Empirical Paper

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Assessing the diversification risk of a single equity market: evidence from the largest European stock indexes

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Abstract: Diversification of financial securities is considered a substantial element of portfolio risk. In this context, the construction of an optimal portfolio is an ongoing concern for portfolio managers. This study measures the risk–reward tradeoffs linked to the stock indexes of Germany, Spain, Italy, France, and England. First, the stock indexes are analyzed as individual portfolios and later compared to the hypothetical common equity index. The results show diversification benefits gained from a hypothetical common European stock market. Individual stock prices and trade volumes are collected weekly from January 1, 2008 to December 31, 2018. The results indicate that, on average, the most well-diversified equity indexes are IBEX35, FTSE MIB, and FTSE100. In contrast, DAX, MDAX, and CAC40 on average tend to be less diversified. The diversification risk for DAX, MDAX, and CAC40 decreases from joining a common hypothetical stock market, while for FTSE100, FTSE MIB, and IBEX it increases.

Keywords: diversification benefits, financial crisis, risk perspective, single equity market, stock index
JEL Classification: G11, G15

1 Introduction

Stock markets are an essential element of the financial system that enables the efficient allocation of funds from savers to investors. Financial investors seek out stocks that minimize the diversification risk and raise portfolio benefits. As such, the volatility of the stock markets has gained increased attention from policymakers, scholars, and the media. Markowitz [1952, 1959] established the profound framework on portfolio management, known as Modern Portfolio Theory (MPT). The theory considers that investors hold diverse risk preferences, influenced by their perceptions of the forthcoming events. Moreover, MPT stands on the efficiency assumption where investors cannot beat the market since stock prices contain all available information. To this end, constructing an optimal portfolio that outperforms market returns relies on the capacity of portfolio managers to anticipate future events. The European Commission's initiative on a single capital market in the European Union (EU) tends to reduce country differences and expand the diversity of listed firms. In 2014, chair commissioner Jean-Claude Juncker launched an action plan for a single EU capital market that would increase efficiency and harmonize trading platforms. In this context, private initiatives have been taken where the Paris Stock Exchange (CAC), Amsterdam Stock Exchange (AEX), and Brussel Stock Exchange launched the Euronext in

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September 2000 [Euronext, 2021]. Currently, Euronext stands as the largest capital market in Europe with a capitalization of over $5 trillion. The merger of stock markets tends to dampen transaction costs but at the same time makes financial problems more interdependent. The study by Espinosa-Méndez et al. [2020] shows that the Euronext Stock Exchange has increased interdependency and reduced diversification opportunities. The case of the Latin Integrated Market represents a situation where, in 2009, the Santiago Stock Exchange, Lima Stock Exchange, and Columbia Stock Exchange established a joint trading entity named MILA [MILA, 2021].

The creation of MILA raised the trade volume of less active exchanges but also amplified their short- and long-run integration [Mellado and Escobari, 2015; Espinosa-Méndez et al., 2017]. The concept of a single capital market with regional characteristics is also known as the Balkan Stock Exchange [SEE Link, 2021], and that of the Baltic countries is known as Nasdaq Baltic [NB, 2021]. The merger of the stock exchanges into a single one does not mitigate the risk level to all countries involved. Aliu et al. [2019] studied diversification risk benefits of the possible single equity market for the Budapest Stock Exchange (BUX), Bratislava Stock Exchange (SAX), and Warsaw Stock Exchange (WIG20). Results indicate that diversification benefits from a single equity market for BUX declines while it increases for SAX and WIG20. Integrated stock markets have reduced the prospect of portfolio optimization through international diversification.

The EU integration process made local economies interdependent with EU members. Furthermore, free capital flows, followed by trade liberalization and the introduction of a single currency, strengthened the interdependency of the European financial system. However, increased integration among components of the international equity market diminishes diversification benefits for financial investors. Such investors can now achieve international diversification even by investing only in domestic stock indexes [Berrill and Kearney, 2010; Oehler et al., 2017]. Financial globalization and deregulation have created interdependency among stock markets, which has dampened the space for diversification opportunities. The financial crisis of 2008–2009 proved that the global financial system is highly integrated, such that problems in one country quickly spill over into other countries. The concept of a single market stands as a controversial topic among scholars, policymakers, and portfolio managers. We have analyzed the risk–return tradeoff of the six largest equity indexes in Europe through standard diversification methods. However, the capacity of this study is constrained by the sample of the six largest equity indexes in Europe. The results of our work report that not all selected equity indexes benefit from the hypothetical single equity market. The diversification risk for the equity indexes FTSE100, FTSE MIB, and IBEX 35 increases as a result of joining the single equity market. However, for indexes like DAX, MDAX, and CAC40, diversification risk declines as a result of joining the single equity market.

