holds the second position with 4 articles, and Blitz is ranked third with 3 articles. According to the quantity of local citations (Fig.6b) the three most prominent authors who have had a significant impact on factor investing in portfolio optimization are Harvey, Kalesnik, and Linnainmaaj with 8 local citations. Following closely behind them is Arnott, with 7 citations, further emphasizing their

significant contributions to the field. Additionally, Amenc and Goltz have also made a notable impact, with 5 citations. The local citations indicate that their work has been referenced multiple times within the analyzed dataset or specific research area, reflecting their prominence and influence in the subject matter.
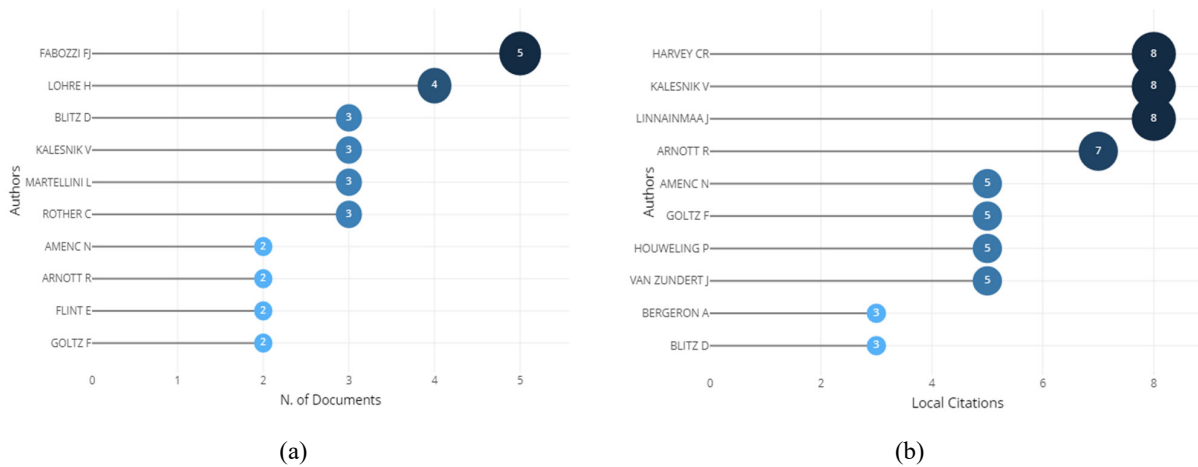

(a)   (b)

Fig. 6. Authors of utmost relevance and considerable impact
(a): Quantity of publications by authors. (b): Authors with the highest local citations
Source: The researcher's original investigation conducted using the Biblio-metrix tool and the WoS.

3.6. Authors' study over Time

Fig.7 highlights the acknowledged publications of the author who has exerted the most influence on factor investment within portfolio optimization analysis throughout the years. The color saturation depicted in the graph corresponds to the year of citation, while the size of the bubbles represents the number of publications by different authors in each specific year. According to Fig.7, Fabozzi has been conducting studies in this field continuously from 2018 to 2023. This indicates that Fabozzi has been actively engaged in research and contributing to the field of study over a span of six years. During this period, his work accumulated a total of five documents. Kalesnik and Arnott began their study in this field in 2019 and their first paper in this area has received significant citations. The fact that their initial paper has garnered notable citation suggests that it has made an impact and has been recognized by the research community.
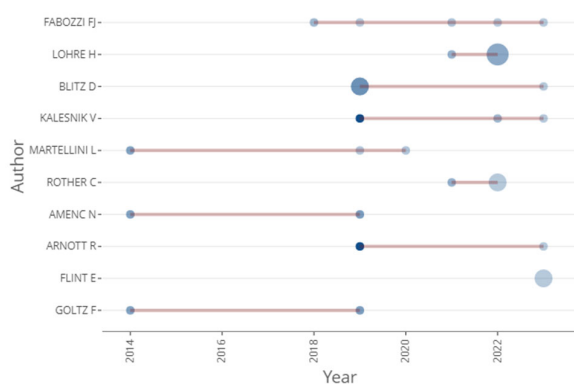

