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Risk-based asset allocation

Sectorial or geographical segmentation?

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***Abstract*—The objective of this work is to show how the risk-based portfolio construction techniques – i.e. strategic asset allocation approaches without forecasts of expected returns – reach different results depending on whether the investment universe of the stock market is divided on the basis of a geographic breakdown or in function of a sector breakdown, carried out in relation to the productive sectors to which the individual companies belong rather than according to the listing market. An empirical analysis, applied on the global equity market, is implemented by making use of the typical and most advanced statistical and financial evaluation measures. The results of this analysis show a significant preference for the sectorial criterion compared to the geographic one.**

Keywords— risk-based strategies, sector indices, geographic indices, risk parity, global minimum variance, equal weighting, maximum diversification.

I. Introduction

The aim of this study is the selection of the segmentation criterion most suited to the implementation of risk-based portfolio construction strategies in the "equity" asset class. An empirical analysis is carried out in order to reach this goal.

The typical top-down asset allocation starts with the division of the investment universe into different asset classes, each one representing a set of financial assets characterized by homogeneity in terms of their risk–return. The identification of the asset classes is significant, since the forecasting process of the market variables is achieved via the formulation of expectations regarding the evolution of the general economic scenario, in order to forecast the trend of each market sector.

In the equity market, asset classes are usually defined using sectorial or geographical criteria. Sectorial criteria are based on the assumption that securities of firms in the same industry are correlated as the industry primarily determines the degree of sensitivity to macroeconomic and political factors. These factors include technological advancements and the consequent changes in production processes, the competitive structure of the market, economies of scale and infrastructural needs, the evolution of consumer preferences, the dynamics of the global economic cycle, and the commodities market. Geographical criteria are based on the assumption that securities listed in the same market tend to be correlated as companies operate with the same currency, have the same basic interest rates, and are subject to the same economic policy and country risk. [2]

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The remainder of this paper is divided into four sections: section II provides a review of the literature on risk-based strategies; section III explains the analysis methodology and the chosen sample; section IV focuses on measurement and interpretation of the results; and section V concludes the study.

II. Risk-based strategies: review of literature

The fundamental and common characteristic of risk-based strategies (also known as μ-free strategies) of portfolio construction is the removal of the expected returns from the set of inputs. The reasons underlying this choice can be traced to the literature concerning estimation risk. [3] Chopra and Ziemba [5] show that an investor with average risk aversion can incur losses, measured in terms of lower utility, eleven times higher in the event of a wrong estimation of the means compared to an identical estimation error of variances. Notwithstanding the advantage derived from the simplification of estimating in-puts, some studies have criticized these models because of the absence of a clearly defined objective function. [11], [17]

Therefore, the implementation of risk-based strategies requires only the estimation of the risk measures (volatilities and correlations or, equivalently, the covariance matrix), as they are the only inputs relevant to the asset allocation process. [4] The following subsections provide details about the most widespread risk-based techniques such as optimal risk parity, global minimum variance, most diversified portfolio, and equal weighting.

A. *The optimal risk parity*

After certain pioneering contributions by asset managers, such as Qian [14], Qian [15] and Neurich [13], the theoretical foundations of risk parity have been defined and formalized for the first time by Maillard, Roncalli, and Teiletche [12]. It is based on the principle of risk budgeting, which allows the portfolio construction process to be set up in terms of risk allocation, rather than asset allocation. [9] The idea behind the optimal risk parity approach is to prevent the concentration of portfolio risks in a limited number of dominant positions.

The risk allocation is defined such that each component of the portfolio offers the same ex-ante risk contribution, namely, an equal contribution to the formation of the overall portfolio risk. [16], [18] Consequently, this procedure does not exclude any component of the investment universe from the portfolio. Furthermore, the allocation of negative risk budgets to one or more constituents of the portfolio determines the concentration of the entire risk exposure regarding the other components of the investment universe; thus, the relative risk budgets are subject to the non-negativity constraint.