Studies and controversial discussions on the single equity market in Europe are quite old, while they were intensified with the creation of the Eurozone. Arguments on an integrated equity market were generally oriented toward increasing trade volume for listed firms and improved operational efficiency for the participants [Dorodnykh, 2014]. On the other hand, the economy of scale as an outcome of the single market tends to diminish transaction costs by attracting international financial investors [McAndrews and Stefanadis, 2002]. Europe is generally dependent on the banking industry as the main lender to the economic activity and less on the equity and bond markets. For this and many other reasons, stock markets in Europe possess diverse levels of market efficiency. Recognizing this issue, Nielsson [2009] documents that the need for a single equity market in the EU arises from the increased competition of well-capitalized exchanges in the US and Asia. As a consequence, the integrated equity markets in the EU tend to facilitate access to finance for corporations and SMEs [Kokkoris and Olivares-Caminal, 2008]. The prospect of establishing a single equity market in the EU cannot be analyzed only in financial terms but requires a more comprehensive approach. The EU countries operate under different tax systems, monetary policies (non-Eurozone members), and economic arrangements, which aggravates the complexity of this issue. Previous studies were mainly focused on co-integration issues within European stock markets as an obstacle for cross-border diversification. This study measures the diversification risk of the major European equity indexes such as DAX, MDAX, CAC40, FTSE100, IBEX35, and FTSE MIB. Moreover, the outcome of the work

provides a historical outlook on the risk perspectives related to the respective stock indexes, by considering them as individual portfolios. To the best of our knowledge, the present study is the first to measure the diversification risk of individual stock indexes using portfolio management techniques. Additionally, the results of the work demonstrate the diversification benefits of creating a common equity market in Europe. Outcomes of this work have implications for investors that tend to diversify their portfolios in the largest European equity indexes. Finally, we provide modest indications for the European policymakers on the diversification benefits of a possible common equity market. Based on the identified problem, the study tries to answer the following research questions:

RQ1: What is the diversification risk of the major European equity indexes from 2008 to 2018?
RQ2: What are the diversification benefits of a hypothetical common equity index for the six major exchanges in Europe?

The rest of the paper is structured as follows: the second part contains a brief literature review on portfolio diversification; part three documents the methodology used; research results are presented in the fourth section; and concluding remarks and recommendations can be found in the final section.

2 Literature review

Stock markets represent the most complex structure of the financial system, attracting constant interest from researchers. Risk linked to the stock market stems mainly from the uncertainties associated with stock price instability. The diversification of financial investments is important for risk management since it tends to reduce uncertainties linked to portfolio returns. Portfolio risk is mainly influenced by the correlation coefficient among financial securities, weights concentration, and volatility of returns. However, there is a positive tradeoff between diversification benefits and increased operational costs [Shawky and Smith, 2005]. Standard portfolio theories confirm that holding all investments in one place exposes financial investors to higher risk. Portfolio optimization should contain diverse types of financial securities, such as stocks, bonds, commodities, etc. Discussions concerning investment diversification and risk dynamics are at least a century old. Lowenfeld [1909] provided initial theoretical concepts of portfolio management and stressed the importance of diversification. Over four decades later, Markowitz [1952] confirmed that portfolio optimization is prone to correlation among financial assets, weight concentration, and standard deviations of return. Previous paradigms on portfolio creation indicate that the international spread of financial investments reduces diversification risk. Grubel [1968] confirmed that distributing financial investments beyond national equity exchanges reduces unsystematic risk. The Asian crisis of 1987 delivered the first signals that international investments are not a significant input in reducing portfolio risk. Multiple studies in the literature [Dwyer and Hafer, 1988; Eun and Shim, 1989; Bertero and Mayer, 1990] have confirmed that the stock markets of Germany, Japan, and the United States were highly interconnected during the 1987 crisis. Likewise, the 2008 financial crisis proved on a larger scale that various stock markets are highly correlated. The crisis which started in the United States quickly affected the world financial system, challenging the neoliberal theories that financial markets correct their excesses. Further studies by Morana and Beltratti [2008] and Tamakoshi and Hamori [2012] confirmed that correlation coefficients tend to increase in times of great uncertainty, like the one of 2008–2009. The equity markets in Germany, France, England, Spain, and Italy experienced an enormous downturn during 2008–2009. Similarly, the Eurozone debt crisis of 2011 dampened investor confidence, which resulted in another slump of equity markets in Europe. Government intervention was required to protect the world financial system from collapse. Karim et al. [2011] proved that the 2007 subprime loan crisis did not have a long-term effect on co-movements within stock indexes worldwide. This is confirmed by Albulescu et al. [2015], who demonstrated that in the short run, correlation among the FTSE100, DAX, and CAC40 increased during periods of high volatility. In addition, De Araújo et al. [2013] documented a strong spillover effect from the DAX and FTSE100 to the CAC40, and from the ATHEX20 to the IBEX35 and PSE20, during the meltdown period. It is well known that

stock markets efficiently reflect bad news generated by national and international stock indexes. Stock markets on occasion are prone to extreme movements caused by unexpected events, e.g., the bankruptcies of Enron and World Com [De Groen, 2011] and the financial collapse of Lehman Brothers [Haas and Horen, 2012]. Globalization and the integration of financial markets have diminished the ability to reduce the unsystematic risk of a portfolio. Moreover, an increased number of synthetic financial instruments have made risk invisible and unpredictable. Portfolio managers aim to reduce unsystematic risk by distributing financial investments to various industries and sectors. On the other hand, the systematic risk that comes from market shocks is beyond a manager's ability to control.

