

Literary Evolution on the Efficient Market Hypothesis

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DOI:

Fecha de recepción: 09 de julio de 2024

Fecha de aprobación: 30 de septiembre de 2024



Cómo citar este artículo: Agudelo Aguirre, A.A. (2024). Literary Evolution on the Efficient Market Hypothesis. *Revista Escuela de Administración de Negocios*, (97), (páginas). DOI:

Abstract

The Efficient Market Hypothesis has been a cornerstone of classical financial theory and has become the conceptual framework on which the investment of financial assets in the stock market revolves. The purpose of this study is to carry out a bibliographic analysis on the Efficient Market Hypothesis, using advanced computational techniques for data and graph analysis. By means of the Tree of Science tool and under the hypothetical metaphor of a tree, a structural analysis is developed to determine the seminal, structural and most recent publications considered within the bibliographic network on Efficient Market Hypothesis. On the other hand, with the support of the Gephi exploration and visualization software, and from an extended bibliographic network, a cluster analysis is carried out to establish the research aspects derived from this topic during the last decades. The results of the study show a prolific body of knowledge on Efficient Market Hypothesis, starting with Fama's (1970) *Efficient Capital Markets*, up to the current research trends largely oriented towards the Adaptive Market Hypothesis, including the application of Artificial Intelligence techniques and tools to technically analyze investment in the stock market.

Keywords: Efficient Market Hypothesis; Adaptive Markets Hypothesis; Share Investment; Bibliometric Analysis; Tree of Science.

Evolución de la literatura sobre la hipótesis del mercado eficiente

Resumen

La hipótesis de la eficiencia del mercado ha sido uno de los principales pilares sobre los que se ha sustentado la teoría financiera clásica, y constituye el marco conceptual que orienta la inversión en activos financieros dentro de los mercados de capitales. El propósito de este estudio es realizar un análisis bibliográfico sobre la hipótesis de la eficiencia del mercado mediante la aplicación de técnicas computacionales avanzadas para el análisis de datos y de redes. A través del programa Tree of Science, se llevó a cabo un análisis estructural bajo la metáfora hipotética de un árbol, con el fin de identificar las publicaciones seminales, estructurales y recientes que conforman la red bibliográfica sobre la hipótesis de la eficiencia del mercado. Adicionalmente, mediante el uso del programa Gephi, y a partir de una red bibliográfica ampliada, se efectuó un análisis de clústeres, con el objetivo de determinar las principales vertientes de investigación que han derivado de esta temática a lo largo de las últimas décadas. Los resultados del estudio evidencian una prolífica generación de conocimiento en torno a la hipótesis de la eficiencia de mercado, desde la publicación seminal de Fama (1970): "Efficient capital markets", hasta las tendencias investigativas más recientes, orientadas en gran medida hacia la hipótesis del mercado

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adaptativo y la aplicación de técnicas y herramientas de inteligencia artificial al análisis técnico y a la toma de decisiones de inversión en los mercados financieros.

Palabras clave: hipótesis de eficiencia del mercado; hipótesis del mercado adaptativo; inversión en acciones; análisis bibliométrico; árbol de la ciencia.

1. Introduction

Market efficiency is a foundational concept in financial economics, positing that the asset and security prices fully reflect all available information to investors, making financial market returns inherently difficult to predict. The origins of this notion can be traced back to Louis Bachelier's 1900 doctoral dissertation in mathematics, *Théorie de la Spéculation*, submitted to the Sorbonne. In this seminal work, Bachelier introduced mathematical finance to the world by modeling the dynamics of asset prices and developing an early framework for option pricing (Bachelier, 1900). As he stated:

Past, present and even discounted future events are reflected in market price, but often show no apparent relation to price changes... and if the market, in effect, does not predict its fluctuations, it does assess them as being more or less likely, and this likelihood can be evaluated mathematically. (Dimson & Mussavian, 2000, p. 959)

Despite its revolutionary nature and Bachelier's pioneering role in the foundation of financial economics, his work remained largely unrecognized for decades. It was only in the late 1950s and early 1960s, with the advent of electronic computers, that his insights into stock price dynamics were revisited. During this period, computational advances aimed to enhance efficiency and convenience in processing the increasing volume of traded securities.

The concept of market efficiency was later independently developed by several leading economists. Paul H. Cootner's *The Random Character of Stock Market Prices* (1964), Paul Samuelson's *Rational Theory of Warrant Pricing* (1965), and Eugene F. Fama's *Random Walks in Stock Market Prices* (1965) are among the most influential early works. Samuelson provided the theoretical underpinnings by modeling stock prices as a martingale process, focusing on the mechanics of price behavior and dynamic asset allocation. Fama, in turn, offered a formal definition of an efficient market as one in which participants act rationally in pursuit of profit, hypothesizing that stock prices follow a

random walk (Sewell, 2011). In recognition of their contributions, the 2013 Sveriges Riksbank Prize in Economic Sciences was awarded to Fama, along with Lars Peter Hansen and Robert J. Shiller, for their empirical analyses of asset prices.

Although the idea that market returns are difficult to predict originates from Bachelier and Samuelson, it is most closely associated with Fama, whose seminal publication *Efficient Capital Markets: A Review of Theory and Empirical Work* (1970) in *The Journal of Finance* synthesized theoretical and empirical evidence on market efficiency. Fama defined an informationally efficient market as one in which prices fully incorporate all available information (Fama, 1970). The Efficient Market Hypothesis (EMH) thus posits that stock price movements are essentially unpredictable and that sustained risk-free profits contradict efficiency (Cochrane, 2014). While Fama's dissertation laid the empirical foundations, both he and Samuelson contributed to interpreting price randomness as an outcome of rational behavior, as articulated in their independent 1965 works (Delcey, 2019). The concept of a *random walk* refers to the unpredictable movement of an asset's price, implying that future prices are not influenced by past behavior (Diongson, 2023). Consequently, asset price variations are random, making consistent outperformance improbable a premise that aligns with the EMH (Diongson, 2023). In essence, the more efficient the market, the more random the price changes appear (Dupernex, 2007). Nevertheless, a vast body of empirical research has examined whether stock prices exhibit predictability, and the debate has intensified as new evidence has challenged the rational assumptions underlying the EMH (Durusu-Ciftci *et al.*, 2019).

The EMH remains a cornerstone of modern financial theory, asserting that no investment strategy based solely on available information can consistently achieve abnormal returns. Instead, maximizing expected returns for a given level of risk requires eliminating firm-specific risk through optimal portfolio diversification (Poitras & Jovanovic, 2010). Cochrane (2013) further illustrated this empirically by examining cases in which the EMH fails: event studies reveal how markets react to the release of inside information, often with significant price adjustments, indicating that such information was not previously incorporated into prices. As Cochrane noted, "restrictions on insider trading are effective, and when markets are not efficient, the tests verify that fact" (Cochrane, 2013, p. 7).

