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RISK, RETURN AND INTERNATIONAL PORTFOLIO DIVERSIFICATION: K-MEANS CLUSTERING DATA

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Abstract. The work is devoted to the study of the international investment portfolio, its features such as risk, profitability and the level of international diversification, as well as global flows of portfolio investments. The methodology of the work is as follows. The paper develops k-means clustering model to study the patterns of global portfolio investment flows and equity markets. The model groups 30 developed and emerging stock markets according to three variables: return, risk and the level of international diversification. Thus, the main purpose of this paper is to investigate different stock markets on a global scale through an in-depth analysis of the respective market portfolios and their measures of risk, return and international diversification, as well as their interrelationships. The researcher develops and builds the model in such a way as to either confirm or refute the hypotheses put forward. The results of the study demonstrate the following results, which present opportunities for further research. The study supports the hypothesis that portfolios of investors from developed stock markets have a better level of international diversification than portfolios of investors from emerging stock markets. However, there is high within-group variation in the levels of international diversification among developed markets. There are three groups of developed markets based on the level of international diversification of investors in their respective markets: low-level markets (ca. 22%); mid-level markets (43%); and high-level markets (ca. 61%), while emerging markets are generally more heterogeneous. The hypothesis that stock markets that are domestic to investors with higher levels of international diversification have higher rates of return and lower rates of risk has not been confirmed. In general, developed stock markets are characterized by higher returns and international diversification with lower risk ratios. Nevertheless, the higher level of international diversification in developed market portfolios is not always accompanied by better stock performance. The best risk-return ratio (return – 0.46%, risk – 5.56%) is observed for markets from the cluster with an average level of international diversification. While the markets in the cluster with the highest level of international diversification have unreasonably high-risk ratios, which are not compensated by better returns. Markets in the cluster with lower levels of international diversification have unreasonably low rates of return that are not accompanied by correspondingly lower risks.

Key words: home bias, international diversification, risk, return, international investment, portfolio investment, investment decision.

JEL Classification: C38, F21, F37, G11, G15, G41

1. Introduction

The field of academic finance poses various challenges to researchers and requires careful study of financial phenomena. For example, global capital flows are one of the most complex and fundamental components of modern finance and constitute a large-scale area of financial research. Global capital flows can be divided into foreign direct investment, international portfolio investment and international debt flows. The purpose of this article is to explore some issues related to international portfolio capital flows. For several decades there has been an active growth of global

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portfolio investments. This has been made possible by the constant liberalization of capital markets and the internationalization of financial transactions. In addition, active economic and political integration at different levels (e.g., the creation of a single European currency) has removed barriers to capital flows. Among other reasons, the emergence of global financial centers such as Singapore, Dubai, and Luxembourg, the increasing pace of digitalization and decentralization of finance, disintermediation, and the formation of complex securities and financial instruments have also contributed to the expansion of portfolio capital flows. As a result, the total value of global portfolio investment is many times greater than that of foreign direct investment.

However, the structure and dynamics of international portfolio investments proved to be very adaptive and changeable. The global financial crisis of 2007–2008, the European debt crisis, the COVID-19 pandemics have left their mark on global portfolio capital flows. In addition, the processes of disintegration and fragmentation that are partly shaping the global economy today have affected the international dimension of portfolio capital flows. It should be noted that there have been significant challenges in international financial markets over the past 5 years. Border closures, disrupted supply chains, a crisis of confidence and loss of certainty have changed the international nature of free flow of capital. As a result, key indicators and characteristics of sustainable financial growth have become unstable. Moreover, financial markets in different countries have responded to the aforementioned challenges in very different ways: some markets have become more resilient, while others have gone into negative territory. The peculiarities of the current situation in global capital flows require a synergistic formula to solve the problems that financial markets are currently facing.

In-depth data analysis and sound empirical results are made possible by the application of contemporary findings by Cooper, Sercu, and Vanpee (2013), Coeurdacier and Gourinchas (2016), Bose, MacDonald, and Tsoukas (2015), Dziuba, Priyatelchuk, and Rusak (2021), and others. With this in mind, this article combines two approaches in its analysis. The neoclassical approach from traditional finance and the behavioral approach from behavioral economics and finance. Thus, the focus of our work is on the analysis of returns, risk, and the level of international diversification of the various markets of the world and their particular interdependence on the example of equities. Risk and return are the two most fundamental characteristics of an investment portfolio. Any portfolio manager uses these two variables and their ratios to assess portfolio performance. The third variable, i.e., the level of international diversification, is based on the phenomenon of home bias and represents the behavioral perspective of international finance. The work is based on the development of the k-means model with the division of markets into different clusters or groups. This type of analysis allows us to classify data according to variables of different nature and specificity. For a number of reasons, our work analyzes two-cluster, four-cluster, and five-cluster models to confirm and/or refute model hypotheses.