The efficient market hypothesis claims that stock prices tend toward an equilibrium where deviations from the equilibrium are random. To this end, stock prices reflect expectations for future cash flows while the future is unknown since it is subject to unmade choices. In contrast, most of the financial markets do not satisfy the required efficiency assumption, since stock prices do not reflect the fundamental settings of the company and the national economy. Fama [1968] established the paradigm that financial markets adjust their excesses, prohibiting anyone from making long-run profits. In contrast, Shiller [2001] recognized physiological factors as additional significant elements driving stock price volatility and generating asset bubbles. Portfolio managers tend to eliminate unsystematic risk via diversification, whereas systematic risk is outside the manager's capacity to control. Moreover, they are not concerned simply with stock price volatility, but also with the correlation within financial assets, which is an important element of portfolio risk. The higher the positive correlation coefficient, the higher the portfolio risk, and vice versa [Syllignakis and Kouretas, 2011; Dajcman, 2015].

Weight concentrations in particular securities expose a portfolio to higher risk since portfolio returns rely mainly on the performance of particular securities. A clear theoretical guideline is not available for the optimal arrangement of a portfolio. Structuring an optimal portfolio stands on a complex set of elements, such as an investor's risk appetite, a manager's talent, political events, economic prospects, etc. The number of stocks stands as an additional element of the portfolio risk exposure. Portfolios with a limited number of stocks hold higher diversification risk, and the other way around. Several studies have shown that a portfolio with 10–20 stocks can achieve a higher level of diversification benefits [Klemkosky and Martin, 1975; Bloomfield et al., 1977; Bird and Tippett, 1986; Statman, 1987; Beck et al., 1996; Brands and Gallagher, 2005]. Other scholars [Jennings, 1971; Fielitz, 1974; Johnson and Shannon, 1974] have argued that a portfolio with 8–16 stocks is adequate for achieving maximum portfolio optimization. Recently, Aliu et al. [2020] have confirmed that diversification risk is completely removed on the portfolios holding more than 47 equity stocks. Still, there is no consensus among scholars concerning the number of stocks that would allow for maximum portfolio diversification. However, buying a market portfolio is considered as a way to achieve optimal diversification. In contrast to previous scholars, we have used portfolio diversification techniques to generate risk–reward tradeoffs associated with the largest stock indexes in Europe. No study (to the best of our knowledge) has measured the internal risk of the stock indexes by considering them as individual portfolios. Furthermore, our research generates historical records of the different poolings within stock indexes, making it possible for a single stock index to be created. Consequently, the study generates signals for the index funds that follow stock exchange performance as a benchmark. From a policy perspective, we analyze the possibility of creating a single equity market in Europe using diversification risk techniques. However, our work sheds light on a limited dimension of such complex problems as the creation of a single equity market in Europe.

3 Research methodology

This study uses secondary data published by the Thomson Reuters Eikon database on stock prices and trade volumes. Stock market prices and trade volumes were collected every week from January 1, 2008 to December 31, 2018 and are expressed in Euros. Diversification risk and weighted average returns are measured on the following stock indexes: FTSE100, CAC40, DAX30, MDAX, IBEX35, and FTSE MIB. The risk level was measured initially for the individual stock indexes. The same methodological process was

then conducted for measuring the risk levels of the different poolings within stock indexes. Weekly stock prices and weekly trade volumes are two main inputs in measuring the diversification risks of the portfolio stock indexes. Collection of the data in the same period enabled joining the stock indexes and measuring the diversification risks of different poolings within the stock indexes (portfolios). A diversification formula was used to obtain results. Portfolio risk was determined from elements such as the correlation coefficient within stock prices (*rij*) and the concentration of the weight (w) based on trading volumes of the listed companies and standard deviations of return (δ). Moreover, each of these elements impacted risk levels. Table 1 below shows the list of sample countries' stock index, the currency used and the period covered:

The following diversification formula has been used to measure the risk level of the individual stock indexes. The same diversification formula was used to measure poolings within the stock indexes of Italy, Spain, France, Germany, and England:

$$\sigma_k^2 = \sum_{i}^{nk} w_{ik}^2 \sigma_{ik}^2 + 2 \sum_{i}^{nk} \sum_{j<i}^{nk} w_{ik} w_{jk} \sigma_{jk} \rho_{ijk} \tag{1}$$

where σ_k^2 of the portfolio in the year k is computed on the sample of n_k companies, index i indicates a company, and j is an auxiliary index assuring that covariance is computed on distinct companies; ω represents the weight of each listed company in the stock index within the portfolio based on its trade volume; ω^2 represents weight in the square; σ^2 indicates variance of returns (stock prices of individual listed companies in the stock indexes); σ stands for the standard deviations of return (stock prices of the individual listed companies in the stock index); and $\varphi(i,j)$ shows the correlation coefficient within returns (stock prices of the individual listed companies in the stock index).

The mathematical formula was implemented from the following computer programs: Python 3.6.3 (version 0.21.0), Numpy (version 1.13.3), and Jupiter Notebook (version 5.2.0). Generating the inputs of the risk level (δ^2) starts with splitting the tables that contain prices and trade volumes. The following matrix was used to generate the results:

$$U_{ij} = \begin{cases} a_{ij} & for\, i < j \\ 0 & for\, i \geq j \end{cases} \tag{2}$$

where a_{ij} indicates combinations (correlation) between companies i and j.