B. *The global minimum variance portfolio*

The objective of the global minimum variance approach is to minimize the total portfolio risk. Among the risk-based approaches, this is the only one to indicate the portfolio that lies on the ex-ante efficient frontier. [7] In fact, the results of the optimization process are portfolio weights that minimize the portfolio variance, with the calculation formula being the objective function. Therefore, the sole inputs of the process are the elements of the covariance matrix. The exclusion of the expected returns from the portfolio construction justifies the inclusion of the global minimum variance portfolio into the class of risk-based strategies. The optimization process is subject to the budget and the no-short selling constraints.

The solution to the problem admits the existence of weights equal to zero, so the global minimum variance approach can exclude some of the components of the investment universe from the portfolio. The minimization of the total risk is achieved when all the components included in the portfolio have equal marginal risks. [4]

C. *The most diversified portfolio*

In the most diversified portfolio approach, asset allocation is based on optimization of the diversification ratio, subject to the usual budget and no short sell constraints. [6] This measure is the ratio between the weighted average of the standard deviations of the returns of portfolio constituents and the standard deviation of the portfolio returns. This model does not require all components of the investment universe to be included in the portfolio; therefore, the procedure can define weights to be equal to zero for some of them. Furthermore, the strategy does not use the risk budgeting tools; thus, the most diversified portfolio approach does not guarantee ex-ante a balanced investment in terms of risk or asset allocation.

D. *The equal weighted portfolio*

The equal-weighted approach is a simple heuristic strategy, which assigns the same weight to each component of the investment universe; thus, it is also referred to as the $1/N$ strategy or naïve diversification. Given the absence of a scientific theory that supports its use, this technique has often been a subject of study in the field of behavioral finance. [1], [20]

A similarity with the optimal risk parity strategy can be noted, although the latter is more sophisticated. To illustrate, the equal-weighted approach applies the $1/N$ rule to the asset allocation, whereas the optimal risk parity approach applies it to the risk allocation. However, another aspect that unites the two approaches is the selection of assets. Unlike the global minimum variance and maximum diversification approaches, the equal weighting and optimal risk parity approaches guarantee that the entire investment universe is always included in the portfolio selected by the investor. Therefore, the equal weighting does not require a statistical analysis of returns; however, despite being very simplified, it is considered a risk-based strategy, as the allocation mechanism seeks a strong diversification of the risks.

Some empirical analyses of the ex-post performances of the equal-weighted portfolios have revealed situations in which this approach shows statistically higher results than those produced by the more sophisticated approaches [8], even though the scientific literature has not reached a unanimous consensus on the subject. [10]

III. Methodology of the empirical analysis

The evaluation of the efficiency of the different asset class breakdown techniques in the risk-based portfolio construction models requires the measurement of their out-of-sample performance. These data can be obtained by implementing a rolling-window procedure, which allows the simulation of the behavior of a portfolio constructed by an investor who performs portfolio optimization based on the available data at the time of the allocation, measures the statistical characteristics of the portfolio, and rebalances its weights according to predefined techniques.

In the subsequent analyses, the optimization processes are carried out using the returns on equity investments in excess of the risk-free rate. Since the empirical analysis is carried out from the perspective of a Eurozone investor, the benchmarks used are all denominated in euro. Accordingly, the 12-month Euribor rate is assumed as the risk-free rate.

A. *Statistical properties of the sample*

Regarding the alternative criteria for segmentation of the global stock market, represented by the MSCI All Country World Index (ACWI) benchmark, the sectorial approach identifies 11 sectors, while the geographical approach designates six main geographical areas. A higher number of geographical segments has not been selected because of two reasons. The first is to avoid assigning high weights to marginal areas in the actual composition of the global market. The second is to limit the number of parameters to be estimated, and therefore, the estimation risk.

The indices used here are total return, gross of taxes, and free-float weighted. For each index, the sample comprises a time series of 240 monthly returns from November 1998 to October 2018. A long-term sample has been chosen in order to obtain a sample time series of 15 years, thus including different market phases and the occurrence of extreme events. The out-of-sample time span of five years is used for estimating the performances of the risk-based portfolios.

The first four sample moments of the entire dataset are shown in Table I. Overall, there is only one case of positive skewness, whereas all the other stock indices are characterized by negative skewness; moreover, all the empirical distributions are leptokurtic.

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Both with the sectorial and the geographical criteria, no negative correlations between the excess returns have been measured, stressing that the stock markets tend to move in the same direction.