2. Literature review

To begin with, in the 1950s, Markowitz (1952; 1959) and Roy (1952) developed the theory of portfolio selection, which provided investors with the ability to analyze the degree of risk in relation to expected returns. For his achievements, Markowitz (along with Sharpe and Miller) was awarded the Nobel Memorial Prize in Economic Sciences in 1991. Markowitz's theory is known today as modern portfolio theory (MPT). Since Markowitz's theory, however, several improvements have been made to the model, including postmodern portfolio theory. Later, in the 1960s, Lintner (1965), Mossin (1966), Sharpe (1964), and Treynor (1965) developed the Capital Asset Pricing Model (CAPM), which became the only fundamental framework for evaluating investment performance in terms of risk and return.

Many of the models used in portfolio investment management are based on consolidated portfolio theory. The most fundamental component of portfolio theory is CAPM. CAPM states that through absolute diversification, an investor can eliminate the unsystematic risk associated with a particular company. Diversification provides a significant reduction in the level of risk if the portfolio components have a low level of correlation. In fact, if the portfolio is properly diversified, taking full advantage of international diversification at different levels, the overall risk level of the portfolio will be virtually zero. Investors make investment decisions on a rational basis, depending on how they evaluate the risk/return ratio. CAPM assumes that rational investors diversify risk that can be eliminated, such as unsystematic risk, leaving only systematic risk, which varies with the beta ratio of the portfolio.

Solnik (1974b) concludes that most portfolio investment models fail to consider the international aspect of capital flows, focusing excessively on disparate, independent markets. Solnik (1974b) notes that the rapid growth of cross-border investment and the increasing share of foreign firms in financial markets calls for a more thorough examination of the international aspect of portfolio investment. Based on CAPM, Solnik develops the International Capital Asset Pricing Model (ICAPM). Rogach and Dziuba

(2011) note that "ICAPM determines what is the equilibrium expected return on financial assets when the expected return is measured in the investor's local currency and is shaped by constant changes in exchange rates". Breuer and Ruiz de Vargas (2021) also confirm that models developed in an international context face additional complexity and need to account for exchange rate risks.

Modern portfolio theory is a theory of investment management according to which an investor maximizes the expected return of a portfolio for a given rate of risk or minimizes risk for a given rate of expected return by determining the necessary parity between different asset classes. Modern portfolio theory has been empirically tested many times and is widely used by investment professionals, as Hu (2022) confirms, but the basic assumptions of the theory are often criticized, as Omisore, Yusuf, and Christopher (2011) note. The main drawback of the theory is its simplistic underlying assumptions. The effectiveness of modern portfolio theory has been called into question because Markowitz's model of financial markets does not correspond to what financial markets actually are. In recent years, especially after the global financial crisis of 2007–2008, the basic assumptions of modern portfolio theory have come under considerable criticism from various scholars, particularly those in behavioral economics and finance. For instance, Rodríguez, Gómez, and Contreras (2021) point out that the approach by Markowitz (1952; 1959) does not consider distributional characteristics of the returns, i.e., skewness and kurtosis, and investor's risk tolerance. Geambasu, Sova, Jianu, and Geambasu (2013) remark that, as a result, investors and researchers began to search for alternative theories of portfolio management.

Portfolio management specifies that an investment portfolio can be substantially characterized using three features such as risk, return and investor's risk tolerance. Dziuba, Pryiatelchuk, and Rusak (2021) note that risk and return are two fundamental and objective characteristics of any investment portfolio. They characterize the efficiency of a portfolio and serve as universal standard indicators for any investment professional. Despite the fact that risk and return are rather basic indicators, their importance for analysis is undeniable.

The term "investor risk tolerance" is defined in a wide variety of ways. There are different views on whether investor risk tolerance is an intrinsic and enduring characteristic of the individual investor and whether it also takes into account external factors (e.g., economic shocks), which depend on how risk tolerance is measured. However, the definitions of investor risk tolerance have strong similarities. In Davies' (2017) opinion risk tolerance is the investor's willingness and ability to take a certain level of risk. Grable (2017) defines that risk tolerance is the willingness to engage in a risky behaviour in which possible outcomes can be negative, and notes that there are many risk-associated concepts that are very different such as risk aversion, risk perception, risk preference, among others. The above definitions follow the behavioral paradigm of studying finance and investment. Grable (2017) concludes that risk tolerance varies among individual investors because it is an individual indicator, but at the same time it can show a certain level of stability over the life of the investor, despite various external factors. However, investor risk tolerance is ultimately an individual characteristic that depends on each investor, and it requires further study and discussion.