The process of pooling two or more stock indexes stands as follows: We present an example of pooling two stock indexes. Let A be the first stock index and B the second stock index. A_d represents dates and data (prices and trade volumes) for stock index A, and B_d represents dates and data for stock index B. Merging the two stock indexes is realized through the intersection within A_d and B_d. The new generated portfolio (A + B) creates a new stock index with existing prices and trade volumes from A_d and $B_{d,}$ since prices and trade volumes are collected on the common dates for both stock indexes (they are intersected by dates). Risk and return calculations of the merged stock indexes follow the same process when calculating a particular stock index.

Table 1. List of sample countries' stock index, the currency used, and the period covered

Country	Index	Portfolio designation	No. of companies	Currency	Period
Germany	DAX – *Equity Index*	Portfolio A	30	Euro	2008–2018
	MDAX – *Equity Index*	Portfolio F	60	Euro	2008–2018
England	FTSE 100 – *Equity Index*	Portfolio B	100	Euro	2008–2018
France	CAC 40 – *Equity Index*	Portfolio C	40	Euro	2008–2018
Italy	FTSE MIB – *Equity Index*	Portfolio E	40	Euro	2008–2018
Spain	IBEX 35 – *Equity Index*	Portfolio G	35	Euro	2008–2018

Source: Authors' elaboration.

4 Research results and discussion

4.1 Diversification risk of CAC40, FTSE100, MDAX, DAX, IBEX35, and FTSE MIB

In this section, we measured the diversification risk linked to the stock markets of Germany (DAX and MDAX), France (CAC40), England (FTSE 100), Spain (IBEX35), and Italy (FTSE MIB) for the period 2008–2018. Each of the stock indexes is named as a portfolio. Table 2 shows the descriptive statistics for the whole sample of the European Stock Indexes used in the analysis:

Table 3 shows the results of the risk levels (diversification benefits) of the six different portfolios. The risk results (δ) generated from Eq. (1) show the risk associated with the individual stock indexes. The results present the most diversified index from 2008 to 2018:

According to Table 3, Portfolio (B)-FTSE100 index on average (2008–2018) was the most well-diversified index (δ = 0.30), followed by Portfolio (E)-FTSEMIB (δ = 0.44), Portfolio (G)-IBEX35 (δ = 0.54), Portfolio (C)-CAC40 (δ = 2.02), Portfolio (A)-DAX (δ = 2.27), and Portfolio (F)-MDAX (δ = 2.66). The size of the index (number of listed companies) is the reason why the FTSE100 is the most diversified (less risky) index. The mathematical formula for measuring the diversification risk (δ) contains a correlation coefficient among companies listed in the index, the volatility of individual listed companies, and their market share (weights). Each of these elements is influential in determining risk level.

Table 2. Descriptive statistics of six European stock index prices (for the period 2008–2018)

	DAX	FTSE 100	CAC 40	FTSE MIB	MDAX	IBEX 35
Mean	59.60722	21.86251	72.62883	16.02681	67.01549	25.12312
Median	58.14654	19.65725	73.66524	17.49506	68.14011	26.01219
SD	14.85281	2.105744	7.065241	2.625164	6.056982	1.991045
Skewness	0.565189	−0.251102	−0.265694	−0.414151	−0.112697	0.215631
Kurtosis	4.159295	3.056694	1.952011	2.622373	3.124191	3.018854
Jarque-Bera	15.19295	4.960236	2.968939	6.409951	4.165313	8.456301
Probability	0.000152	0.000294	0.000621	0.000657	0.000219	0.000806
No. of companies	30	100	40	40	60	35
Observations	3,025	3,025	3,025	3,025	3,025	3,025

Source: Authors' calculations [*EViews output*].

Table 3. The results of risk level (diversification benefits) linked with the six different portfolios

Years	Portfolio (A) *DAX*	Portfolio (B) *FTSE100*	Portfolio (C) *CAC40*	Portfolio (E) *FTSE MIB*	Portfolio (F) *MDAX*	Portfolio (G) *IBEX35*	All Portfolios *(ABCEFG)*
2008	1.83	0.23	1.38	0.21	2.35	0.37	0.33
2009	4.86	0.85	3.68	0.95	7.05	0.94	1.45
2010	2.89	0.47	3.04	0.82	3.34	1.13	1.12
2011	1.48	0.19	1.17	0.28	2.41	0.42	0.42
2012	3.33	0.25	3.10	0.73	3.80	0.57	0.88
2013	1.66	0.19	1.34	0.29	1.35	0.50	0.82
2014	1.89	0.21	2.02	0.32	1.10	0.49	0.50
2015	1.12	0.18	0.94	0.22	1.44	0.33	0.27
2016	2.95	0.41	2.05	0.33	2.16	0.48	0.61
2017	1.40	0.21	1.72	0.36	1.89	0.31	0.51
2018	1.61	0.12	1.83	0.37	2.33	0.39	0.36

Source: Authors' calculations based on the Thomson Reuters Eikon database.

Table 4 shows average correlation coefficients (*rij*) measured from all available correlations within companies listed on the stock market. Average standard deviation (*std*) measures the average standard deviation of individual listed companies in the respective stock indexes in each year. The number of combinations (*comb*) is determined from the number of listed companies in the respective years.