Fig.7. Top authors' study over time in researching the factor investing from 2014 to 2023.
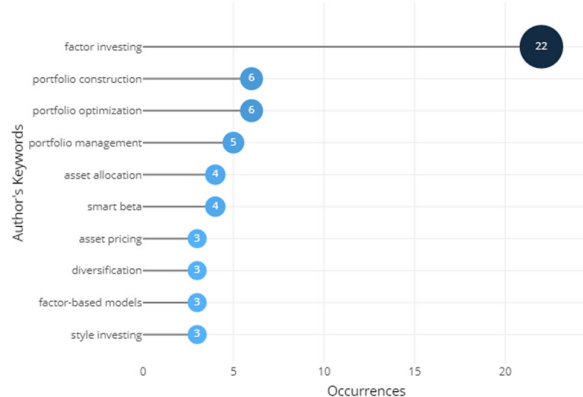
Fig. 8. Author's Keywords

Source: The researcher's original investigation conducted using the Biblio-metrix tool and the WoS.

3.8. Most frequent author's keywords

Author keyword analysis provides valuable insights regarding research trends from the perspective of researchers themselves. This examination helps identify recurring themes, key concepts, and areas of emphasis within a body of scholarly literature, contributing to a better understanding of the focus and evolution of research in a specific field. According to Fig.8 the analysis reveals that "factor investing" is the most frequently used keyword among authors, with a total of 22 occurrences in the search conducted for our study. In terms of the second most used keywords, both "portfolio

construction" and "portfolio optimization" share this position with 6 occurrences. "Portfolio management" is identified as the third most frequently used keyword by authors, appearing five times in the search.

3.9. Three-field Plot

A three-field plot Sankey diagram is a visualization that represents the flow or transition of data   between three different fields or categories. It is a type of Sankey diagram that displays the connections and magnitude of data movement between three distinct entities or variables (Riehmann et al., 2015). The diagram typically consists of three vertical columns or sections, each representing a specific field or category. The width of the flow lines or arrows in the diagram corresponds to the magnitude or volume of data transitioning between the fields. In Fig.9 the first column represents authors, the second column represents authors' keywords, and the third column represents countries. In Fig.9 the diagram indicates that "factor investing" is a commonly used keyword among authors. It further indicates that this keyword has been widely used in Germany. Specifically, it highlights that the authors "Lohre H" and "Rother C" have utilized this keyword in their work. The diagram visually demonstrates the prominence and prevalence of the term "factor investing" within the context of German authors and their research.
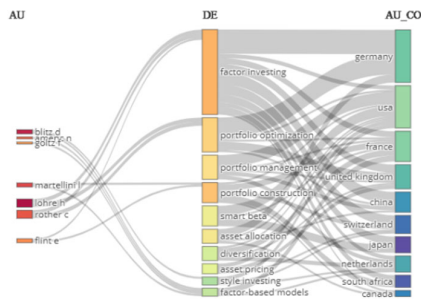