In light of the sample moments shown in Table I, it is necessary to test the deviations from normality of the time series. To this end, the following aspects are analyzed: normality, autocorrelation, heteroscedasticity, and stationarity of distributions, with a significance level of 5% being selected. [19] The results of the statistical tests are summarized in Table II.

The statistical analyses presented here highlight severe deviations from the hypotheses formulated in the modern portfolio theory and the capital asset pricing model for the construction of efficient portfolios. Consequently, risk-based allocation techniques appear more suitable, as they are more parsimonious in terms of estimates necessary for their implementation.

TABLE I. DESCRIPTIVE STATISTICS OF THE BENCHMARKS' EXCESS RETURNS

	Benchmark	**Expected return**	**Standard deviation**	**Skewness**	**Kurtosis**
Sector	MSCI ACWI/Consumer Discretionary	0.48%	4.82%	-0.46	4.76
	MSCI ACWI/Consumer Staples	0.45%	2.96%	-0.86	4.19
	MSCI ACWI/Energy	0.56%	5.34%	-0.11	3.62
	MSCI ACWI/Financials	0.32%	5.14%	-0.64	5.73
	MSCI ACWI/Health Care	0.44%	3.52%	-0.58	3.22
	MSCI ACWI/Industrials	0.48%	4.69%	-0.90	5.77
	MSCI ACWI/Information Technology	0.59%	6.90%	-0.38	4.45
	MSCI ACWI/Materials	0.57%	5.32%	-0.61	5.48
	MSCI ACWI/Real Estate	0.48%	4.85%	-0.87	6.74
	MSCI ACWI/Telecom Services	0.18%	4.66%	-0.37	4.90
	MSCI ACWI/Utilities	0.33%	3.37%	-0.92	4.14
Geographic	MSCI Emerging Markets	0.81%	5.10%	-0.53	4.73
	MSCI Europe ex UK	0.35%	4.77%	-0.54	4.27
	MSCI Japan	0.26%	4.88%	0.11	3.46
	MSCI North America	0.43%	4.20%	-0.67	4.33
	MSCI Pacific ex Japan	0.53%	4.08%	-0.68	4.54
	MSCI United Kingdom	0.29%	3.93%	-0.63	3.74

TABLE II. TESTS OF DEVIATIONS FROM NORMALITY OF THE BENCHMARKS' EXCESS RETURNS

		Jarque-Bera test[1]		**Lilliefors test[1]**		**Ljung-Box test**		**Engle's ARCH test**		**Ljung-Box test on x^2**		**ADF test[1]**	
	Benchmark	**stat**	**p-value**	**stat**	**p-value**	**stat**	**p-value**	**stat**	**p-value**	**stat**	**p-value**	**stat**	**p-value**
Sector	MSCI ACWI/Consumer Discretionary	39.423	0.10%	0.079	0.11%	10.794	**5.56%**	18.670	0.22%	23.711	0.02%	-6.279	0.10%
	MSCI ACWI/Consumer Staples	43.704	0.10%	0.074	0.27%	6.609	**25.14%**	24.015	0.02%	22.762	0.04%	-5.613	0.10%
	MSCI ACWI/Energy	4.297	**9.14%**	0.037	**50.00%**	2.524	**77.29%**	10.996	**5.15%**	8.800	**11.73%**	-6.643	0.10%
	MSCI ACWI/Financials	91.161	0.10%	0.077	0.16%	17.626	0.35%	53.495	0.00%	102.346	0.00%	-6.352	0.10%
	MSCI ACWI/Health Care	13.720	0.66%	0.088	0.10%	5.755	**33.08%**	14.539	1.25%	19.254	0.17%	-6.295	0.10%
	MSCI ACWI/Industrials	108.955	0.10%	0.097	0.10%	14.749	1.15%	24.576	0.02%	37.487	0.00%	-6.028	0.10%
	MSCI ACWI/Information Technology	26.833	0.10%	0.090	0.10%	6.435	**26.62%**	61.968	0.00%	95.067	0.00%	-5.568	0.10%
	MSCI ACWI/Materials	76.683	0.10%	0.055	**7.59%**	12.101	3.34%	29.713	0.00%	32.053	0.00%	-6.928	0.10%
	MSCI ACWI/Real Estate	170.766	0.10%	0.086	0.10%	18.838	0.21%	42.888	0.00%	77.899	0.00%	-6.246	0.10%
	MSCI ACWI/Telecom Services	41.636	0.10%	0.080	0.10%	17.767	0.33%	38.783	0.00%	78.058	0.00%	-5.491	0.10%
	MSCI ACWI/Utilities	47.264	0.10%	0.100	0.10%	5.759	**33.03%**	10.486	**6.26%**	13.168	2.19%	-5.303	0.10%
Geographic	MSCI Emerging Markets	41.120	0.10%	0.057	**5.57%**	15.462	0.86%	11.405	4.39%	14.976	1.05%	-6.423	0.10%
	MSCI Europe ex UK	27.667	0.10%	0.067	1.16%	10.365	**6.55%**	21.526	0.06%	35.073	0.00%	-5.364	0.10%
	MSCI Japan	2.608	22.46%	0.043	**34.48%**	15.852	0.73%	5.721	**33.43%**	5.329	**37.75%**	-5.845	0.10%
	MSCI North America	35.523	0.10%	0.086	0.10%	8.625	**12.50%**	31.052	0.00%	52.229	0.00%	-5.992	0.10%
	MSCI Pacific ex Japan	42.370	**0.10%**	0.077	0.17%	7.033	**21.82%**	13.777	1.71%	15.188	0.96%	-5.972	0.10%
	MSCI United Kingdom	21.417	0.10%	0.063	2.41%	6.816	**23.47%**	26.421	0.01%	39.185	0.00%	-5.628	0.10%