The average correlation coefficients within all companies operating from 2008 to 2018 are as follows: FTSE100 has an average correlation of *rij* = 0.33, IBEX *rij* = 0.40, FTSE MIB *rij* = 0.44, CAC40 *rij* = 0.46, MDAX *rij* = 0.39, and DAX *rij* = 0.44. In addition, stocks of the companies within the FTSE100 index on average are 15% less positively correlated than those in the IBEX35, 17% less positively correlated than those in the MDAX, 24% less positively correlated than those in the FTSE MIB, 32% less positively correlated than those in the DAX, and 37% less positively correlated than those in the CAC40 (Table 4). In terms of volatility measured through the standard deviation of returns (*std*), the FTSE100 has the lowest average volatility, followed by the IBEX35 and the FTSE MIB. The highest average volatility from 2008 to 2018 is linked to the DAX index. The FTSE100 on average is approximately three times less volatile than the DAX, MDAX, and CAC40 (Table 4). However, even though the IBEX35 and FTSE MIB have a smaller number of listed companies compared with the FTSE100, they are characterized by low volatility and lower positive correlation coefficients. An additional reason why the FTSE has the lowest risk (highest diversification benefits) stems from the number of listed companies and it is an influential element of diversification risk. The FTSE on average has 6.1 times more combinations (correlation coefficient) compared with the CAC40, 11.5 times more than the IBEX35, 8.4 more than the FTSE MIB, 6.4 times more than the MDAX, and 10.4 times more than the DAX.

Figure 1 presents the diversification risk (δ) of the stock indexes yearly. Risk levels increased during the financial crisis of 2008–2009 in each of the stock indexes. The lowest diversification benefits (highest risk) during the crisis period were recorded by the MDAX, followed by the DAX, IBEX35, CAC40, FTSE MIB, and

Table 4. Risk elements of the individual stock indexes

Portfolios	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
std-FTSE100	1.15	1.43	0.98	0.82	0.91	1.03	1.11	1.20	1.77	1.68	1.44
std-CAC40	3.32	5.72	4.31	2.91	3.92	3.35	3.75	3.22	4.89	4.60	5.80
std-DAX	4.23	7.91	4.69	3.79	4.71	3.87	4.59	3.64	6.94	5.39	5.14
std-IBEX35	2.08	3.61	1.53	1.27	1.58	2.91	1.39	1.15	1.60	1.49	1.79
std-FTSEMIB	1.28	2.66	1.71	1.01	1.58	0.86	1.25	0.99	1.32	1.33	1.60
std-MDAX	3.66	6.14	3.85	3.38	4.24	2.93	3.80	3.44	5.15	4.41	5.58
rij-FTSE100	0.21	0.62	0.66	0.41	0.24	0.43	0.32	0.19	0.33	0.15	0.12
rij-CAC40	0.30	0.73	0.80	0.31	0.61	0.36	0.55	0.22	0.50	0.29	0.42
rij-DAX	0.30	0.75	0.76	0.37	0.58	0.46	0.48	0.23	0.43	0.17	0.34
rij-MDAX	0.25	0.64	0.75	0.62	0.42	0.26	0.36	0.16	0.35	0.20	0.31
rij-IBEX35	0.10	0.70	0.68	0.37	0.47	0.43	0.51	0.25	0.29	0.22	0.34
rij-FTSEMIB	0.22	0.78	0.78	0.23	0.67	0.36	0.56	0.25	0.54	0.15	0.31
comb-FTSE100	3,741	4,005	4,095	4,095	4,095	4,186	4,371	4,656	4,753	4,851	4,950
comb-CAC40	666	703	703	703	703	703	703	703	703	741	780
comb-DAX	406	406	406	406	406	406	406	435	435	435	435
comb-MDAX	435	496	496	496	561	595	666	780	861	990	1081
comb-IBEX35	276	300	300	300	325	406	406	406	435	496	496
comb-FTSEMIB	351	406	406	465	465	496	496	561	630	666	741

Average correlation coefficient (*rij*) is measured from all available correlations within companies listed on the stock market. Average standard deviation (*std*) measures the average standard deviation of individual listed companies in the respective stock indexes in each year.
The number of combinations (*comb*) is determined from the number of listed companies in the respective years.
Source: Authors' calculations based on the Thomson Reuters Eikon database.

