Research Article

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Optimization of Portfolio Management Models with Indexed Stocks on the Lima Stock Exchange

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Abstract

Investment fund managers are limited by the fact that Latin American financial markets offer very few investment possibilities, which forces them to carry out operations at a global level. The objective is to optimize the portfolio management models with indexed stocks in the Lima Stock Exchange (27 stocks considering 2082 days from January 02, 2014 to April 13, 2022) applying the Markowitz models that determine the portfolios of the frontier of investment possibilities. The Sharpe model (CAPM), which calculates the expected return considering systemic risks, and the Sharpe index, which measures the stock return with total risk. Finally, the Black-Litterman (BL) model adjusts the ex-post expected return with expert opinion. By comparing the BL/CAPM ratio, an index is obtained that improves the predictability of expected returns and it is observed that the efficiency of this indicator is greater than the Sharpe index of subsequent expected returns (Sharpe BL). Therefore, the hypothesis that optimizing the portfolio management models improves the predictability of the expected returns of the indexed shares of the Lima Stock Exchange is accepted.

Keywords: *Portfolio optimization, CAPM model, Black-Litterman, Efficient frontier, Sharpe ratio, R Studio*

1. Introduction

In Peru, the stock market is limited compared to Latin American and global markets. In the framework of the Pacific Alliance, the Latin American Integrated Market (MILA, from initials in Spanish) was created with the stock exchanges of Mexico, Lima, Santiago, Bogota in order to be able to diversify the investment portfolio to improve returns (Ortegón & Torres, 2016; SMV, 2011). Likewise, Álvarez-Franco *et al.* (2017), Vargas (2012), Medina & Cáceres, (2016); Núñez & León (2019); Sotelo (2015), Cabezas *et al.* (2020), state that portfolio management in Latin American countries uses empirical and intuitive methods which generate systemic risk.

Investments made in portfolios face market concentration, which generates systemic risk, and can be corrected by expanding the supply of investment options. The indexed shares of the Lima Stock Exchange can be one of them.

In Peru, as of 2015, the pension fund managers (AFPs, from initials in Spanish) recorded a capital endowment level of S/ 124,135 million, which has been increasing due to the growth in the number of members and their respective individual contributions (Medina & Cáceres, 2016). A similar situation occurs in Mexico (Núñez & León, 2019).

Investments with pension contribution funds lately generate insufficient profitability to meet owners' expectations, and the management companies do not present results with transparency, which deteriorates their image. The Congress of the Republic of Peru, due to the questioning of the management of the AFPs, because of the low return of the managed funds that is reflected in the amounts of pensions obtained by the contributors, a commission was formed in 2016 to evaluate the improvement of the existing pension system. The workers are not satisfied with the current system and the state cannot assume the payment of decent pensions through the National Pension Office, so a tool would have to be developed to allow fund managers to optimize results so that contributors obtain better benefits (Congress of the Republic, 2020). For this purpose, very effective econometric models are used, such as Markowitz (1952); Sharpe (1964); Black-Litterman (1992) and Treynor-Black (1973).

Taking into account this context, the question is: Does optimizing portfolio management models improve the predictability of expected returns conformed by indexed shares of the Lima Stock Exchange?

Therefore, as an alternative hypothesis, it is shown that, by optimizing the portfolio management models, the predictability of the expected returns of the indexed shares of the Lima Stock Exchange improves.

As a null hypothesis, it is considered that optimizing the portfolio management models does not improve the predictability of the expected returns of the indexed shares of the Lima Stock Exchange.

The general objective is to optimize econometric models of portfolio management to improve the predictability of expected returns conformed by indexed shares of the Lima Stock Exchange (BVL, from initials in Spanish), and the specific objectives are to apply econometric models to define the investment portfolios of indexed shares of the Lima Stock Exchange, select the best performing portfolios, compare the results of the different models applied, and determine an index that improves the predictability of the returns of the indexed shares of the Lima Stock Exchange.