Following the foundational work of Fama and Samuelson in the 1960s and 1970s, numerous scholars extended the theoretical and empirical framework of the EMH. LeRoy (1973) explored the endogenous intertemporal distribution of risky assets, while Rubinstein (1976) modeled firm investment cash flows as stochastic processes valued through intertemporal arbitrage pricing. Lucas (1978) further advanced the theory by developing a general equilibrium model in which identical agents interact in an economy of infinitely lived assets (Carroll, 2023). These contributions introduced risk aversion and neoclassical optimization into the EMH framework, broadening its analytical scope. Since then, the EMH has informed a wide range of theoretical and empirical inquiries, fueling both controversy and insight into the mechanisms of price discovery (Lo, 2007). Its applications now encompass topics such as transaction costs, asset pricing with heterogeneous investors, asymmetric information, state-dependent preferences, and the integration of human capital as a non-traded asset (Lo, 2007). Despite persistent debate, the core premise of market efficiency continues to hold significant relevance. Given the enduring influence of the EMH in modern financial research, the present study aims to consolidate the most influential publications on the topic, tracing its evolution from its origins to contemporary developments. Specifically, this work seeks to: i) Identify the main thematic streams through which the EMH has evolved; ii) Map its bibliographic foundations and structural milestones and; iii) Highlight the most recent empirical contributions. Considering the longevity and intensity of the academic debate surrounding stock price behavior, this study also addresses two contextual questions: *Has the EMH lost its cogency over time, or has it become more robust? And, what directions has EMH research taken to the present day?*

Accordingly, this research seeks to answer the following operational question: *To what extent is it possible to identify the thematic areas into which Efficient Market Hypothesis research has evolved over time, and to trace its bibliographic roots, key structural contributions, and the most recent empirical advances?*

2. Theoretical Framework

The Efficient Markets Hypothesis (EMH) is an investment theory largely derived from postulates attributed to Eugene Fama back in 1970 and constructed by two main claims. Firstly, that the securities or assets in a market are fairly priced so it is virtually impossible

to consistently “*eat the market*” based on risk-adjustment only, since asset prices will only react to new information (Delcey, 2019). This is based on the idea that securities or assets reflect all known information that is available for investors to trade on, so the prices reflect economic fundamentals. In simple words, an efficient market is one where the prices of various financial assets reflect their true intrinsic value. Secondly, that the price changes are nearly random in the financial markets, with essentially the same implication, and consistency for investors as the *Random Walk Theory* (Dimson & Mussavian, 2000; Delcey, 2019), since *The Random Walk Theory* assumes price movements in the stock market are not predictable as they are determined by unexpected events with no correlation to the past.

On the other hand, EMH is based on a set of assumptions, with those concerning the perfect market forming the core of its claims. A perfect market is conceived as one in which security prices fully reflect available information —costless and widely available— and hence *universally shared* among all investors, a market with no transaction costs, and one where investors are rational, exhibiting homogenous expectations and, therefore, efficient. EMH defines three levels of market efficiency, that represent three different assumed levels of market efficiency (Fama, 1970), to answer the question on to what extent do security markets quickly and fully reflect different available information (Damodaran, 2012).

2.1. Weak EMH

The weak form assumes that asset prices reflect all available public market information, but may not reflect new information that has not been yet made public, so prices have discounted all past relevant information (Clarke *et al.*, 2001). However, incoming new information can be useful to identify overvalued or undervalued assets in the market. It additionally assumes that past information on price, volume, and returns is independent of future prices. Based on these arguments, the weak EMH implies the inability of technical trading strategies to consistently provide excess returns since future price action based on new information cannot be predicted by past price performance. It also leaves open the possibility that higher-level fundamental analysis may provide a means of outperforming the market’s average return on investment. In simple words, the weak

form acknowledges that anomalies can and do occur, and that investors may exploit them, tending to remove the anomaly, and restoring efficiency via arbitrage.

2.2. Semi-strong EMH

This form of EMH suggests that all relevant public information is rapidly reflected in the asset prices, and that new incoming publicly available information (beyond historical prices) is quickly collected and processed by market participants so prices are quickly adjusted to any new public information that becomes available. Thus, a new equilibrium occurs as a consequence of the new supply or demand forces, which, again, renders fundamental analysis incapable of predicting about future price movements (Damodaran, 2012). Under this form of EMH, investors can only outperform the general market and boost their returns if they possess information that is not readily available to the public.

2.3. Strong EMH

The strong version of the EMH suggests that all information —both the information available to the public and any information not publicly known— is discounted in the current price of financial assets and there is no type of information that can give an investor an advantage on the market. The strong EMH hypothesizes that there is a perfect market, with investors having no edge over the market and there is no type of information that can give an investor an advantage on the market. Strong EMH supporters advocate that exceeding the market benchmark returns is practically impossible, regardless of information retrieved or research conducted.

3. Methodological Approach

This study's methodology comprised four main steps, as described by Agudelo Aguirre & Agudelo Aguirre (2023). Figure 1 depicts the overall approach followed in the study. Initially, a science mapping using *Bibliometrix* package on R (free-software environment for statistical computing and graphics) was carried out, according to Aria & Cuccurullo (2017), to extract bibliometrics (quantitative parameters) of the subject *Efficient Market Hypothesis* from the top two major and most comprehensive sources of academic publication metadata in the world: *Scopus* from *Elsevier* (with a coverage of approx. 90.6 million items (Paperpile, 2023) and *Web of Science* (henceforth *WoS*), also known as the

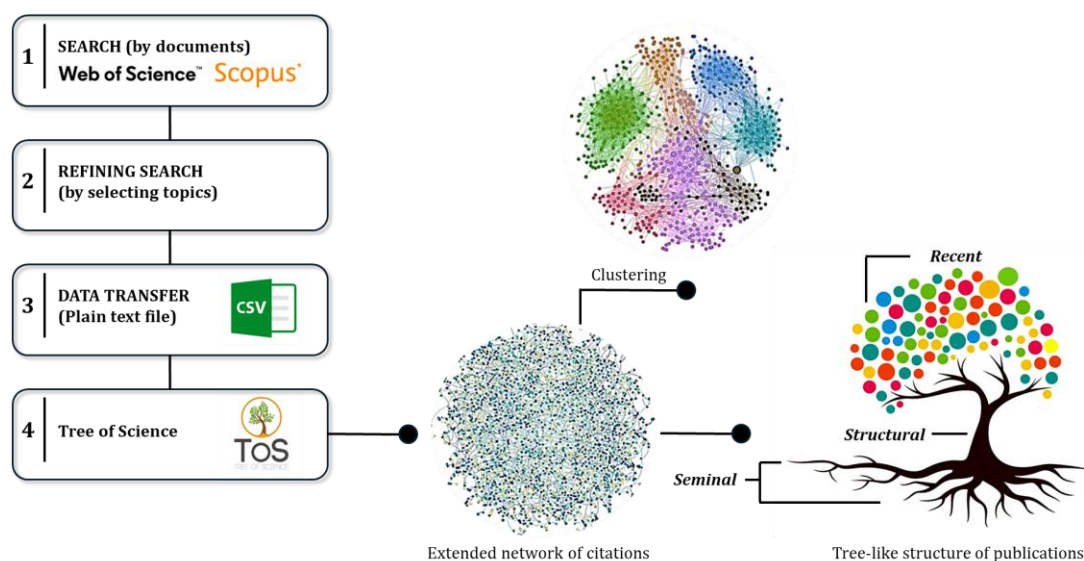
Web of Knowledge from *Clarivate Analytics* (with a coverage of approx. 100 million items (Paperpile, 2023). Both databases cover scholarly literature from almost any discipline and possess various valuable search and information retrieval options (such as comprehensive data export capabilities). The mapping process considered Bibliometrics such as annual rate of publications on the Efficient Market Hypothesis, most notorious authors (researchers) on the subject *Efficient Market Hypothesis* based on their contribution in terms of citations, top academic indexed journals in terms of number of publications on the Efficient Market Hypothesis, and geographic hubs of scientific production on the studied subject.