In this paper, the k-means cluster model is based on the classification of 30 markets into different clusters based on 3 attributes (variables). These three variables are profitability, risk, and the level of international diversification. Since the motivations for using risk and return have already been substantiated in our model, it is important to discuss the third variable. The third variable used in the analysis is the level of international diversification. The theory of international diversification advanced by Solnik (1974a) is considered the basis for international portfolio management and one of the most important aspects of modern portfolio theory. Solnik (1974a) argues that an investor benefits from an investment portfolio built using foreign investment assets because it increases portfolio returns and reduces risk. The benefits of international diversification theory have been repeatedly empirically tested and recognized by global academic community, e.g., Levy and Sarnat (1970), Sercu (1980), Grauer and Hakansson (1987), among others. However, another body of research argues that investors are not taking full advantage of international portfolio diversification. In fact, the structure of many investment portfolios does not match the recommended international portfolio. This discrepancy between the practice and theory of international portfolio investing has been called the home bias. Home bias is a kind of suboptimal investor behavior because it does not maximize the utility of an investment decision. It is one of the unresolved phenomena in modern finance and part of an array of different behavioral biases.

Home bias is a complex phenomenon in international finance. It can be considered at different levels for different markets and securities. There are various definitions of home bias, so it is necessary to cite some of them. Cooper, Sercu, and Vanpee (2013) identify equity home bias as "the empirical phenomenon that investors' portfolios are concentrated in domestic equities to a much greater degree than justified by portfolio theory". Fidora, Fratzscher, and Thimann (2007) set out that home bias is "(an attitude)

towards holding domestic financial assets". Chan, Covrig, and Ng (2005) determine that home bias is "a phenomenon, when investors do not exploit diversification opportunities, as they allocate a relatively large fraction of their wealth to domestic equities".

As far as 1970s Levy and Sarnat (1970) revealed that foreign investment assets made up less than expected share of American investors portfolio. Another fundamental research has been made by French and Poterba (1991) who demonstrate that investors in the USA, Japan, UK, Germany, and France have very strong preference towards domestic stock market. Moreover, the dominant part of global equity market is owned at domestic level. Then the number of other studies confirmed the results of Levy and Sarnat, including existence of home bias for other markets, e.g., Cooper and Kaplanis (1994), Tesar and Werner (1994), Ahearne, Griever, and Warnock (2001), Karolyi and Stulz (2003), Solnik (2008), Vanpée and DeMoore (2012), among others. A huge body of data on home bias confirms that this phenomenon exists in virtually all markets around the world. Home bias is well documented for various stock markets around the world. However, home bias for other securities, such as bonds, requires further analysis. It is clear that the bond market differs from the stock market in terms of pricing of securities, dynamics, institutions, regulation, etc. Yakubovskiy, Dominese, Rodionova, and Derenko (2021) investigate the yields dynamics of government bonds for some countries of the EMU and find that internal factors of yield determination have become less significant, while the central bank policy and its monetary instruments play more important role in the dynamics of bonds yields.

Even though there is a broad range of different papers on the causes of home bias existence, such as Ahearne, Griever, and Warnock (2001), Cai and Warnock (2005), Dvorak (2005), Daude and Fratzscher (2008), Coeurdacier and Gourinchas (2016), Bose, MacDonald, and Tsoukas (2015), among others, there is still no consent on the fundamental cause of home bias. Many different assumptions have been made, ranging from asymmetries of information to the degree of development of financial markets and the level of financial education. From the authors' point of view, behavioral factors play an important role in the spread of home bias, as many investors, especially non-professional investors, often perceive foreign financial markets as something unknown, unpredictable and uncertain due to a lack of professional competence and experience. Kim and Kim (2022) maintain that unfamiliarity with a specific country has a strong positive correlation with the level of home bias in the international equity markets. Hiraki and Liu (2021) find out that, in general, managers of global equity mutual funds in the USA do not tend to exhibit home bias. Fund managers are more likely to diversify internationally if they are younger or better educated (MBA or international education). One of the other reasons for the existence of a "home bias" is the degree of development of the financial markets. It is clear that investors prefer developed capital markets with better liquidity and lower transaction costs. However, if an investor wants to analyze a specific market to develop his or her strategy, it is necessary to identify key indicators for evaluation. For example, it should be noted that investors pay a lot of attention to the international investment position (IIP) of the country entering the market. Based on a country's international investment position, an investor can monitor the financial openness, debt sustainability, financial stability and creditworthiness of, among other things, a particular market. Zadoia (2021) points out that there are different models of an international investment position and finds that Ukraine, for instance, has balanced IIP model, while Czech Republic is moderate recipient, and Hungary is active recipient. Also, Kim and Kim (2021) note that one of the reasons for home bias is the hedging against real exchange rate and wage risks. In general, it is possible to determine some groups of factors, such as institutional factors, behavioral factors, transaction factors and other factors as it is outlined in Dziuba and Shtogrin (2020).