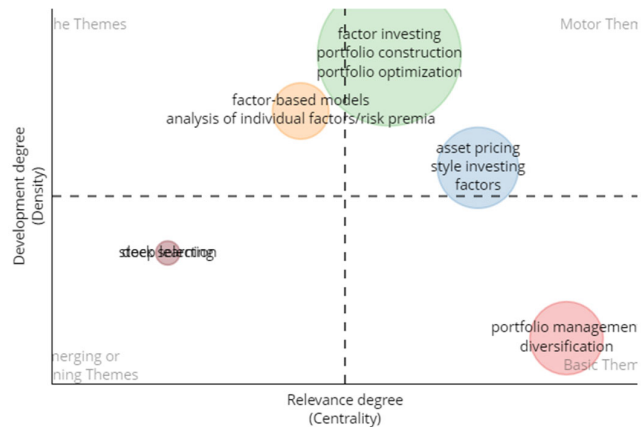
Fig. 9. Three-field Plot

Fig. 10. Thematic Map

3.10. Thematic map

This section introduces a thematic map, categorizing it into four quadrants according to the concentration and significance of the topic, considering both density and centrality. The first quadrant, labeled "motor themes", is characterized by high density and centrality, indicating that these themes have a strong presence and influence within the field. According to Fig.10 "factor investing", "portfolio construction" and "portfolio optimization" are related to this quadrant suggesting that these topics are highly concentrated and central to the field. The second quadrant, termed "basic themes," has low density but high centrality, suggesting that these themes are foundational and widely recognized within the field despite not being as prevalent in terms of research output. "Portfolio management" and "diversification" are mentioned as topics that fall within this quadrant, indicating their importance and significance in the field. The third quadrant, referred to as "niche themes," exhibits high density but low centrality, signifying that these themes are highly concentrated within specific areas or subfields of the larger research domain (Bretas & Alon, 2021).

The thematic map provides researchers and analysts with a visual representation of the themes, encouraging them to delve deeper into the intricacies, relationships, and implications of these themes. By conducting more profound studies, researchers can gain a better understanding of the complexities of these themes and their impact on the overall analysis.

3.11. Keyword co-occurrence analysis

Co-word or co-occurring keywords analysis is a method that aims to identify the principal or most important keywords within a collection of bibliographic records. By examining the frequency of occurrence and co-occurrence patterns of keywords, researchers can determine the prominent categories or topics within a particular field of study. The size of a keyword within the analysis typically corresponds to its frequency of occurrence. Keywords that appear more frequently in the bibliographic records will have a larger size, indicating their higher occurrence in the research domain. Conversely, keywords that occur less frequently will have a smaller size.

Co-word analysis provides a quantitative approach to understand the intellectual structure of a research field and can assist in identifying the main areas of investigation. It helps researchers determine the most relevant categories or topics for further analysis or exploration within the field of study.

According to Fig.11a, "portfolio optimization" and "portfolio construction" and "portfolio management" are the most frequently occuring author keywords. This implies that these three topics are prominent and widely discussed within the analyzed literature. On the other hand, the analysis of keywords Plus (Fig.11b) highlights "risk" and "return" as crucial keywords. This suggests that in addition to the focus on portfolio optimization and portfolio construction, there is also significant attention given to the broader concepts of risk and return within the analyzed documents.
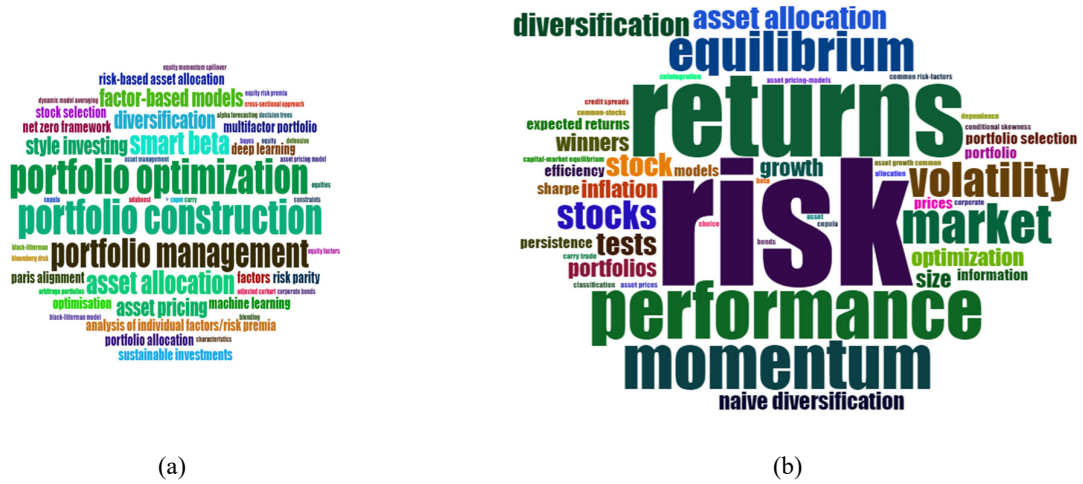

(a)   (b)

Fig. 11. Keyword co-occurrence analysis. (a): Author keywords. (b): Keywords plus

Source: The researcher's original investigation conducted using the Biblio-metrix tool and the WoS.