The initial stage of the approach was a database search for bibliographic records (Figure 1). The phrase search used was “Market Efficiency Hypothesis” AND “Investment” (AND acting as the Boolean operator to narrow the search and tell the database that all search terms must be present in the resulting records). The phrase search was applied on the following fields of the database record: title, keywords and abstract. Academic journal articles, books, book chapters, annual/conference proceedings and conference abstracts were then selected as *Type of publications* (document type) in the databases menu option. English was the used language, and the timeframe of the search was 2000 (01 January) - 2021 (12 November). In stage 2 the search was refined by citation topics (Figure 1), by selecting in the enabled option Menu of each database the specific areas of study that serve as grounds and play a role in the development of the Efficient Market Hypothesis, that is, *economics, econometrics, finance, social sciences, business, management and accounting*. The search results (bibliographic records) were saved as a Plain Text File in a CSV (comma-separated values) file (stage 3, figure 1) from the menu option in the databases. This enabled the records to be saved in a table-structured format for further graphical analysis using the software *Tree of Science (ToS)* and the open-source platform *Gephi* 0.10.1 (<https://github.com/gephi/gephi>) in stage 4.

Extracted bibliographic records (.csv format) were imported into *ToS* and the option “removal of duplicate records” was chosen to eliminate repeated records (those found in both databases). An extended citation network and links with interconnected nodes and edges from duplicates-free data was graphically generated (see figure 1). Plain text format data from the extended network was then used for cluster analysis, as well as graphical

depiction of publications based upon their contribution character in a tree-like structure (as shown in Figure 1). Cluster analysis was performed with collected data (.CSV format) imported from the extended network using *Gephi* and following the sequential procedure described by Agudelo Aguirre & Agudelo Aguirre (2023). Once data was downloaded in the working file it was validated by opening the sum up data report in the *Gephi* main menu (summarizing information on number of nodes, number of edges, and type of graph among other parameters). *ForceAtlas_2* layout algorithm was selected in the spatialization layout properties for clearer and aesthetically illustration. Any possible overlapping in the graphical outline was avoided by selecting *prevent overlap* and *Dissuade Hubs* options in the layout settings. Additionally, the collected text format data (with all general information for each particular publication such as title, author(s), date of publication, journal title and digital object identifier (doi) if so) was used to hierarchal assembly a tree-like structure of publications. Each publication was allocated either in the root, trunk or leaves based on its seminal, structural or more recent (fresh) contribution to knowledge characteristics, as shown in Figure 1. This criterion was algorithmically applied by the *ToS* and was based on the number of links between publications (degree of inputs and outputs for each publication) as detailed in Agudelo Aguirre & Agudelo Aguirre (2023).

Figure 1. Methodologic approach followed in the study



Note. CSV: Comma-Separated Value Format. ToS: *Tree of Science*.

Source. Own elaboration.

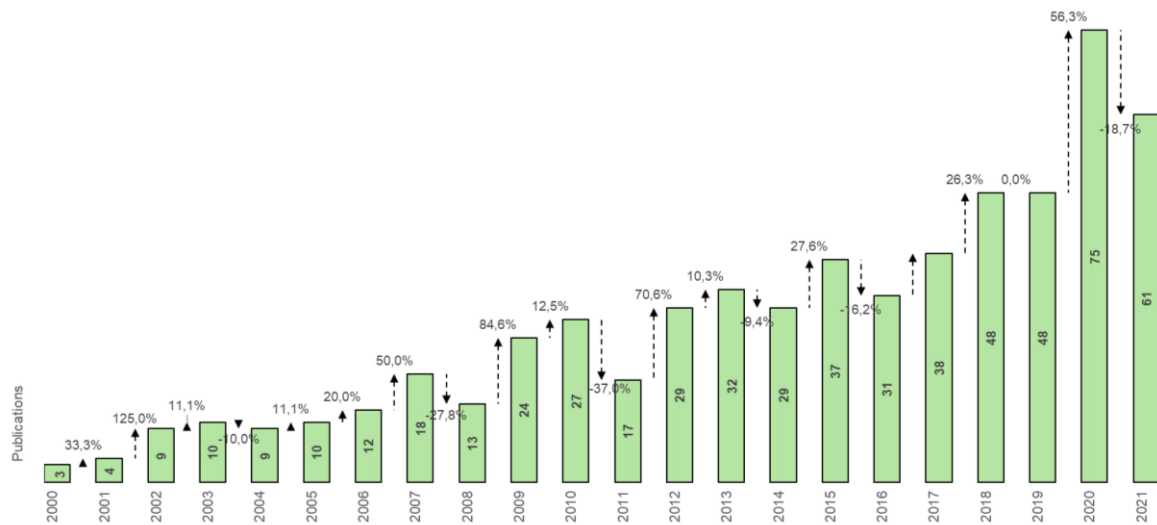
4. Results

The bibliographic search on both *WoS* and *Scopus* databases resulted in 381 and 391 publications retrieved, respectively. After eliminating duplicate records, in which 154 records were removed, a final file with 618 documents was prepared. Further, all the citations from the final file with refined publications were included and an extended citation network was created, consisting of 2901 nodes (publications) and 7495 edges (bibliographic references). Basic metrics such as scientific production, most cited works and citations of most prominent publications per year were extracted for analysis.

4.1. Basic metrics

In the present study, important metrics to assess productivity in the EMH investment as subject of study and their impact in the academic world were considered. Scientific productivity was assessed by the number of publications (annually) in the timeframe 2000-2021, as an indication of the scientific evolution and development of the EMH investment (Agudelo Aguirre & Díaz Restrepo, 2022). The number of citations showed the impact of publications in the studied field, and provided the most influential ones, accordingly. The annual scientific production in EMH investment is shown in figure 2. A total of 584 publications dealing with EMH investment were published in the studied period, according to the query performed. A trend of increasing scientific production is shown annually with few exceptions for 2008, 2011, 2014 and 2016 which showed a substantial reduction as for their previous years but still higher than that from several years prior. Up to the day of the search (November 2021), 2020 was the most productive one with nearly 56% more publications as for 2019 which at the same time showed unexpectedly invariable number of publications in 2018 and 2019 with 48. The general trend of the evolution of scientific production in the studied period indicated a pronounced strengthening in the debate and contribution to knowledge in the area of Efficiency Hypothesis Theory in investment thought the years, with nearly 22% of average increase annually during the entire period studied.