P-values above 5% are in bold.
Note 1: p-value is bounded by the 0.10%-50% interval.

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B. *The implementation of the empirical analysis*

The strategies of portfolio construction subjected to analysis are the following:

- optimal risk parity, using the standard deviation as the measure of risk;
- global minimum variance portfolio;
- most diversified portfolio;
- The equal-weighted portfolio;
- optimal risk parity, using the expected shortfall at the 95% confidence level as the measure of risk;
- minimization of the expected shortfall (95%);
- maximization of the Sharpe ratio, included for comparison with risk-based techniques.

Each strategy is implemented using both the sectorial and the geographical criteria to determine which of the two is preferable.

Given that risk decomposition techniques can be applied using different risk measures, empirical analyses are also carried out with the objective of comparing risk-based strategies that differ from each other in this element, with the selected risk measures being the standard deviation and the expected shortfall (95%). The first is chosen because it is used in traditional asset allocation models, while the use of the expected shortfall is consistent with the presence of significant deviations from the Gaussian distribution, as previously verified empirically.

The budget and the no short-selling constraints are imposed on the optimization processes. It has been decided not to use additional constraints, both in terms of portfolio allocation and risk allocation, as their presence would attenuate the distinctive features of the different approaches, making them more similar to each other, which would lead to significant difficulties in the comparative assessment.

Calendar rebalancing, with a quarterly frequency, is chosen for the empirical analysis. Therefore, given the sample length of 240 months and the 60 months used in samples estimates, 60 portfolios are processed for each strategy examined with a rolling-window procedure, for a total of 180 monthly out-of-sample observations. With a quarterly frequency, the specific portfolio optimization process is carried out (based on the data provided by the rolling-window procedure) for each portfolio construction strategy, and the previous portfolio weights are modified.

The quantification of the transaction costs has an important role, since some strategies are less stable than others. A lower stability means higher rebalancing costs, and therefore, lower net returns. In this case, a uniform cost of 0.2% is defined for each component of the portfolio, since the financial instruments that allow the replication of the return of each asset class are characterized by a similar level of liquidity.

IV. The results of the empirical analysis

A. *Statistical properties of the out-of-sample portfolios*

Table III summarizes the out-of-sample first four moments of the excess returns of the different strategies. As a first consideration, it can be noted that the strategies are suitable for the construction of portfolios with performance objectives that are also significantly higher than the risk-free rate; thus, the investor's choice is not limited to defensive portfolios only. In general, all the distributions present negative skewness and leptokurtosis, with the results being similar to those found in the analyses of the asset class benchmarks.