Montenegro (2018) and Duvoba (2005) explain that in the markets of Ecuador and Colombia they apply the Markowitz and CAPM models determining that the markets are very uncertain and that they do not have higher participation. In the electricity sector, Jisma, Mohan & Thomas (2023); Unni, Ongsakul & Madhu (2022) use the Markowitz efficient frontiers and adjust the results with the Black-Litterman model including the opinion of the specialists of electricity transmission operators and, on the other hand, the opinion of the electricity distribution operators obtaining as a result a better profitability-risk index of the expected returns. In the Indonesian market, Subekti, R., Abdurakhman, & Rosadi, D. (2022) analyze and adjust the results to the Shariah principle and the impact of COVID-19 using the CAPM, the Markowitz efficiency frontier and the Black-Litterman model.

Colasanto, Grilli, Santoro & Villani (2022) and Gómez, Trujillo & Quimbayo (2022) use the Black-Litterman model to optimize portfolio performance by considering polarized Bert feelings and diffused logic in the valuation of Views. Sahamkhadam, Stephan & Östermark (2022), using the Black-Litterman model, analyze the vine copulas to determine the symmetry and asymmetry of the tails, determining better performance of the portfolios in terms of lower tail risk and higher risk-adjusted returns.

Sotelo Rojas (2015); Cabezas, Ramos & Vidal (2020); Medina & Cáceres (2016); Franco-Arbelaez *et.al*. (2011) and Giraldo et al. (2015) compare the results of different portfolio management analysis

models concluding that using the Black Litterman model yields more efficient results. Li, Uysal & Mulvey (2022) use a successive convex program algorithm model to improve the outcome prediction, considering Sharpe, Bayes-Stein and Black -Litterman as an index. Stoilov, Stoilova, K., & Vladimirov, M. (2022) create an algorithm to optimize market parameters and, thus, are used to measure expert opinion by comparing them with historical results.

The authors Fuhrer & Hock (2023); Sun, Wu & De (2023); Han, & Li (2023) and Teplova, Evgeniia, Munir & Pivnitskaya (2023) start from the importance of Bayesian analysis used in the Black-Litterman model to calculate expected returns considering risk and expert opinion, and through econometric adjustments manage to obtain better results by including multiple covariance analysis in the risk calculation.

Vargas Sánchez, (2012) applies the Treynor-Black model to evaluate the excessive concentration of high-risk assets in investments that present non-parametric returns and amplify exposure in the non-systemic risk zone. This situation is generated by the difference between market prices and equilibrium values, for which market indicators were estimated based on the SP500 stock index, resulting in an expected return of 12.55% per year, a volatility of 6.93% and a Sharpe ratio of 1.81.

Núñez and León (2019), in their research, proposed, based on the 21 SIEFORE indexes, the calculation of the investment possibilities frontier without considering the regulatory limits. On the other hand, considering only the 17 indexes that were available before the 2008-2009 crisis, another efficient frontier was obtained.

Gomero (2014), exposes the problems of the Peruvian capital market and the limited strategies that are used in light of speculative decisions instead of elaborating optimal portfolio structures with the application of financial investment theory. For this reason, he methodologically exposes the Sharpe and Treynor models to facilitate decision making. As a result, it is convenient to choose portfolios with assets whose covariances are negative, in order to minimize the portfolio risk, reflected in the typical deviation.

In the following table we present the different models used to evaluate assets and portfolios in order to optimize their performance, reducing risk and maximizing returns.