Figure 2. Annual scientific production based on the number of published articles on EMH investment for the period 2000-2021



Note. Arrows next to the bars show increment/decrement (percentage) in productivity with respect to the previous year.

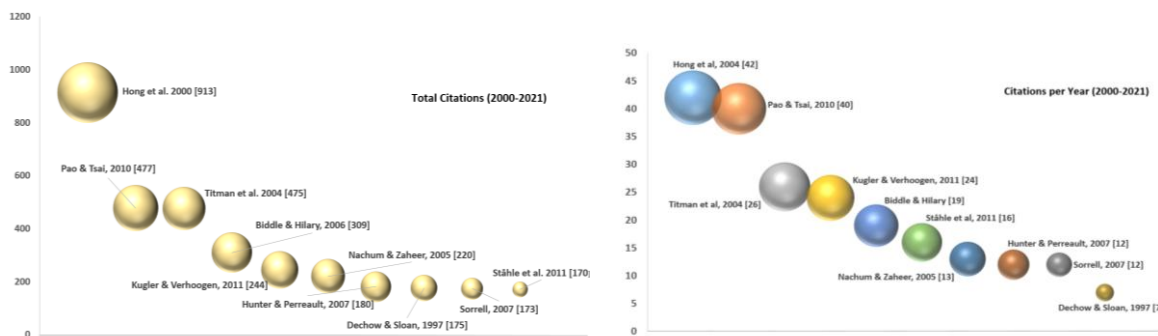
Source. Own elaboration.

The most influential publications on EMH investment based on the total average number of citations for the period 2000-2021 are shown in Figure 3. This metric gives a fairly good picture of the leading publications in the subject matter that serve as a basis for developing and enriching the debate on EMH investment. The results showed a clear dominance among papers with *Bad News Travels Slowly: Size, Analyst Coverage, and the Profitability of Momentum Strategies* by Hong *et al.* (2000) in *The Journal of Finance*, being the one leading in terms of total citations (913) in the whole studied period. This publication almost doubled the citations of the second and third most cited works: *CO₂ Emissions, Energy Consumption and Economic Growth in BRIC Countries* by Pao & Tsai in *Energy Policy Journal*, and *Capital Investments and Stock Returns* by Titman *et al.* (2004) in *Journal of Financial and Quantitative Analysis*. The publication *Accounting quality and firm-level capital investment* by Biddle & Hilary in *The Accounting Review* (2006) was the fourth among the most cited works in this study totaling 309 citations (figure 3. Left Panel).

The average number of citations of a publication per year is calculated by dividing the total number of citations by the number of years (timeframe) of the study for that specific

publication. Figure 3 (Right Panel) shows the average number of citations per year for the most influential publications found in the EMH investment as subject matter. This can be a very useful metric to assess the yearly impact of a publication or its author(s) with that particular work. It gives an indication of the extent to which a scientific work impacts the field on a yearly basis (Oliveira-Militão *et al.*, 2020). The publication by Hong *et al.* (2000) also showed the highest average annual number of citations (42), although it was fairly close to the average citations found for Pao & Tsai (2010) with 40 (figure 3. Right panel). The citations per year for these two leading publications also doubled the third and fourth in the rank, Titman *et al.* (2004) and Biddle & Hilary (2006).

Figure 3. Most prominent publications and Citations per Year for the most prominent publications on EMH investment



Note. (Left Panel): Most prominent publications on EMH investment based on average total citations in the period 2000-2021. The numbers below bubbles indicate the average total citations. (Right Panel): Citations per Year for the most prominent publications on the same subject. Period of study 2000-2021. Publications are listed in full format in the reference list of this manuscript.

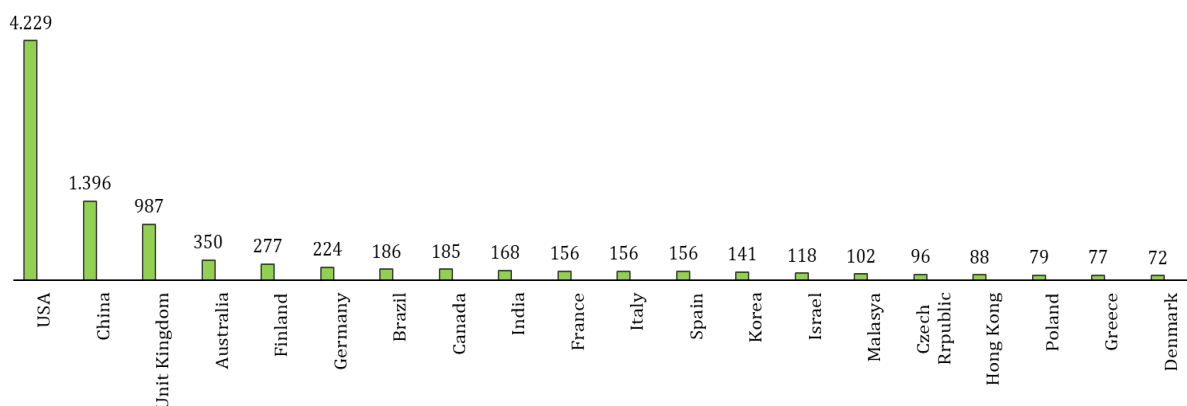
Source. Own elaboration.

Although in general, the results showed a fairly comparable trend of citations per year as that found for total citations of the most influential publications, bibliometric performance in terms of annual citations for Pao & Tsai's work was remarkable and comparable with Hong *et al.* albeit it was published much later.

A relevant indicator for identifying the geographical origin of scientific production in the field corresponds to the number of publications by country. The United States ranks first with 94 publications, followed by China with 70, and the United Kingdom with 35. Beyond these, and with a significant, progressive decrease in the number of publications from 22 to 7 per country, the group of the 20 most prominent countries in this bibliometric

indicator is completed. As a complementary measure to the origin of publications, figure 4 shows the number of citations by country.

Figure 4. Number of citations on the Efficient Market Hypothesis during the analysis period



Source. Own elaboration.

This metric shows a consistent relationship with the previous results regarding the three main producers of scientific output. In this regard, publications originating from the United States stand out with 4,229 citations, followed by those from China with 1,396, and the United Kingdom with 987 citations.