Home bias refers to a group of behavioral biases studied in behavioral economics and finance. Behavioral economics and finance are based on the fundamental assumption that economic agents are not completely rational in their decisions. However, people's behavior may have limited or suboptimal rationality, which does not produce the best results, but is quite effective in meeting the needs of the economic agent. It should be noted that there is a wide range of various behavioral biases that influence the financial decisions of investors, including FOMO effect (Hershfield, 2020), irrational exuberance (Shiller, 2015), loss aversion (Pompian, 2012), overconfidence (Glaser and Weber, 2007), disposition effect (Yang, 2019), endowment bias (Thaler, 1980), hindsight bias (Biais and Weber, 2009), and other effects (Baker and Nofsinger, 2010). Byrne and Brooks (2008) note that there is an alternative treatment of investors' behaviour, meaning that a significant minority of investors act under behavioral biases so that their investment decisions are not fully effective. Hirshleifer (2015) stresses that "modern understanding of the finance field requires grounding in psychological as well as rational approaches". Since modern portfolio theory is thought to be part of the neoclassical approach to finance, applying a behavioral finance perspective to the model will contribute to a better understanding of global investment flows.

3. Methodology, hypothesis, and data

Based on the themes and issues in international finance, behavioral finance, and portfolio investment management discussed in the literature review section, the following hypotheses would be motivated. The authors' first hypothesis suggests that portfolios of investors from developed markets have a better level of international diversification than portfolios of investors from emerging markets. The second hypothesis assumes that markets that are domestic to investors with a higher level of international diversification have a higher rate of return and a lower level of risk.

The model was developed using the cluster analysis method. The cluster method was chosen for several reasons due to the nature and specificity of the data, as well as the advantages of cluster analysis. Cluster analysis belongs to the group of methods of classification analysis. It allows to divide a set of observations into different clusters or groups, so that the observations in one cluster are sufficiently similar to each other. The main advantage of cluster analysis is that observations can be classified into several variables of any nature, and the required number of clusters can be determined depending on the goals of the study. There are different types of cluster analysis. However, this model is based on the k-means clustering method. The purpose of k-means is to group similar observations into clusters using centroids with the number of clusters denoted by k. One of the drawbacks of k-means clustering is the selection of the optimal number of k (clusters). However, the model is based on the silhouette method of choosing k, which guarantees the correctness of the chosen number of clusters.

Thirty markets were selected for analysis, such as Great Britain, France, Germany, USA, Japan, Norway, Canada, Hong Kong, Ireland, Italy, Netherlands, Spain, Thailand, Turkey, Poland, Indonesia, Korea, India, Argentina, Austria, Denmark, Belgium, Sweden, Egypt, Brazil, Switzerland, Greece, Hungary, Mexico, Malaysia. The MSCI market classification was used to develop the model. The model includes the following market categories: 17 MSCI Developed Markets (UK, France, Germany, USA, Japan, Norway, Canada, Hong Kong, Ireland, Italy, Netherlands, Spain, Austria, Denmark, Belgium, Sweden, Switzerland); 12 MSCI Emerging Markets (Thailand, Turkey, Poland, Indonesia, Korea, India, Egypt, Brazil, Greece, Hungary, Mexico, Malaysia); and 1 MSCI Standalone Market (Argentina). The raw data are absolute monthly returns for 30 stock markets, denominated in U.S. dollars, at the gross index level. Stock size is standard (large- and mid-cap stocks). Data are for the 5-year period from June 30, 2017 to June 30, 2022. This data became the basis for calculating monthly return and risk percentages in order to determine the market portfolios for each market in question. The main idea of the model is to describe each market using three characteristics, such as the rate of return, the rate of risk and the level of international diversification.

The figures for levels of international diversification have been calculated using data on home bias based on papers by Bose, MacDonald, and Tsoukas (2015), Boermans, Cooper, Sercu, and Vanpée (2022). In particular, the choice of markets for the study was driven by the availability of home bias data. For many frontier markets, home slope data are not available due to a lack of information on investment activity in these markets. It should be noted that the methodology for calculating home slope is quite diverse. Among others, we prefer the methodology provided by Fidora,

Table 1

The average monthly levels of return and risk, and level of international diversification for 30 MSCI markets (2017–2022)