Table 1: Comparison of econometric models of assets and portfolios

Author	Model	Advantages	Disadvantages
Markowitz (1952)	$E(r_p)=\sum_{i=1}^{n} Z_i F(r_i)$ Where E(rp) are the expected returns, Zi are the individual weights and F(ri) are the individual returns.	It considers the rational behavior of the investor under risk conditions. Efficient portfolio frontier.	The only information it uses is the mean and variance of the returns. Market stability is assumed.
Sharpe (1964) CAPM	$E(R_\mu)=\sigma_\mu + B_\mu E(R_{Mi})$ Where E(ru) is the expected returns, σ is the risk-free rate, B is the beta and E(Rmi) is the risk premium.	It considers two types of risk, systematic and non-systematic. It measures the asset-market relationship through the beta. The beta provides a simple method to measure the risk of an asset that cannot be diversified.	All investors have the same opinion about the distribution of expected returns and risks. The beta is not always a determining factor in the performance of a title.
Black-Litterman (1992)	$[R]=\left[(\tau\Sigma)^{-1}+P\Omega^{-1}P\right]^{-1}$ $\left[(\tau\Sigma)^{-1}\Pi+P\Omega^{-1}Q\right]$ R is the a priori probability that the investor's expectations will be met; it specifies a level of confidence. τ is a constant that reflects the degree of uncertainty with respect to the precision with which Π is calculated. P is the known matrix K x n; Q is the vector of expectations known as K x 1. ε is the random vector K x 1 with zero mean and diagonal covariance matrix Ω, normally distributed.	It includes the investor's expectations and according to its confidence level will be the weighting of the asset within the portfolio. It allows a flexible review of the market and therefore of investment strategies. Reasonable, intuitive, balanced and stable portfolios are achieved over time.	It is based on the assumption that the market has a normal distribution. Bayesian theory bases are required.

Source: Black, F., & Litterman, R. (1992); Sharpe, W. F. (1964); Markowitz, H. (1952).

2. Materials and Methods

The data obtained from the daily quotations of 272 stocks listed on the Lima Stock Exchange were used and the sample was constituted by the closing price of the daily quotations of 27 stocks indexed in BVL from January 02, 2014 to April 13, 2022 of the most relevant sectors due to the fact that Peru's macroeconomic indicators decreased their growth dynamics. The S&P Lima General Index (SPBLPGPT) from investing.com (s.f.) was used for market performance.

The sample was organized and homogenized, taking into consideration that the last closing price was repeated on the dates when there was no quotation, obtaining a homogeneous database using Excel software.

With the database, the averages of the stock prices were found, transforming the daily prices into returns. With this information, the portfolio profitability, the covariance matrix and the portfolio risk for 10,000 combinations were calculated using random numbers to obtain the Sharpe ratio.

Using R Studio software, the Excel database was imported to calculate the expected risk, the CAPM econometric model was used, considering the average return with the general stock market index (S&P Lima General) and the betas of each stock were obtained (Table 2).

The R Studio software processes the returns of the 27 shares obtaining different combinations from which it chooses the 100 most profitable portfolios of the efficient frontier (Table 3 and Figure 3).

The BL index was then calculated using the opinion of experts (AFP managers), resulting in the expected return ex-post.

With these results, the Sharpe BL index was calculated, which indicates the profitability of each portfolio considering the total risk adjusted to expert opinion.

With the results obtained from the CAPM and the BL, the BL/CAPM index was constructed, and with this adjustment a better predictability of the returns of equity assets was obtained, which helps in the objective choice in the portfolio management (Table 5).

3. Results

The CAPM, Sharpe index, efficient portfolio frontier (Markowitz) and Black-Litterman models were used to optimize the portfolio management models and whose results are shown below.

3.1 CAPM Model

The CAPM model allows us to calculate the expected return, based on the systemic risk and the risk-free rate.