4.2. Cluster analysis

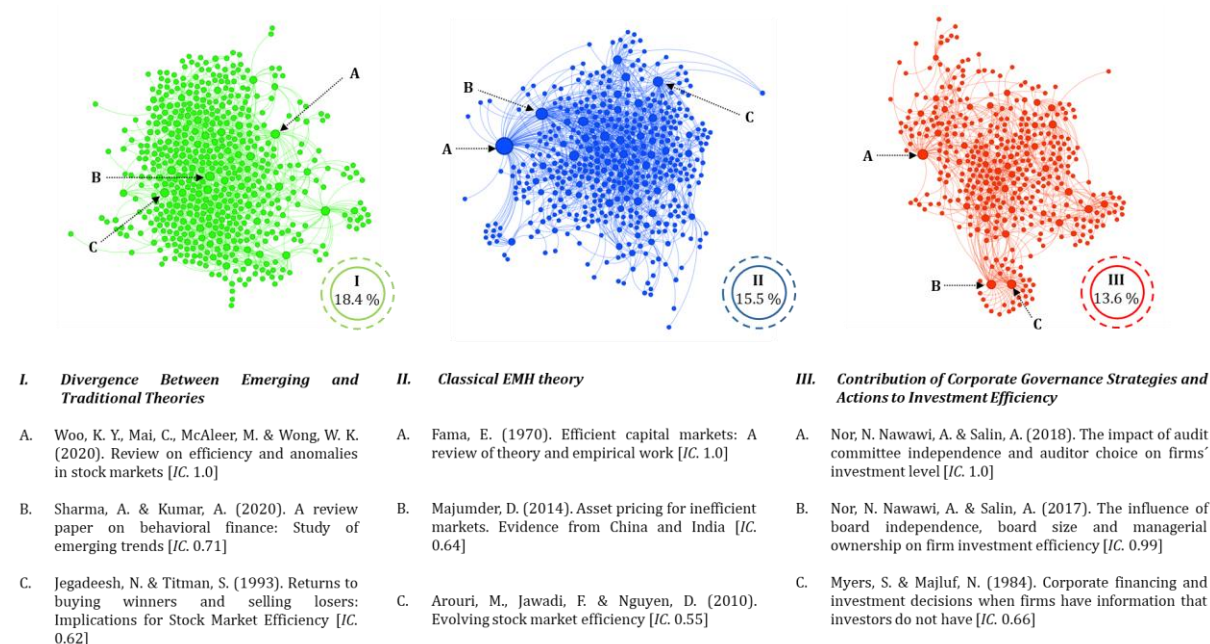
Cluster analysis is a statistical method for processing data, consisting of organizing items into groups (commonly known as clusters) based on how closely associated they are. Clustering was performed to find similar groups of publications, where the similarity between each pair of publications represented a unique characteristic of a sub-division (branch) in the broad subject matter of EMH investment (the whole sample of publications in the extended citation network). The concept of similarity and agglomerative hierarchy was applied in the clustering process (Everitt & Hothorn, 2011; Omran *et al.*, 2007).

Cluster analysis results are shown in figure 5 with publications displayed as nodes, with the purpose of identifying the different strands in which the study of the Efficient Market Hypothesis (EMH) has evolved over the years. The extended network on the EMH,

composed of publications and the relationships established through citations, comprises 2,901 nodes and 7,495 edges, distributed across 10 clusters. In the analysis the dataset was segmented into the 3 most important groups based on similarities of branch, namely ***Classical Efficient Market Hypothesis Theory***, ***Divergence between Emerging and Traditional EMH Theories***, and ***Contribution to Corporate Governance Strategies and Actions to Investment Efficiency***. Categorized groups accounted for 47,44% of the total publications in the extended citation network. ***Classical EMH Theory*** was the perspective with the highest number of publications with 18,4% of the total nodes (534 nodes and 1138 edges) in the extended network compared to ***Divergence between Emerging and Traditional EMH Theories*** (15,5% of publications, 449 nodes and 1246 edges) and ***Contribution to Corporate Governance Strategies and Actions To Investment Efficiency*** with 13,6% (393 nodes and 838 edges); both perspectives still highly relevant.

Betweenness centrality concept (Xu *et al.*, 2022) was applied to each resulting group to extract the tree most important publications regarding the impact of each publication on the cluster. Betweenness centrality index is, in this case, a normalized index giving the highest possible value of 1,0 to the node with the highest betweenness centrality, and zero (0.0) to that with the lowest one. Betweenness centrality index (henceforth *IC*) measures how close the association between nodes and edges within each cluster is, representing the degree to which nodes stand between each other. That is, a node with higher betweenness centrality would have more control over the network of the cluster, because more information will pass through that node. Figure 5 shows the three most cited works (the size of each node proportionally embodies the number of citations for each particular publication into the cluster), as they represent the major players in each identified group.

Figure 5. Main clusters as branches of EMH investment for the period 2000-2021, and their most prominent publications



Note. Percentages indicate the proportion of each of the cluster's nodes with respect to the total number of nodes in the extended citation network. IC: Betweenness centrality Index.

Source. Own elaboration.

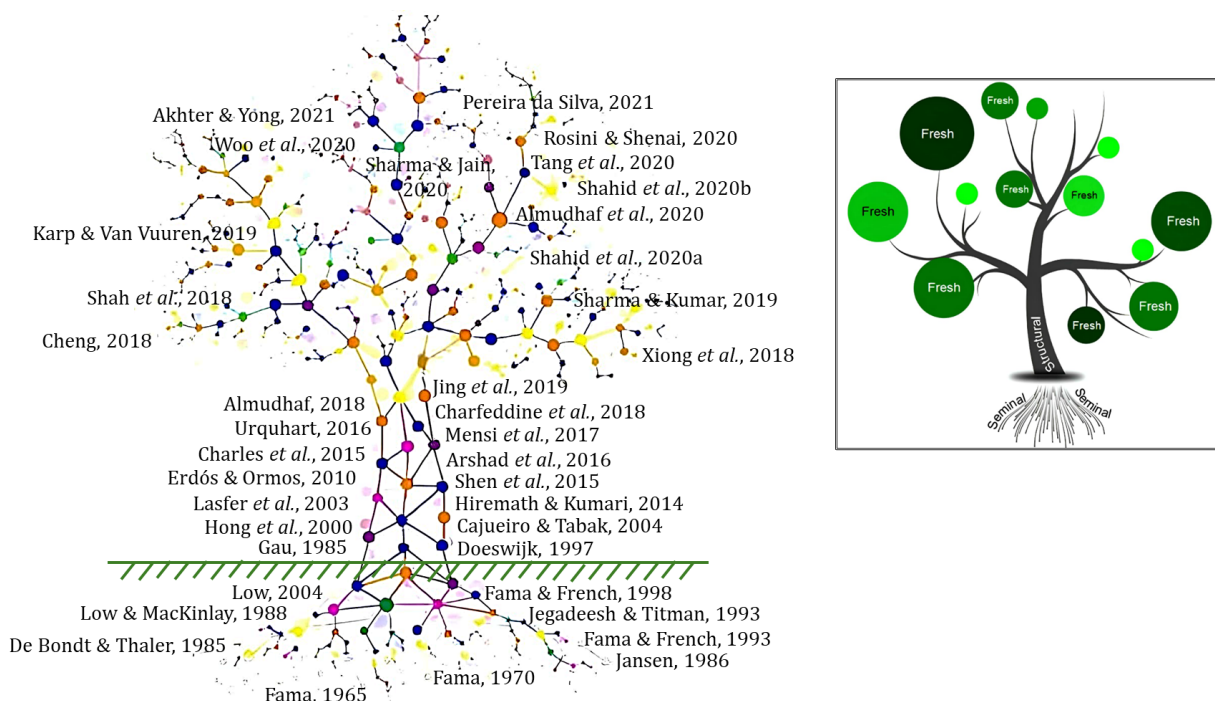
Efficient capital markets: A review of theory and empirical work (1970) by Fama was the most cited publication in its group (*Classical Efficient Market Hypothesis Theory*), with IC 1,0 followed by *Asset pricing for inefficient markets: Evidence from China and India* (2004) by Majumder, with IC 0.64, and *Evolving Stock market efficiency* (2010) by Arouri *et al.*, with IC 0,55. The branch **Divergence between Emerging and Traditional EMH Theories** showed **Review on efficiency and anomalies in stock markets** (2020) by Woo *et al.* as the most relevant publication [IC 1,0], followed by **A review paper on behavioral finance: Study of emerging trends** (2020) by Sharma & Kumar (2019) with an IC much lower (0,71), and **Returns to buying winners and selling losers: Implications for stock market efficiency** (1993) by Jegadeesh and Titman (IC 0,62). Finally, the most influential papers in the perspective **Contribution to Corporate Governance Strategies and Actions To Investment Efficiency** were *The impact of audit committee independence and auditor choice on firms' investment level* (Nor *et al.*, 2018), *The influence of board independence, board size and managerial ownership on firm investment efficiency* (Nor *et al.*, 2017), and *Corporate financing and investment decisions when firms have information*