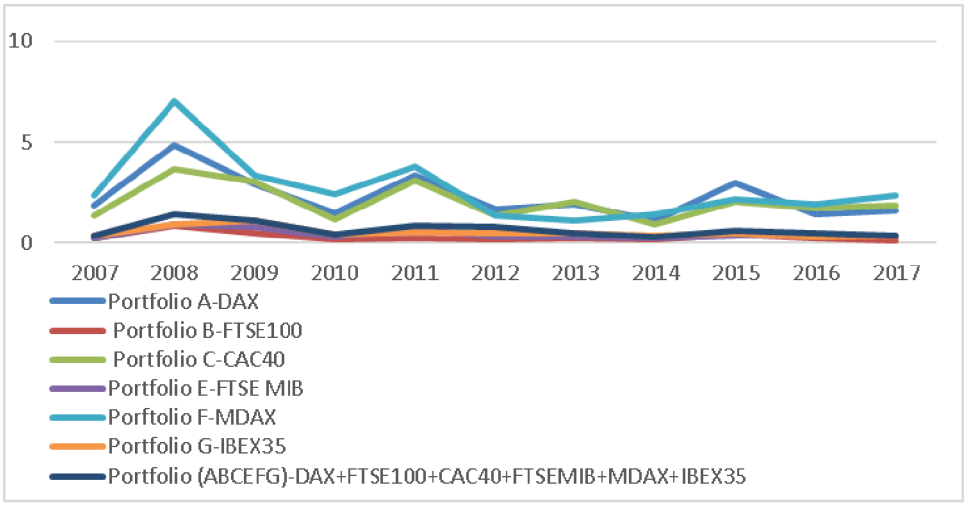


Figure 1. Risk diversification of different portfolios. *Source:* Authors' calculations based on the Thomson Reuters Eikon database.

FTSE100. The least risky index during the crisis period was the FTSE100. An increase in the average positive correlation coefficient during the financial crisis of 2008–2009 is justified by an average decline in the price level of the stocks listed in the respective indexes. The highest risk (lowest diversification) during the crisis period came in the MDAX, followed by the DAX and CAC40. The lowest risk (highest diversification) appeared in the FTSE100, IBEX35, and FTSEMIB. The financial turmoil of 2008 influenced all six stock indexes. Moreover, the Eurozone debt crisis of 2011 did not affect the FTSE100, IBEX35, and FTSEMIB in the same magnitude at which it affected the DAX, MDAX, and CAC40.

An additional objective of the study was to observe if there are diversification benefits when the six stock indexes are pooled together, named as a portfolio (ABCEFG). For the DAX, MDAX, and CAC40, it is better to operate under the common stock index in terms of diversification risk. In contrast, for the FTSE100, FTSEMIB, and IBEX35, it is not beneficial to join the common stock index since the risk level increases. Average volatility would be reduced 1.5 times for the DAX if it joins the common stock index, 1.4 times for the MDAX, and 1.3 times for the CAC40. In contrast, average volatility for the FTSE100 would increase 2.4 times by joining a common stock index, 2.1 times for the FTSEMIB, and 1.5 times for the IBEX35.

4.2 Diversification risk within different poolings of the CAC40, FTSE100, MDAX, DAX, IBEX35, and FTSE MIB

In this section, we consider different poolings of the stock indexes that generate a diverse set of portfolios, as presented in Table A1 in Appendix. In this part, we do not consider the risk in the time interval, but only the average risk from 2008 to 2018. First, we examined the pooling of portfolios with two stock indexes, followed by portfolios with three stock indexes, and ending with pooling of five stock indexes. The number of portfolios with two stock indexes amounts to 15. According to Table A1 in Appendix, within portfolios pooled with two stock indexes, portfolio (BG) is the most well-diversified. Portfolio (BG), which contains the FTSE100 and IBEX35, delivers the lowest risk and highest reward. In contrast, portfolio (AF), which contains the DAX and the MDAX, delivers the highest risk and the lowest reward.

Pooling with three stock indexes delivers 20 possible portfolios. Within the pooling of portfolios with three stock indexes, portfolio (BEG), which contains stocks from the FTSE100, FTSEMIB, and IBEX35, shows the lowest risk. In contrast, the highest risk is generated in the portfolio (ACF), in which the DAX pools with the CAC40 and MDAX. However, even though the portfolio (BEG) shows lower risk, it still generates the highest return (Table A1 in Appendix).

In the pooling of portfolios with four stock indexes, maximum diversification is achieved in the portfolio (BEFG) that consists of the FTSE100, FTSEMIB, MDAX, and IBEX35. In contrast, the lowest diversification in

the pooling with four stock indexes is reached when pooling is carried out between the DAX, CAC40, FTSEMIB, and MDAX, and the combination generated by this pooling is named portfolio (ACEF). A portfolio (BEFG) is 40% less risky than another portfolio (ACEF) but generates seven times more weighted average return.

A pooling of the portfolios with five stock indexes generates six possible portfolios. Portfolio (BCEFG) stands as the most diversified portfolio. However, the portfolio (ACEFG) is positioned as the riskiest portfolio. A portfolio (BCEFG) contains 16% more weighted average return than another portfolio (ACEFG). Moreover, higher-risk portfolios generate a lower weighted average return than less-risky portfolios, which contradicts standard theories on portfolio management.

5 Conclusions

Stock markets are considered a fundamental component of the financial system, which facilitates the transference of funds from savers to borrowers. Stock markets do not hold a major position within the European financial system, since Europe was traditionally oriented toward banks as the main lenders for business operations and human consumption. The results of our study confirm that the stock markets of Germany, Italy, Spain, France, and England were highly influenced by the financial crisis of 2008–2009. Moreover, the DAX, MDAX, and CAC40 had the lowest diversification benefits (highest risk) during the crisis period. In contrast, the FTSE100, IBEX35, and FTSE MIB were less influenced by the crisis. The financial crisis of 2007–2008 generated a downturn in stock prices that caused the average correlation coefficient to increase. Volatility, as measured through the standard deviation of returns, increased during the crisis period. The most well-diversified index from 2008 to 2018 was the FTSE100, while the least diversified was the MDAX. The Eurozone debt crisis of 2011 produced an additional financial shock within the stock indexes of Germany, Spain, England, Italy, and France. The lowest diversification benefits (highest risk) during the European debt crisis appeared in the CAC40, followed by the DAX and MDAX. The two financial crises proved that the six stock indexes deliver fewer diversification benefits during bad times. In addition, the crisis periods were characterized by higher positive correlations and increased volatility.