№	Country	Return, %	Risk, %	Level of international diversification, %
1	Argentina	0.12	13.91	13.47
2	Austria	0.26	8.77	57.23
3	Belgium	-0.25	6.25	48.17
4	Brazil	0.69	10.69	2.60
5	Canada	0.77	5.65	44.00
6	Denmark	1.02	4.61	42.78
7	Egypt	-0.52	7.00	1.07
8	France	0.49	5.78	33.82
9	Germany	0.01	6.04	30.63
10	Greece	-0.41	9.24	9.49
11	Hong Kong	0.31	4.90	22.40
12	Hungary	-0.04	8.67	17.57
13	India	0.80	6.28	2.08
14	Indonesia	0.28	6.82	0.57
15	Ireland	0.04	5.94	65.86
16	Italy	0.34	7.09	45.43
17	Japan	0.26	4.05	21.35
18	Korea	0.20	6.65	7.18
19	Malaysia	-0.14	4.15	3.62
20	Mexico	0.29	7.68	1.90
21	Netherlands	0.67	5.48	66.53
22	Norway	0.84	6.49	54.65
23	Poland	-0.45	8.66	3.43
24	Spain	-0.09	6.60	14.61
25	Sweden	0.37	5.99	43.54
26	Switzerland	0.64	4.06	42.70
27	Thailand	0.26	6.69	1.67
28	Turkey	-0.75	10.42	0.43
29	UK	0.31	5.01	43.52
30	USA	1.01	4.98	28.00

Notes:
1. Figures calculated by the authors using data from the MSCI indices (MSCI, 2022).
2. Yield and risk levels are calculated as monthly averages using the mean and standard deviation, respectively.

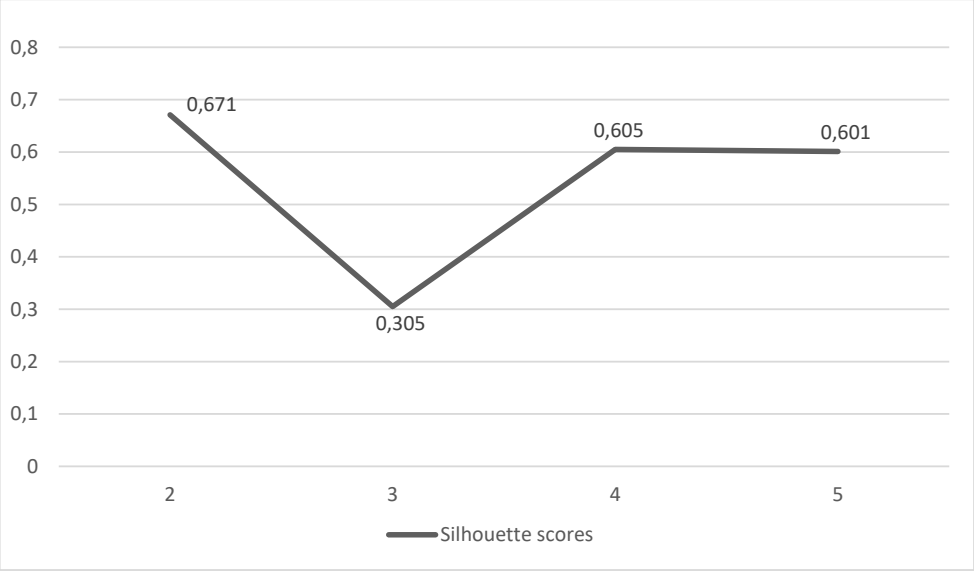

Figure 1. Development of the silhouette scores for different clusters

Notes:
1. The corresponding figures have been calculated and the graphs have been compiled by the authors.
2. In order to simplify and facilitate the perception of the results, the underlying calculations are not given.

Fratzscher, and Thimann (2007) for calculating equity home bias based on Coordinated Portfolio Investment Survey by IMF.

The model is designed for two, three, four, and five clusters. The silhouette estimation method is used to determine the most optimal number of clusters. The results of the evolution of the silhouette estimates show that the model with two clusters has the highest level of accuracy. The lowest score is attributed to the three-cluster model. Nevertheless, the four- and five-cluster models also have quite high performance in comparison with the two-cluster model. Therefore, this article analyzes three models: two-, four-, and five-cluster models.

4. Results and discussion

The two-cluster model divides markets into two groups. The first group consists of 14 markets, and the second group consists of 16 markets. The first group includes Great Britain, France, Germany, the United States, Norway, Canada, Ireland, the Netherlands, Austria, Denmark, Belgium, Sweden, and Switzerland, and the central object of the cluster is Italy. The second group includes Japan, Hong Kong, Spain, Thailand, Turkey, Poland, Indonesia, India, Argentina, Egypt, Brazil, Greece, Hungary, Mexico, Malaysia, while Korea is the centerpiece of the cluster.