that investors do not have (Myers & Majluf, 1984) with ICs 1,0, 0,99 and 0,66, respectively (figure 5). Contributions to the growth of the studied field of the selected publications in each cluster will be given in more detail in the Discussion section.

4.3. Analysis in Tree of Science (ToS)

The bibliographic search looked at how the general framework of the EMH Investment field has been outlined since its very beginning to the present in terms of key publications and their specific role as seminal, structural or more recent (or fresh) in order to quickly identify major players of its evolution. To accomplish that, an analysis of the citations using *Tree of Science* software was performed on the extended citation network data. The publications identified as seminal based on the citation parameter are located in the root, acting as seeds of knowledge in the field of study. Those publications, derived from the seeds, are located in the trunk and finally, and the most recent publications are located in the leaves of a tree-like structure, as shown in figure 6.

Figure 6. Tree-like structure of selected publications on the evolution of the EMH investment up to date



Source. Own elaboration.

Seminal, Structural or Fresh refers to the type of contribution of each particular publication to the general outline of EMH investment, either as foundational, supporting or recent, respectively. Bibliographical entries are given in full in the Reference List at the end of this manuscript.

In order to picture the historical development of EMH investment and the research themes that this field has expanded in its scientific domain, understanding its roots and origins by acknowledging the domain's seminal theoretical frameworks is required. The analysis results identified the most influential works and most significant representatives of the EMH investment domain in terms of its foundations. Seminal publications, sometimes called pivotal or landmark studies, are publications that initially presented an idea of great influence and importance within a particular discipline or area of knowledge. Seminal publications in this (EMH investment) and any area of knowledge are distinctive for their high citation rates, as they are recurrently referenced in the research, so it is likely to see these sources frequently cited in other journal papers, book chapters, dissertations, etc. Likewise, seminal works may most probably have been published quite some time ago and by renowned academics. The use of the database generated from the extended citation network guarantees that the most influential works of seminal traits in the subject matter have been included in the present study. The most relevant nine publications of seminal nature on EMH investment, whose merit lies in the importance they have had to their derived works (those structural and more recent ones) are shown in figure 6. Fama's works published in 1965 and 1970 represent the seeds that served as geminal thoughts and may have been new for the EMH investment beginnings. Other works co-authored by Fama and French, no less important than the former ones, are also featured as seminal works (figure 6).

On the other hand, publications that were identified as structurally supporting, that provide the necessary stiffness and strength to the EMH investment domain and are the directly derived works from seminal ones, were also pinpointed in the whole tree-like structure of evolution of EMH investment. Fifteen structural publications were highlighted as the more relevant to be included in the aforementioned structure, as shown in figure 6. Structural publications are those works featuring a number of exit-entries that go to the seminal publications while exhibit a high number of entries of the documents

that, in the analogy of the tree, are located in those considered as the leaves (figure 6). These publications build knowledge by connecting seminal theoretical frameworks on which EMH investment is founded with the ones with the newest developments (recent ones). The results showed a wider range of publication years for the papers in this category, starting with *Public information and abnormal returns in real estate investment* by Gau (1985), published in the journal *Real Estate Economics*, up to *Time-varying efficiency of developed and emerging bond markets* by Charfeddine *et al.* (2018) (Physica A: Statistical Mechanics and Its Applications), and *Stock investment and excess returns: A critical review in the light of the efficient market hypothesis* by Yin *et al.* published in the Journal of Risk and Financial Management in 2019. It is also clear that the structure of EMH investment embodies more diverse contributors compared to the prominent ones condensed in the roots.

Finally, considering that there is consensus among scientists and researchers that articles less than five years old are recent publications, the fresher (recent) publications in the field of EMH investment were also identified by the *ToS* analysis. In this category the works with a high amount of exit-entries in the extended citation network of both seminal and structural publications, and also displaying a low level of entry citations were considered recent. Figure 5 shows the fourteen most significant fresh publications in the field of EMH investment within the five years from the search date. The results showed that 7 out 14 (50% of the selected fresh publications) had 2020 as publication year, followed by 2021 with 21% of the publications in this group (figure 5). The latest in this category were *Can adaptive market hypothesis explain the existence of seasonal anomalies? Evidence from Dhaka Stock Exchange, Bangladesh* by Akhter & Yong (2021) (Contemporary Economics), and *Do managers pay attention to the market? A review of the relationship between stock price informativeness and investment* by Pereira da Silva from the same year.

Major and most significant contributions made to enrich the debate and knowledge on EMH investment of the selected publications highlighted in each category (roots, trunk and leaves) will be provided in the Discussion section.

5. Discussion

The publications grouped in the *Classical Efficient Market Hypothesis Theory* cluster are characterized by the presentation and defense of the Efficiency Market Hypothesis (EMH) approaches, which assume a perfect market without taxes, transaction costs, fluency and free-of-charge information, and especially the rationality of market participants. The most important publication within this conglomerate is undoubtedly the seminal article of Fama (1970), in which he proposes the EMH approach. This publication has been a reference for multiple theoretical and applied studies that seek to examine its validity. It includes a wide range of results from the consolidation of the hypothesis with justifications for the different anomalies exhibited by the market, to the controversy of its postulates and the assumptions of the perfect market (Dhankar & Shankar, 2016). This has led to new theories with strong argumentative content and new approaches based on discrepancies not explained by the traditional finance paradigm (Caballero-Márquez & Morales-Pelagio, 2017; Costa *et al.* 2019). The study of Majumder (2014), located in this cluster, was based on the assumptions of the EMH on the rationality of investors and the diversification of their portfolios to achieve the expected utility where competition between market participants leads to a balance in which the returns of each investor reflect the fair value of their client portfolio. However, it differs in determining that those assumptions might not be descriptions of real life, because the decisions of investors are driven by feelings that could be the implicit factor behind the predictability of long-term equity returns. Majumder proposed a transformation, whereby the original market would become a relatively efficient hypothetical market, with the presumption that the price of current market assets is the product of a combined effect between published information and the subsequent investor sentiment (Majumder, 2014).