This study primarily explored whether there would be diversification benefits if the six indexes operated together. In terms of volatility and diversification benefits, the DAX, MDAX, and CAC40 would have higher diversification benefits by joining a common stock index. In contrast, for the FTSE100, FTSE MIB, and IBEX35, risk and volatility would increase by joining a common stock index. The second objective of the study was to observe diversification benefits within different poolings of stock indexes. Among the portfolios with two stock indexes, maximum diversification (risk and reward) is achieved in portfolio (BG), which pools the FTSE100 and IBEX35. Possible portfolios with three stock indexes confirm that portfolio (BEG), which consists of the FTSE100, FTSEMIB, and IBEX35, delivers the highest diversification. Portfolios with four stock indexes show that when the FTSE100 pools together with the FTSEMIB, MDAX and IBEX35, maximum diversification is generated by a portfolio (BEFG). Portfolios with five stock indexes confirm that portfolio (BCEFG) delivers the lowest risk and highest rewards.

This study does not consider transaction costs and exchange rate risks when calculating weighted average returns, which is a limitation. Future research should identify diversification benefits when stock indexes of the entire EU operate together. Future research should also control transaction costs. Moreover, future research might identify which EU countries would benefit, and which would not, from a common stock index; this information could have important policy and managerial implications.

Declarations

Conflict of interest

The authors declare that they do not have any competing financial, professional, or personal interests from other parties.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

FA contributed by handling the literature write-up, conducting statistical analysis, and drafting the manuscript. FA, AN and BP contributed by handling the manuscript preparation, supervision, and validation. AN dealt with the data collection and data screening processes, provided inputs for designing the data workflow and coordinating its implementation, and helped to draft the manuscript. All authors read and approved the final version of the manuscript.

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APPENDIX

Table A1. Average risk and return tradeoffs for different poolings of the portfolios (stock indexes), 2008–2018

Portfolios	Stock indexes	Omega, *average*	SD, *average*	Correlation coefficient, *average*	No. of stock indexes	WAR (%)	No. of stocks
Portfolio (AB)	DAX + FTSE100	0.69	3.04	0.30	2	6.33	129
Portfolio (AC)	DAX + CAC40	2.17	4.65	0.42	2	0.17	70
Portfolio (AE)	DAX + FTSE MIB	0.87	3.22	0.40	2	0.56	69
Portfolio (AF)	DAX + MDAX	2.26	4.65	0.41	2	0.08	77
Portfolio (AG)	DAX + IBEX35	0.96	3.66	0.39	2	0.05	62
Portfolio (BC)	FTSE100 + CAC40	0.64	2.89	0.27	2	6.30	139
Portfolio (BE)	FTSE100 + FTSE MIB	0.52	2.19	0.26	2	5.12	138
Portfolio (BF)	FTSE100 + MDAX	0.56	2.96	0.26	2	7.11	146
Portfolio (BG)	FTSE100 + IBEX35	0.47	2.27	0.26	2	4.95	131
Portfolio (CE)	CAC40 + FTSE MIB	0.91	3.09	0.42	2	0.96	79
Portfolio (CF)	CAC40 + MDAX	2.03	4.34	0.42	2	0.04	87
Portfolio (CG)	CAC40 + IBEX35	0.85	3.28	0.42	2	0.03	72
Portfolio (EF)	FTSE MIB + MDAX	0.59	3.12	0.38	2	0.67	86
Portfolio (EG)	FTSE MIB + IBEX35	0.58	1.93	0.38	2	0.66	71
Portfolio (FG)	MDAX + IBEX35	0.59	3.45	0.35	2	0.00	79
Portfolio (ABC)	DAX + FTSE100 + CAC40	0.78	3.32	0.30	3	5.67	169
Portfolio (ABE)	DAX + FTSE100 + FTSEMIB	0.64	2.77	0.28	3	4.73	168
Portfolio (ABF)	DAX + FTSE100 + MDAX	0.70	3.38	0.29	3	6.32	168
Portfolio (ABG)	DAX + FTSE100 + IBEX35	0.60	2.85	0.28	3	4.55	161
Portfolio (ACE)	DAX + CAC40 + FTSE MIB	1.14	3.71	0.40	3	0.87	109
Portfolio (ACF)	DAX + CAC40 + MDAX	2.16	4.58	0.41	3	0.17	117
Portfolio (ACG)	DAX + CAC40 + IBEX35	1.14	3.88	0.41	3	0.03	102
Portfolio (AEF)	DAX + FTSEMIB + MDAX	0.89	3.66	0.39	3	0.57	101
Portfolio (AEG)	DAX + FTSEMIB + IBEX35	0.79	2.99	0.37	3	0.62	101
Portfolio (AFG)	DAX + MDAX + IBEX35	0.99	3.99	0.38	3	0.07	109