3.2 Calculation of the Beta

Considering a risk-free rate of 0.000214 per day of the Peruvian government sovereign bond equivalent to 8% per year with a maturity of 30 years, the following algorithm was applied in the R Studio program to the 27 indexed shares.

```
Rfree=0.000214
premium_market = r_market – Rfree
prima_aenza = r_aenza – Rfree
beta2_aenza = lm (prima_aenza ~ prima_market)
beta2_aenza
```

Table 2. Results of the linear CAPM model with R Studio

Enterprise	Alpha	Beta	Market profitability	Risk-free rate	Daily CAPM	Annual CAPM (%)	Sharpe Ratio
AENZA	-0.001218	1.052	0.00019276	0.000214	0.0001917	7.14%	0.02106343
ALICOR	-0.0004197	0.673	0.00019276	0.000214	0.0001997	7.45%	0.02023801

Enterprise	Alpha	Beta	Market profitability	Risk-free rate	Daily CAPM	Annual CAPM (%)	Sharpe Ratio
BACKUA	0.0002367	0.018	0.00019276	0.000214	0.0002136	7.99%	-0.00936856
BAP	-0.0002022	1.311	0.00019276	0.000214	0.0001862	6.93%	0.02505491
BROCAL	-0.0001482	0.189	0.00019276	0.000214	0.00021	7.85%	0.02124829
BBVA	-0.0005741	0.718	0.00019276	0.000214	0.0001987	7.42%	0.00580992
BUENAV	0.0000607	0.241	0.00019276	0.000214	0.0002089	7.81%	0.00495346
CASAGR	-0.0000578	0.872	0.00019276	0.000214	0.0001955	7.29%	0.02362495
CORARE	0.0004393	0.266	0.00019276	0.000214	0.0002084	7.79%	0.00565781
CPACAS	-0.0002485	0.505	0.00019276	0.000214	0.0002033	7.59%	0.01617784
CVERDE	0.0000727	0.952	0.00019276	0.000214	0.0001938	7.23%	0.02794007
ENDISP	-0.0001022	0.344	0.00019276	0.000214	0.0002067	7.72%	0.01010597
ENGEPE	-0.0001272	0.292	0.00019276	0.000214	0.0002078	7.77%	0.00750199
FERREY	-0.0000292	0.838	0.00019276	0.000214	0.0001962	7.32%	0.02668218
GBVLA	-0.0006857	0.055	0.00019276	0.000214	0.0002128	7.96%	0.00010071
IFS	-0.0001815	1.013	0.00019276	0.000214	0.0001925	7.17%	0.02282941
INRET	0.000296	0.536	0.00019276	0.000214	0.0002026	7.57%	0.01344646
INVCEN	-0.0005117	0.017	0.00019276	0.000214	0.0002136	7.99%	-0.00445883
MINSURI	0.0004833	0.991	0.00019276	0.000214	0.0001929	7.19%	0.03055441
NEXAPE	0.0000581	0.924	0.00019276	0.000214	0.0001944	7.25%	0.02730366
PML	-0.0005554	0.651	0.00019276	0.000214	0.0002002	7.47%	0.0188115
RIMSEG	-0.0003344	0.081	0.00019276	0.000214	0.0002123	7.94%	-0.00463112
SCCO	0.0002184	1.121	0.00019276	0.000214	0.0001902	7.09%	0.01933454
SIDER	0.0005284	0.898	0.00019276	0.000214	0.0001949	7.27%	0.02597462
TV	-0.0000895	1.598	0.00019276	0.000214	0.0001801	6.70%	0.02931266
UNACEM	-0.0004682	0.786	0.00019276	0.000214	0.0001973	7.36%	0.02520271
VOLCAA	0.0001384	0.099	0.00019276	0.000214	0.0002119	7.93%	-0.00153683

Source: Lima Stock Exchange. April 18, 2022. Retrieved from https://www.bvl.com.pe/emisores/listado-emisores
Prepared by the authors.

Analyzing Table 2, it can be determined that the shares with the highest expected return are Unión de Cervecerías Peruanas Backus y Johnston S.A.A. and Inversiones Centenario S.A.A. with a return of 0.02136% per day or 7.994% per year, taking into account that the Peruvian government sovereign bond has a risk-free return of 8% per year.