Aligned with the EMH, Arouri *et al.* (2010), conducted a comprehensive review on information efficiency and explored the arrival and processing of new information to emerging country markets to discern the heterogeneity of such markets in terms of size and levels of development, which lead to specific results in each country, taking into account transaction costs, poor information quality, deficiencies in information disclosure, the limited number of inadequate financial and accounting transactions and regulations. With results that differ from Fama's EMH generalization, in the sense that

they show that the degree of efficiency in these countries can evolve over time, different stages of development, as well as gradual processes of liberalization arise (Arouri *et al.*, 2010). Thus, the studies by Majumder, 2014 and Arouri *et al.* (2010), despite supporting themselves in the postulates of the EMH, are characterized by conducting their studies considering the real-life conditions in which the markets operate with imperfections and, in many cases, far from the ideal assumptions proposed by Fama in 1970, whose results not always remain in the generality and timelessness implicit in the EMH.

The studies contemplated within the *Divergence between Emerging and Traditional EMH Theories* cluster are characterized by developing research based on the study of the postulates of Fama's Efficient Market Hypothesis (1970) and the analysis of the quantity and diversity of anomalies that arise in different types of markets. Additionally, these deal with speculative bubbles, economic recession and technical analysis as an investment strategy, all of which are unknown, ignored or belittled by the defenders of the EMH in order to maintaining the conceptual supremacy of its postulates. The study by Woo *et al.* (2020) begins with the assumption of rationality of investors on which the EMH is based and turns to a number of research projects that challenge it, based on the fact that not all individuals participating in the market carry out the dynamic optimization processes necessary to respond to the expectation of rationality posed by the classical financial theory (Woo *et al.*, 2020).

The study by Sharma & Kumar (2019) coincides with Woo *et al.* (2020) doing research on phenomena such as the internet bubble of the 1990s and the economic recession of 2008, and adds the study of the increasing number of individual investors in the market that lead returns to deviate from their fundamental objectives and values. Meanwhile, Jegadeesh & Titman (1993) analyze the historical behavior of shares, demonstrating that under the strategy of purchasing profitable shares in the past and selling shares with previous losses, reveal patterns that allow achieving significant positive returns during holding periods of three to twelve months, with the possibility that part of these abnormal returns obtained will dissipate in the two years following the year of portfolio preparation, concluding that the expectations of the investors are systematically biased, which is reflected in the sub- or over-reaction to news coming to the market (Jegadeesh & Titman, 1993). The research studies of this cluster, although may differ in some of the

particular topics addressed, reach similar conclusions: many market phenomena can be explained by the EMH, but a significant number cannot be explained by the hypothesis, and finds its reason in behavioral finance.

The publications within the *Contribution to Corporate Governance Strategies and Actions to Investment Efficiency* cluster seek to analyze the contribution of corporate governance to the company's investment efficiency, which is reflected through the definition of a fair share price in the market. Thus, the study by Myers & Majluf (1984) in terms of the issue of shares for financing new projects, suggests the existence of asymmetry of information between the directors of the company —deeply knowledgeable of the projects to be financed— and the new investors away from detailed, and sometimes relevant, information of the projects. The conclusions of the study raise the possibility of the loss of the effect of this asymmetry when the investment is made in projects with positive net present value (Myers & Majluf, 1984).

The works of Nor *et al.* (2017, 2018) belonging to this cluster, coincide in targeting their efforts towards the effects of corporate governance on investment efficiency, but from different perspectives. The first publication is based on the independence of the board of directors, the size of the board of directors and the participation of executives in the ownership of the company. The second publication is based on the relationship between the characteristics of the audit and the level of company's investment efficiency, through the impact of the independence of the audit committee and the election of the auditor.

The results of both research studies confirmed the contribution of a solid corporate governance mechanism to the performance of the company through the mitigation of potentially inefficient investment levels due to insufficient or excess investment and the incidence of the size of the board of directors and the audit committee on the protection of the shareholders' interests (Nor *et al.*, 2017, 2018). The research studies included in this cluster make an interesting analysis that moves away from the study of the traditional market and link processes of corporate governance as a key element that contributes to the efficiency of the stock market from the perspective of providing relevant information and contributing to the formation of the fair price of financial assets.

Another important analysis in this research corresponds to the Tree of Science (ToS) analysis, which classifies the works published according to their position in the hypothetical tree-like structure as seminal, structural or recent (Robledo *et al.*, 2014). The seminal publications are those that gave rise to the topic of study, the recent publications describe the contemporary research trend and the structural publications represent the structural support for the study of the EMH in such a way that link the theoretical conceptualization with the latest published research. A large part of the publications classified at the root of the ToS are characterized by the presentation of the approaches and assumptions of the Efficient Market Hypothesis, with studies that compile the existing research until the 1960s and its conceptual consolidation, starting with the article by Fama (1965): *The Behavior of Stock-Market Prices*, which describes the price of market assets as a random walk where successive price variations correspond to the behavior of independent and identically distributed random variables, which is why past price changes cannot be used to describe future behavior (Fama, 1965). Subsequently, Fama's article published in 1970, is considered the genesis of the study of the Efficient Market Hypothesis, with the approach of three types of efficiency: weak, semi-strong and strong, depending on the type of information that reaches the market and with the implication that there is no predictability of asset prices, because any price variation corresponds to the response to random events (Patil & Rastogi, 2019).

Fama's publication (1970) is characterized by being the starting point for multiple research studies that address the behavior of the financial asset prices in the market, many of them supporting the EMH and a significant amount revealing inconsistencies of various types that have, in general, been known as market anomalies. Such studies include the publications of De Bondt & Thaler (1985), Lo & MacKinlay (1988) and Jegadeesh & Titman (1993), who study inconsistencies of various types to demonstrate that asset prices are influenced by behavioral aspects of market participants. De Bondt & Thaler (1985), incorporate psychological aspects of individuals in investment decision-making and study the exaggerated reaction that people have to unexpected and dramatic news events to determine that, such a reaction, affects asset prices and market efficiency in a weak way and leads to exceptional returns, with the anomaly known as the January effect (De Bondt & Thaler, 1985). Lo & MacKinlay (1988) test the random walk hypothesis for weekly returns of assets in the stock market, with results that lead to the absolute

rejection of the model due to the serial correlation observed in stock prices, mainly among the so-called small-cap stocks classified by the size of the underlying company (Lo & MacKinlay, 1988). Jegadeesh & Titman (1993) analyze the effect of overreaction as a response to changes in the market, with the design of a strategy of buying and selling selected shares based on previous results, concluding that the expectations of investors are systematically biased, which results in the possibility of proposing investment strategies that derive exceptional returns (Jegadeesh & Titman, 1993).