Obviously, the first group includes only markets from the MSCI developed markets classification. Although the second group covers mostly MSCI Emerging Markets, it includes three markets from the developed markets group. The inclusion of Japan, Hong Kong, and Spain in the second group appears to be due to a relatively low level of international diversification (21.35; 22.40; 14.61, respectively). However, this inclusion may be incorrect due to the absence of the other two factors (e.g., the risk level of these markets indicates that they belong to the first group). The average rate of return in the first cluster is significantly higher than in the second (0.47% vs. 0.05%). The average rate of risk in the first cluster is lower than in the second cluster (5.87% vs. 7.65%). The average level of international diversification is also significantly higher in the first cluster (46.20% vs. 7.72%). It is possible to conclude that the first cluster of markets has higher efficiency with more optimally constructed portfolios of developed markets. Moreover, investors in the first cluster choose more internationally diversified portfolios.

The four-cluster model divides markets into four groups. The first cluster consists of 8 developed markets: Great Britain, France, Canada, Italy, Denmark, Belgium, Switzerland and Sweden, the center of the cluster. The second cluster covers 6 markets: Germany, the United States, Japan, Spain, Hungary and Hong Kong, the centerpiece of the group. These five markets are developed, although one market (Hungary) is developing. This can be explained by the fact that Hungary has the highest level of international diversification among emerging markets. The third cluster unites 4 markets: Norway, Ireland, the Netherlands and Austria, which is the center of the cluster. All four markets are developed and have the highest level of international diversification. The fourth cluster covers 12 emerging markets: Thailand,

Table 2
Statistics for centroids of clusters of the two-cluster model

Cluster	Return, %	Risk, %	Level of international diversification, %	Sum of weights	Within-cluster variance
1	0.47	5.87	46.20	14	137.41
2	0.05	7.65	7.72	16	66.45

Notes:
1. Figures calculated by the authors using data from the MSCI indices (MSCI, 2022).

Table 3
Descriptive results for the two-cluster model

Cluster	1		2	
Number of objects by cluster	14	UK, France, Germany, USA, Norway, Canada, Ireland, Italy, Netherlands, Austria, Denmark, Belgium, Sweden, Switzerland	16	Japan, Hong Kong, Spain, Thailand, Turkey, Poland, Indonesia, Korea, India, Argentina, Egypt, Brazil, Greece, Hungary, Mexico, Malaysia
Intra-cluster dispersion	137.41		66.45	
Minimum distance to the centroid	1.45		1.14	
Average distance to the centroid	8.93		7.08	
Maximum distance the to centroid	20.33		14.94	
Central object	Italy		Korea	

Notes:
1. Figures calculated by the authors using data from the MSCI indices (MSCI, 2022).

Turkey, Indonesia, Korea, India, Argentina, Egypt, Brazil, Greece, Mexico, Malaysia and Poland – the center of the cluster. The first cluster has the highest rate of return and the lowest level of risk among the four clusters. The fourth cluster has the lowest rate of return and the highest rate of risk among the four clusters. However, the first cluster is not the leader in terms of international diversification. The third cluster has the highest level of international diversification and fairly high rates of return. It should be noted that the market portfolios of the first cluster have the most optimal risk and return indicators, but, nevertheless, investors prefer to invest almost 43% of the portfolio globally. In addition, this can be explained by the fact that investors from developed markets prefer to invest in assets from developed markets. On the other hand, the second cluster, consisting mainly of developed markets, has a relatively low level of international diversification. The main reason for this phenomenon is that most popular stocks for international portfolio diversification are national for the markets of the second cluster. The most effective stocks are those of multinational corporations, located, in addition, in the United States, Germany, and Japan. Therefore, national investors from these markets have no incentives to diversify internationally. At the same time, there is a third cluster, which unites developed markets and has the highest level of international diversification. The dynamics of this cluster can be explained by two reasons. Ireland and the Netherlands are well-known global financial centers and are known for their excellent offshore financial services. Offshore investment funds provide a very high level of international diversification due to the nature of offshore financial centers. Norway and Austria have a high level of international diversification because their domestic stock markets do not offer the full range of investment opportunities due to the limited presence of multinational companies. It can also be concluded that a low level of international diversification (i.e., less than 5%) is usually accompanied by lower returns and higher market portfolio risk. It should also be noted that despite the lower level of the silhouette index compared to the 2-cluster model, the 4-cluster model leads the study to more complex results.

The five-cluster model divides markets into five clusters. The first cluster includes 7 markets: UK, Italy, Denmark, Belgium, Sweden, Switzerland and Canada, which is the central object of the cluster. The

Table 4
Statistics for cluster centroids of the four-cluster model

Cluster	Return, %	Risk, %	Level of international diversification, %	Sum of weights	Within-cluster variance
1	0.46	5.56	43.00	8	18.02
2	0.24	5.87	22.43	6	39.70
3	0.45	6.67	61.07	4	38.51
4	0.03	8.18	3.96	12	23.18

Notes:
1. Figures calculated by the authors using data from the MSCI indices (MSCI, 2022).