The hypothesis of normality of the excess returns of risk-based portfolios is tested using the same procedures and methods set for the individual indices. The results are reported in Table IV.

TABLE III. DESCRIPTIVE STATISTICS OF THE PORTFOLIOS' EXCESS RETURNS

	Strategy	Expected return	Standard deviation	Skewness	Kurtosis
Sector	Equally weighted	0.60%	3.60%	-1.12	6.46
	Global minimum variance	0.61%	2.74%	-1.01	4.99
	Max Sharpe ratio	0.73%	3.61%	-0.97	4.78
	Minimum expected shortfall 95%	0.56%	2.91%	-0.92	4.48
	Most diversified portfolio	0.65%	3.22%	-1.18	6.08
	Risk parity expected shortfall 95%	0.61%	3.39%	-1.22	6.63
	Risk parity standard deviation	0.61%	3.37%	-1.19	6.47
Geographic	Equally weighted	0.56%	3.47%	-1.06	5.81
	Global minimum variance	0.60%	3.40%	-1.25	6.21
	Max Sharpe ratio	0.85%	4.42%	-0.80	6.24
	Minimum expected shortfall 95%	0.58%	3.52%	-1.10	5.97
	Most diversified portfolio	0.45%	3.29%	-0.90	5.41
	Risk parity expected shortfall 95%	0.56%	3.40%	-1.14	6.02
	Risk parity standard deviation	0.56%	3.41%	-1.10	5.91

TABLE IV. TESTS OF DEVIATIONS FROM NORMALITY OF THE PORTFOLIOS' EXCESS RETURNS

		Jarque-Bera test[1]		Lilliefors test[1]		Ljung-Box test		Engle's ARCH test		Ljung-Box test on x^2		ADF test[1]	
	Strategy	**stat**	**p-value**	**stat**	**p-value**	**stat**	**p-value**	**stat**	**p-value**	**stat**	**p-value**	**stat**	**p-value**
Sector	Equally weighted	127.383	0.10%	0.100	0.10%	13.548	1.88%	28.535	0.00%	45.147	0.00%	-5.397	0.10%
	Global minimum variance	60.306	0.10%	0.087	0.22%	3.798	**57.88%**	29.007	0.00%	35.078	0.00%	-4.957	0.10%
	Max Sharpe ratio	51.743	0.10%	0.064	**7.20%**	3.932	**55.92%**	16.180	0.63%	19.538	0.15%	-4.832	0.10%
	Minimum expected shortfall 95%	41.817	0.10%	0.089	0.14%	3.717	**59.09%**	17.349	0.39%	22.966	0.03%	-5.187	0.10%
	Most diversified portfolio	113.395	0.10%	0.088	0.16%	7.162	**20.89%**	22.432	0.04%	29.699	0.00%	-5.113	0.10%
	Risk parity expected shortfall 95%	143.760	0.10%	0.098	0.10%	13.377	2.01%	30.839	0.00%	46.954	0.00%	-5.258	0.10%
	Risk parity standard deviation	132.903	0.10%	0.105	0.10%	13.010	2.33%	28.751	0.00%	44.774	0.00%	-5.239	0.10%
Geographic	Equally weighted	92.643	0.10%	0.112	0.10%	15.758	0.76%	23.317	0.03%	40.364	0.00%	-5.303	0.10%
	Global minimum variance	123.948	0.10%	0.117	0.10%	16.968	0.46%	24.942	0.01%	38.929	0.00%	-5.693	0.10%
	Max Sharpe ratio	97.920	0.10%	0.104	0.10%	10.802	**5.55%**	15.095	1.00%	20.734	0.09%	-5.619	0.10%
	Minimum expected shortfall 95%	102.566	0.10%	0.085	0.33%	9.634	**8.63%**	24.037	0.02%	27.006	0.01%	-5.805	0.10%
	Most diversified portfolio	67.871	0.10%	0.101	0.10%	16.531	0.55%	21.753	0.06%	37.059	0.00%	-5.691	0.10%
	Risk parity expected shortfall 95%	107.167	0.10%	0.110	0.10%	15.835	0.73%	21.293	0.07%	36.179	0.00%	-5.380	0.10%
	Risk parity standard deviation	99.630	0.10%	0.105	0.10%	16.902	0.47%	23.515	0.03%	40.794	0.00%	-5.361	0.10%

P-values above 5% are in bold.
Note 1: p-value is bounded by the 0.10%-50% interval.