In response to studies that challenge the EMH with conceptually structured and empirically proven theories, Fama appears again at the root of the ToS: Fama & French, (1993) and Fama & French (1998) with the purpose of strengthening the EMH with justifications for the anomalies and deviations from the generality proposed in their 1970 article. Fama & French (1993) explain the excess returns in a portfolio by its exposure to three factors: a market risk premium, a market capitalization premium and a market capitalization premium calculated from the book value ratio (Fama & French, 1993). Fama & French (1998), based on the traditional capital asset valuation models—ICAPM by Merton and APT by Ross—incorporate two new factors for international companies that explain the excess returns of this type of companies, such as a relative stress risk factor and a premium for international returns, in a model they called ICAPM or two-factor APT (Fama & French, 1998). But despite the challenges and number of publications that have shown various types of anomalies in markets of different characteristics since 1980, the EMH remains one of the fundamental pillars on which the theoretical structure is built and applied to the valuation of financial assets, inspiring researchers and market professionals to develop a growing number of publications on the pricing behavior of financial assets.

The ToS tool also helps outline the research trends on EMH, reflected in the publications located in the leaves of the Tree of Science. These are characterized by studying the application of EMH approaches in different types of markets with emphasis on markets in developing countries and across different time frames. However, a significant number of these studies confront the classic theory represented by Fama's 1970 EMH with the most outstanding theories that have challenged the hypothesis in recent decades, mainly Behavioral Finance and the Adaptive Market Hypothesis, reaching conclusions that are

outlined by the AMH approaches of Lo (2004), such as the studies of Shahid *et al.* (2019), Akhter & Yong (2021), Xiong *et al.* (2018) and Rosini & Shenai (2020).

These studies coincide methodologically through advanced statistical and econometric applications, such as unit root tests, homoscedasticity, autocorrelation and autoregressive conditional heteroscedasticity, among others, under normal and abnormal conditions of the market, such as speculative bubbles, market crises, cycles, sustained price rises and falls, sudden stock market falls, the start of automated trading, and a system of circuit breakers that can affect asset prices. Shahid *et al.* (2019) determined that market efficiency varies over time depending on market conditions, such as bubbles, shocks, crises and cycles, allowing for temporary predictability of asset prices, with periods of efficiency and inefficiency alternating over time. Akhter & Yong (2021) found justification for some calendar effect anomalies that showed seasonality, although not all anomalies showed variability over time, and the results determined the adaptive capacity to changing market conditions as an element of greatest value for investors. The results of the study by Xiong *et al.* (2018) showed significantly higher returns in the calendar effect periods considered, compared to the other periods and with market efficiency results that fluctuate from one period to another. Rosini & Shenai (2020) present non-concomitance results between changes from a state of dependence to a state of independence of returns and vice versa, and the capture of calendar anomalies with inconsistent and variable behavior over time, to demonstrate that the market appears dynamic with changes from efficiency to inefficiency temporarily and vice versa. All these studies are consistent with the Adaptive Market Hypothesis (AMH), that reconciles the efficiency of the market of Fama (1970) with behavioral finance based on the principles of evolution, adaptation, competition and natural selection of living beings, Lo (2004).

6. Conclusions and Research Trends

The Efficient Market Hypothesis has been one of the most important supports of classical financial theory during the last five decades, characterized by the assumption of rationality of individuals, moved by the common purpose of maximizing their utility function. Since the publication of Fama in 1970, there has been a large body of knowledge derived from this theory, which poses the impossibility of achieving returns higher than the market average, regardless of the investment strategy used. A large number of studies

throughout history since Fama's publication (1970) have supported the hypothesis with theoretical and applied research around the world that ratifies its postulates. However, not all research derived from the EMH has been exclusively oriented to strengthen its approaches, because many of them have challenged and debated it after finding inconsistencies that have generally been known as market anomalies, mainly publications framed within the so-called Behavioral Finance. This is a branch of finance that emerged in the 1980s and focused on studying market participants' behavior, with the frequent demonstration of anomalies and effects that cannot be explained in the EMH postulates, such as calendar effects, the flock effect, the ostrich effect, the anchoring effect, the overreaction effect, the *momentum* effect, the size effect, the disposition effect and the speculative bubbles, among others.

However, the controversy over the EMH does not only come from Behavioral Finance. The publication of Lo (2004) provides a new vision that presents the lack of temporal consistency of the EMH and the intermittent efficiency of the market, leading to a conciliatory position between the classical theory represented by the EMH and Behavioral Finance focused on demonstrating the recurrence of market inconsistencies. According to Lo (2004), this new vision, which he called the Adaptive Market Hypothesis, presents an evolutionary approach to economic iterations and shows research results in cognitive neuroscience that have transformed and revitalized the intersection between psychology and economics. The evolutionary dynamics based on competition, mutation, reproduction and natural selection of living beings applied to financial markets and investment is part of the criticism of the EMH around the preferences and behavior of market participants, seen by many researchers as often irrational and predictable in their behavior.

The Adaptive Market Hypothesis and the application of Artificial Intelligence (AI) techniques to investing in the stock market stand out among the most recurring publications located in the ToS leaves and are presented as the main current research trends. The AMH provides the most relevant research trend towards which many researchers currently direct their efforts, when evaluating the postulates presented in the EMH, but at the same time recognizing the various types of inconsistencies occurring under specific circumstances, highlighted by Behavioral Finance. On the other hand, the

growing computational capacity has enabled the analysis of greater datasets and has led to the increasing use of advanced Artificial Intelligence techniques in combination with investment strategies such as Technical Analysis, particularly Genetic Algorithms and Neural Networks. This reflects a research trend in the stock market investment for the coming years.

7. Limitations of the Study and Future Research

The search equation used to extract the publications that make up the academic network on the EMH study was: *Market Efficiency Hypothesis* and *Investment*, applied to the different fields and types of publications described in the methodological approach of the academic databases *Scopus* and the *Web of Science*. The delimitation determined by the authors regarding the search words and the other specific fields allowed the selection of the most valuable publications on the topic of interest. However, this specific delimitation may have excluded other publications from the network. Another limitation of the study are the databases used for the search, because the ToS software, a differentiating tool in carrying out this study, only has access to the Scopus and Web of Science databases, and, although they are among the most widely recognized ones for their quality and plurality of topics included, those found in non-indexed journals or exclusively in other different databases could have been left out of the EMH network. However, these limitations should have been partially or totally solved naturally by forming the extended network of publications that included all the bibliographic references cited in the documents that were part of the initial academic network.

As a recommendation for future bibliographic studies employing methodologies such as the *Tree of Science*, it is suggested to extend the analysis to a larger number of clusters and the publications contained within each of them, with the aim of incorporating emerging theories and approaches that are gaining relevance in the fields of management and finance.

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