Table 5
Descriptive results of the four-cluster model

Cluster	1	2	3	4
Number of objects by clusters	8	6	4	12
Intra-cluster dispersion	18.02	39.7	38.51	23.18
Minimum distance to the centroid	0.70	0.98	4.38	0.86
Average distance to the centroid	2.81	5.08	5.32	3.91
Maximum distance to the centroid	9.18	8.21	6.43	11.10
Markets	UK, France, Canada, Italy, Denmark, Belgium, Sweden, Switzerland	Germany, USA, Japan, Hong Kong, Spain, Hungary	Norway, Ireland, Netherlands, Austria	Thailand, Turkey, Poland, Indonesia, Korea, India, Argentina, Egypt, Brazil, Greece, Mexico, Malaysia
Central object	Sweden	Hong Kong	Austria	Poland

Notes:
1. Figures calculated by the authors using data from the MSCI indices (MSCI, 2022).

second cluster includes 5 markets: France, Germany, Japan, Hong Kong and the United States, which is the central object of the cluster. The third cluster consists of 4 markets, including Norway, Ireland, and the Netherlands, and the central object of the group is Austria. It should be noted that the third cluster fully coincides with the third cluster in the 4-cluster model. The fourth cluster combines Spain, Argentina, Greece and Hungary, with Spain as the central object of the cluster. The fifth cluster includes 10 markets: Thailand, Turkey, Poland, Indonesia, Korea, India, Egypt, Brazil, Malaysia and Mexico – the central site. The first cluster has the highest rate of return. However, the second cluster has the lowest risk, and the third cluster has the highest level of international diversification. Moreover, the fourth and fifth clusters have the lowest rates of return and the highest rates of risk with the lowest levels of international diversification. The first cluster appears to be the most optimal in terms of the three variables. The second cluster is also quite efficient in terms of risk and return, even though it has relatively average levels of international diversification. The third cluster has the highest level of international diversification, but, as in the 4-cluster model, the level

Table 6
Statistics for cluster centroids of the five-cluster model

Cluster	Return, %	Risk, %	Level of international diversification, %	Sum of weights	Intra-cluster dispersion
1	0.46	5.52	44.31	7	4.97
2	0.42	5.15	27.24	5	29.13
3	0.45	6.67	61.07	4	38.51
4	-0.11	9.61	13.79	4	20.76
5	0.07	7.50	2.46	10	8.06

Notes:
1. Figures calculated by the authors using data from the MSCI indices (MSCI, 2022).

Table 7
Descriptive results of the four-cluster model

Cluster	1	2	3	4	5
Number of objects by clusters	7	5	4	4	10
Intra-cluster dispersion	4.97	29.13	38.51	20.76	8.06
Minimum distance to the centroid	0.46	0.98	4.38	3.12	0.62
Average distance to the centroid	1.75	4.39	5.32	3.92	2.37
Maximum distance to the centroid	4.00	6.61	6.43	4.32	4.80
Markets	UK, Canada, Italy, Denmark, Belgium, Sweden, Switzerland	France, Germany, USA, Japan, Hong Kong	Norway, Ireland, Netherlands, Austria	Spain, Argentina, Greece, Hungary	Thailand, Turkey, Poland, Indonesia, Korea, India, Egypt, Brazil, Mexico, Malaysia
Central object	Canada	USA	Austria	Spain	Mexico

Notes:
1. Figures calculated by the authors using data from the MSCI indices (MSCI, 2022).

of risk is suboptimal, although the rate of return is quite high. Based on the 5-cluster model, it is possible to conclude that the level of international diversification below 15% can be accompanied by a relatively low rate of return and a high risk rate. However, it remains unclear why there is a strong 17% difference in international diversification between the first and second clusters, despite the fact that the economic structure and level of development of financial markets are the same.

A comparison of all three cluster distributions yielded the following results. Although the two-cluster model has the highest silhouette score and the most optimal distribution of markets across clusters, its results are quite predictable and follow conventional wisdom. However, models with more clusters provide some interesting results for further discussion. Developed markets generally have a better level of international diversification, although it may vary from market to market, and better risk-return ratios. Markets in which investors prefer low levels of international diversification (below 5% for the 4-cluster model and below 15% for the 5-cluster model) were found to have lower returns and higher risk ratios. These markets practically belong to the MSCI emerging markets group. As a consequence, these markets need further integration into global financial markets in order to better exploit portfolio diversification opportunities. Second, there are markets with a high level of international diversification, such as Norway, Ireland, the Netherlands, and Austria, due to a number of factors, such as offshore financial activity and limited opportunities in national stock markets. In addition, investors in a number of developed markets prefer to diversify their portfolios globally, while their national stock markets provide an effective risk-return ratio. However, there are some developed markets that are domestic to various multinational companies, and, as a consequence, investors in these markets prefer to invest more capital in national stock markets. At the same time, there is a large difference in the levels of international diversification between some clusters, and this result requires further discussion. It is also important to note that the simultaneous efficient operation of a national stock market and a high level of international diversification can only occur if international diversification occurs between units of the same cluster or units of clusters with similar risk and return ratios. The high rate of internalization and liberalization of financial markets has led to global financial integration and the emergence of transfer mechanisms. The crisis events of recent years throughout the global economy have tended to shift from one market to another. Quite similar risk and return ratios in developed market clusters suggest that developed markets are interdependent, while the significant differences between developed and emerging market clusters demonstrate the potential gap between these markets.