According to the Jarque-Bera test in no case the hypothesis of Gaussian distribution is accepted, while with the Lilliefors test there is only one portfolio with a p-value higher than the significance level of 5% and thus the Gaussian distribution hypothesis of excess returns is accepted only in this single case. The presence of autocorrelation is verified using the Ljung-Box test, whose results indicate six cases in which the hypothesis of absence of autocorrelation is accepted, and eight cases in which the hypothesis is rejected. The presence of heteroscedasticity is verified using the Engle's ARCH test and the Ljung-Box test on the squared residuals. The results indicate that homoscedasticity is rejected in every portfolio. The verification of stationarity is carried out using the Dickey-Fuller ADF test. In all cases, the hypothesis of unit root is rejected; thus, all the time series are stationary. In general, all the hypothesis tests carried out on the time series of excess returns validate the characteristics observed in benchmarks.

B. ***Comparative analysis of the risk-based strategies***

The identification of the segmentation technique most suitable for risk-based portfolios requires the evaluation of different elements such as the portfolio risk, portfolio efficiency, and the higher moments of the distribution of excess returns.

The first element considered is the portfolio risk. It is a highly distinctive characteristic of risk-based strategies, which are based above all on it. Risk is assessed using the measures previously considered in the portfolio optimization process, namely, the standard deviation and the expected shortfall (95%).

The second element considered is efficiency, as the identification of the portfolio with the best risk-adjusted performance is the investor's primary objective. The evaluation of portfolios' efficiency is carried out using three metrics, namely, the Sharpe ratio, the Sortino ratio, and the conditional Sharpe ratio at 95% (i.e., the ratio between the mean excess return and the expected shortfall at the 95% confidence level).

The third element is represented by the higher moments of the distributions. As the tests carried out previously on the time series reject the hypothesis of normality, it is necessary to consider skewness and kurtosis.

It is possible to obtain some observations based on the sample standard deviation, measured out-of-sample on a monthly basis (Table III). Firstly, the sectorial criterion is significantly superior to the geographical criterion, as shown by the comparative results for each strategy that uses it, with the exception of equal weighting. Secondly, traditional strategies produce unsatisfactory results maximizing the Sharpe ratio.

Table V reports also the expected shortfall (95%) measured for the different strategies. In line with the estimations of the standard deviation, the sectorial criterion appears to be systematically preferable to the geographical criterion regarding all allocation techniques. In particular, the two techniques of segmentation of the investable equity universe produce antithetical results, precisely when applied to the minimization of the expected shortfall (95%). In fact, the portfolio built by making use of sector indices has a lower level of ex-post risks than almost every other strategy, with the exception of the global minimum variance. On the contrary, the geographical minimization strategy of the expected shortfall (95%) achieves an extremely negative result, among the worst in the sample, demonstrating empirically the inconsistency of the ex-post asset allocation with respect to the ex-ante measured inputs.

According to the traditional capital asset pricing model (CAPM), the measure that enables the identification of the most efficient portfolio is the Sharpe ratio. Thus, the efficiency analysis begins with this index, whose values are reported in Table V.

TABLE V. RISK-ADJUSTED PERFORMANCE OF THE PORTFOLIOS' EXCESS RETURNS

	Strategy	Sharpe ratio	Sortino ratio	Expected shortfall (95%)	Conditional Sharpe ratio (95%)
Sector	Equally weighted	0.17	0.23	-9.02%	0.07
	Global minimum variance	0.22	0.32	-6.67%	0.09
	Max Sharpe ratio	0.20	0.29	-8.75%	0.08
	Minimum expected shortfall 95%	0.19	0.28	-7.01%	0.08
	Most diversified portfolio	0.20	0.28	-8.10%	0.08
	Risk parity expected shortfall 95%	0.18	0.25	-8.66%	0.07
	Risk parity standard deviation	0.18	0.25	-8.56%	0.07
Geographic	Equally weighted	0.16	0.22	-8.92%	0.06
	Global minimum variance	0.18	0.24	-8.98%	0.07
	Max Sharpe ratio	0.19	0.29	-10.20%	0.08
	Minimum expected shortfall 95%	0.17	0.23	-9.32%	0.06
	Most diversified portfolio	0.14	0.19	-8.51%	0.05
	Risk parity expected shortfall 95%	0.17	0.23	-8.95%	0.06
	Risk parity standard deviation	0.16	0.23	-8.87%	0.06