3.12. Countries scientific production

Country's scientific production refers to the quantity and quality of research output generated by researchers and institutions within a specific country. It is often measured by various metrics such as the number of scientific publications, citations, patents, and research collaborations.

According to Fig.12a the most cited country in our study field is the Netherlands, with a total of 86 citations. The United States occupies the second position with 53 citations, and the United Kingdom holds the third place with 32 citations. These findings indicate the prominence and influence of research conducted in these countries within the specific field or dataset being analyzed. The high citation counts for the Netherlands, the United States, and the United Kingdom suggest that these countries have made significant contributions to the body of knowledge in the studied area, reflecting the impact of research originating from institutions based in these countries.

Fig.12b provides a visual representation of the scientific research output across various nations.

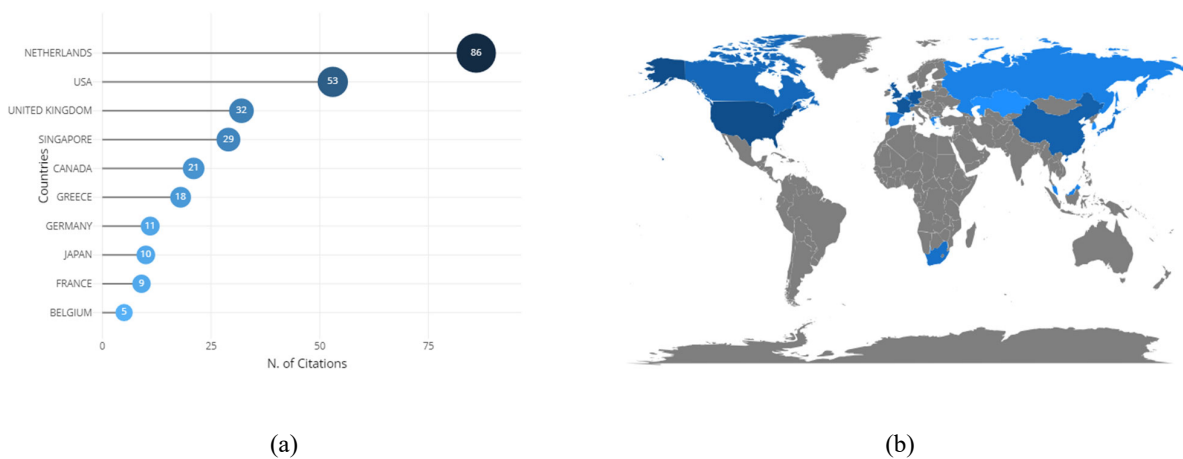High-production regions or countries are represented with sharper or more intense colors.

(a)   (b)

Fig. 12. Countries scientific production. (a): Most cited countries. (b): Country scientific production map
Source: The researcher's original investigation conducted using the Biblio-metrix tool and the WoS.

4. Conclusion

The main objective of this study was to conduct a thorough review and bibliometric analysis of previous empirical research on factor investment for portfolio optimization. The aim was to enhance the theoretical understanding of this topic by synthesizing and analyzing relevant literature. To accomplish this goal, a comprehensive search was conducted in the WoS database, specifically targeting studies related to factor investment in portfolio optimization. The selection criteria focused on empirical research published within a 10-year timeframe, spanning from 2014 to 2023. The bibliometric analysis was performed using rigorous methodologies to examine the identified literature. This analysis involved assessing publication patterns, citation counts, co-authorship networks, and keyword co-occurrence. These metrics provided valuable insights into the intellectual structure and scholarly dynamics surrounding factor investment in portfolio optimization. By focusing on a specific time period, this study captured recent developments and trends in the field of factor investment.

The findings from this study contributes to the theoretical understanding of factor investment in portfolio optimization by synthesizing and analyzing the relevant literature through a rigorous bibliometric analysis. The insights gained from this study can inform future research endeavors and practical applications in the field of factor investing.

Declaration

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