5. Conclusions

The paper examines 30 different markets around the world using three variables such as risk, return, and the level of international diversification. The paper combines traditional finance and behavioral finance approaches for in-depth analysis. The work is based on the development of a k-means clustering model. Three different types of models were analyzed, such as two-cluster, four-cluster, and five-cluster. The choice of the number of clusters was determined using the silhouette scoring method. The highest number of silhouette scores was awarded to the model with two clusters. However, models with four and five clusters also yield results of interest for this paper. The main purpose of the model is to confirm and/or refute the following two hypotheses of the paper.

The first hypothesis is that portfolios of investors from developed markets have a better level of international diversification than portfolios of investors from emerging markets. The first hypothesis is confirmed by the results of the model. Developed markets generally have a better level of international diversification (hence, a lower level of "home bias") compared to emerging markets. The two-cluster model clearly differentiates markets into developed and emerging markets, with the exception of Japan, Hong Kong, and Spain (this was done because of their relatively lower international diversification rates). Among developed markets, however, there is extremely high within-group variation in international diversification levels. Based on the four-cluster model, three clusters (groups) of developed markets can be identified. The first group has an average level of international diversification (43%). The second group of markets has a low level of international diversification (about 22%), and the third group of markets has the highest level of international diversification (about 61%). The results of clustering in the five-cluster model confirm the above conclusions. One likely reason for the very high level of international diversification in some markets, such as Ireland and the Netherlands, is their offshore financial services, including offshore investment funds. Moreover, while developed markets have been divided into three different clusters, most emerging markets have been combined into one cluster. This might suggest that emerging markets are more homogeneous in terms of model variables, while developed markets are more heterogeneous for some reason (for example, there are some financial inequalities between developed markets, or portfolio investment flows are unbalanced). However, only the

five-cluster model differentiates emerging markets into two clusters, with one cluster having about 14% international diversification and the second cluster having about 2.5% international diversification.

The second hypothesis is that markets that are domestic to investors with a higher level of international diversification have a higher rate of return and a lower level of risk. However, the results of clustering with different k-numbers leave some doubt about this hypothesis. The two-cluster model clearly shows that developed markets have higher rates of return and international diversification with lower rates of risk. However, the results from the other two models again point to significant intra-group differences. The best international diversification performance of investors from developed markets is not always followed by the best stock performance in these markets. Based on the four cluster model, the best risk-return ratio (0.46% return, 5.56% risk) is observed for markets from the cluster with medium international diversification. While the markets in the cluster with the highest level of international diversification have unjustifiably high risk indicators, which are not compensated by the best yield (yield – 0.45%, risk – 6.67%). With almost the same rates of return, the level of risk is higher by almost one percent. At the same time, markets from the cluster with a lower level of international diversification have unreasonably low rates of return, not accompanied by correspondingly lower risks (return – 0.24%, risk – 5.87%). The reasons for these conclusions may be very different. Nevertheless, one of the possible obvious explanations for the low level of international diversification is the high level of listing of multinational companies on the stock exchanges of a number of developed markets. For emerging markets, the two-cluster and four-cluster models indicate a tendency for markets with lower levels of international diversification (e.g., lower levels of global financial integration) to have lower returns and higher risk. For the two-cluster model, the return is 0.05% and the risk is 7.65%, while for the four-cluster model the return is 0.03% and the risk is 8.18%. However, the five-cluster model divides emerging markets into two clusters (clusters № 4 and 5). Cluster № 5 has the lowest level of international diversification with a rate of return of 0.07% and a risk rate of 7.50%. On the contrary, cluster № 4 has six times higher international diversification, but its rate of return is negative (-0.11%) and its risk rate is higher than that of cluster № 5. One likely reason for this discrepancy is that a market with a negative rate of return encourages international diversification in investors' portfolios.

Author Contributions

Pavlo Dziuba: Term, Conceptualization, Methodology, Formal analysis, Supervision, Writing – original draft, Writing – review and editing. Darya Glukhova: Literature review, Methodology, Formal analysis, Writing – original draft. Kyryl Shtogrin: Literature review, Formal analysis, Writing – original draft.

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