Also in this case, the sectorial criterion is significantly preferable to the geographical one. Furthermore, the traditional CAPM strategy, which selects the portfolio with the maximum ex-ante Sharpe ratio, produces a positive ex-post result; however, the most efficient portfolio is the one constructed by the global minimum variance strategy using sector indices.

The non-normality of distributions makes the Sharpe ratio a suboptimal indicator of portfolio efficiency. Therefore, the Sortino ratio is also used, as it is calculated as the ratio between the mean excess return and the downside deviation. Additionally, the Sortino ratio represents the extra yield compared to the objective rate of return per unit of asymmetric risk (i.e., of downside risk). In this analysis, the target rate is set equal to the risk-free rate to consider the risk-free return as the opportunity cost.

The values of the Sortino ratio are reported in Table V. Despite the different measurement methodology, its ranking replicates the one achieved previously with the Sharpe ratio. The previous considerations are also verified, indicating that the sectorial criterion is significantly preferable to the geographical one.

The conditional Sharpe ratio (95%) aims to consider investors' preference in preventing extreme negative events (i.e., "tail risk"). The results presented in Table V show a very strong similarity with those drawn from the other two risk-adjusted performance measures. Also in this third case, the considerations discussed above and the superiority of the sectorial segmentation when compared to the geographical one are verified.

The preceding empirical analyses show that both the time series of the excess returns of the benchmarks and of the risk-based strategies are subject to negative skewness and leptokurtosis.

The values of the skewness are shown in Table III. The fact that this measure is not considered in the portfolio optimization processes causes a certain degree of randomness in the results; therefore, the dominance of a segmentation criterion cannot be inferred.

The investors' interest in risk-based strategies is due to their conservative nature and their focus on the risk alone. Hence, kurtosis can be particularly important, given its effect on determining the probability of extreme events. As for the skewness, it must be considered that the parameter is not included in the inputs of the optimization processes. The levels of kurtosis are presented in Table III. In this case, the best result is produced by the strategy of minimization of the expected shortfall (95%) using sector indices.

V. Conclusions

This comparative empirical analysis provides substantially coherent results with regards to the two alternative approaches for the segmentation of the stock market, demonstrating a significant preference for the sectorial criterion compared to the geographical one.

This result can be attributed to the subdivision of the investment universe into sectorial indices characterized by greater internal coherence and better external differentiation, in addition to the lower concentration of sectorial segmentation compared to the geographical one. In fact, this last characteristic ensures that the outcome of the risk-based strategies is not strongly linked to the relative performance of the markets characterized by a greater weight, as happens in the geographical decomposition.

Risk-based strategies aim to provide a solution to the critical elements of traditional asset allocation models. Based on the results of the empirical analysis, the strategies based on the minimization of the risk measure show overall superior results to sector indices. In particular, the strategy that has shown the best results is the global minimum variance with sectorial segmentation, which particularly benefits from the considerable capacity for diversification inherent in this decomposition technique.

Conversely, in all cases, strategies based on the optimal risk parity do not rank in the top positions of the various evaluation methods employed. Nevertheless, for these techniques, the results produced using the sectorial criterion dominate those produced using the geographical alternative.

These empirical evidences can be interpreted starting from the theoretical foundations underlying the optimal risk parity approach. Assuming a high estimation error in the parameters, this is a strategy that imposes tight constraints on the portfolio construction process, since all the components of the investment universe must have the same ex-ante percentage risk contribution; therefore, no component can be excluded from the asset allocation. The constraints imposed have two purposes, the first is to avoid the concentration of risk in a limited number of assets, and the second is the containment of transaction costs due to rebalancing. If, as in the present case, the estimation error is not sufficiently severe, these constraints make it impossible to reach an optimal allocation in the mean-variance space, empirically verifying the criticisms formulated by Lee [11] and Scherer [17].

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