(Continued)

Table A1: Continued

Portfolios	Stock indexes	Omega, *average*	SD, *average*	Correlation coefficient, *average*	No. of stock indexes	WAR (%)	No. of stocks
Portfolio (BCE)	FTSE100 + CAC40 + FTSE MIB	0.60	2.67	0.27	3	4.72	178
Portfolio (BCF)	FTSE100 + CAC40 + MDAX	0.65	3.24	0.27	3	6.29	186
Portfolio (BCG)	FTSE100 + CAC40 + IBEX35	0.57	2.74	0.27	3	4.54	171
Portfolio (BEF)	FTSE100 + FTSE MIB + MDAX	0.53	2.73	0.26	3	4.25	185
Portfolio (BEG)	FTSE100 + FTSE MIB + IBEX35	0.48	2.16	0.25	3	3.99	170
Portfolio (BFG)	FTSE100 + MDAX + IBEX35	0.49	2.80	0.26	3	4.96	178
Portfolio (CEF)	CAC40 + FTSE MIB + MDAX	0.93	3.57	0.40	3	0.96	126
Portfolio (CEG)	CAC40 + FTSE MIB + IBEX35	0.73	2.79	0.41	3	0.58	111
Portfolio (CFG)	CAC40 + MDAX + IBEX35	0.89	3.72	0.40	3	0.00	119
Portfolio (EFG)	FTSE MIB + MDAX + IBEX35	0.60	2.91	0.36	3	0.67	118
Portfolio (ABCE)	DAX + FTSE100 + CAC40 + FTSEMIB	0.71	3.06	0.29	4	4.39	208
Portfolio (ABCF)	DAX + FTSE100 + CAC40 + MDAX	0.79	3.53	0.29	4	5.67	216
Portfolio (ABCG)	DAX + FTSE100 + CAC40 + IBEX35	0.69	3.13	0.29	4	4.21	201
Portfolio (ABEF)	DAX + FTSE100 + FTSE MIB + MDAX	0.65	3.11	0.28	4	4.75	215
Portfolio (ABEG)	DAX + FTSE100 + FTSEMIB + IBEX35	0.58	2.66	0.284	4	3.75	200
Portfolio (ABFG)	DAX + FTSE100 + MDAX + IBEX35	0.61	3.18	0.287	4	0.87	208
Portfolio (ACEF)	DAX + CAC40 + FTSEMIB + MDAX	1.16	3.92	0.39	4	0.55	141
Portfolio (ACEG)	DAX + CAC40 + FTSE MIB + IBEX35	0.90	3.35	0.39	4	4.57	141
Portfolio (ACFG)	DAX + CAC40 + MDAX + IBEX35	1.16	4.04	0.39	4	0.05	149
Portfolio (AEFG)	DAX + FTSEMIB + MDAX + IBEX35	0.81	3.43	0.36	4	0.63	148
Portfolio (BCEF)	FTSE100 + CAC40 + FTSEMIB + MDAX	0.61	3.01	0.27	4	4.74	225
Portfolio (BCEG)	FTSE100 + CAC40 + FTSEMIB + IBEX35	0.55	2.57	0.27	4	3.74	210
Portfolio (BCFG)	FTSE100 + CAC40 + MDAX + IBEX35	0.58	3.07	0.27	4	0.59	218
Portfolio (BEFG)	FTSE100 + FTSE MIB + MDAX + IBEX35	0.49	2.63	0.26	4	4.01	217
Portfolio (CEFG)	CAC40 + FTSEMIB + MDAX + IBEX35	0.75	3.26	0.39	4	3.74	158
Portfolio (ABCEF)	DAX + FTSE100 + CAC40 + FTSEMIB + MDAX	0.72	3.28	0.29	5	4.41	255

(Continued)

Table A1: Continued

Portfolios	Stock indexes	Omega, *average*	SD, *average*	Correlation coefficient, *average*	No. of stock indexes	WAR (%)	No. of stocks
Portfolio (ABCEG)	DAX + FTSE100 + CAC40 + FTSE MIB + IBEX35	0.65	2.92	0.29	5	3.53	240
Portfolio (ABCFG)	DAX + FTSE100 + CAC40 + MDAX + IBEX35	0.69	3.35	0.29	5	4.24	248
Portfolio (ABEFG)	DAX + FTSE100 + FTSEMIB + MDAX + IBEX35	0.59	2.97	0.28	5	3.77	247
Portfolio (ACEFG)	DAX + CAC40 + FTSEMIB + MDAX + IBEX35	0.92	3.60	0.38	5	0.57	188
Portfolio (BCEFG)	FTSE100 + CAC40 + FTSEMIB + MDAX + IBEX35	0.56	2.89	0.27	5	0.66	257

Stock indexes represent the pooling of different stock indexes within one portfolio.
Omega average represents the average risk (δ) of the different portfolios for the period 2008–2018.
Standard deviation (SD) and *Correlation coefficient* represent, respectively, the average volatility and the average correlation.
WAR stands for the weighted average returns of the different portfolios.
No. of stocks represents the average number of stocks within the portfolios.
Source: Authors' calculations based on the Thomson Reuters Eikon database.