3.3 Efficient Frontier

This model indicates the possible portfolios with which the best risk-return combination is obtained. In the study, the portfolios with the different combinations of the 27 shares were formed with the R Studio program, from which 100 portfolios were chosen, which are points of the efficient frontier.

Applying the quadratic programming Solver in the R Studio software, the 5 portfolios in Table 3 were obtained. Applying the Sharpe index to these results, the optimal portfolio is the efficient point 74, with a return of 0.03% daily and a risk of 1.52% daily, and with a Sharpe index of 0.0197638.

Table 3. Risk and Target Return

	Efficient point 1	**Efficient point 25**	**Efficient point 50**	**Efficient point 74**	**Efficient point 99**
mean	-0.001	-0.0006	-0.0001	0.0003	0.0007
Cov	0.0319	0.0103	0.0058	0.0069	0.0302

	Efficient point 1	Efficient point 25	Efficient point 50	Efficient point 74	Efficient point 99
CVaR	0.077	0.0247	0.0144	0.0152	0.0701
VaR	0.0463	0.0129	0.0079	0.009	0.0458
Sharpe	-0.012987	-0.0242915	-0.0069444	0.0197368	0.0099857

Source: Lima Stock Exchange. April 18, 2022. Retrieved from https://www.bvl.com.pe/emisores/listado-emisores
Prepared by the authors.

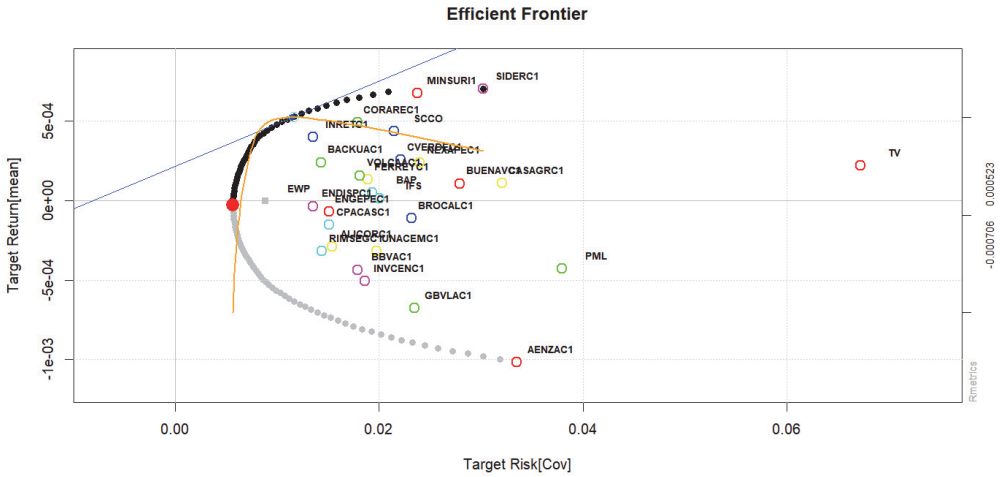

Figure 1: Distribution of the CAPMs of the LSE indexed shares and the efficient frontier of the 100 most efficient portfolios
Source: Lima Stock Exchange. April 18, 2022. Retrieved from https://www.bvl.com.pe/emisores/listado-emisores
Prepared by the authors.

Figure 1 shows the lowest risk portfolio (red dot), and the portfolios that coincide with the tangent. The behavior of the Sharpe ratio (orange curve) can also be observed coinciding with the point of the optimal portfolio (light blue circle).

3.4 Black Litterman model

The matrix of expected returns of the 27 indexed shares of the LSE was constructed, considering the following expert opinions (View), the market has an upward trend since 1995; the AFP managers (Prima AFP, 2022) work with expected annual returns in the order of 13% in the highest risk funds and 6% in the moderate risk funds. Therefore, in this study a View of 0.05 or 5% (conservative scenario) has been considered. In the annual report of the SBS 2021, the Peruvian AFP system has had as strategies to increase the percentage of local investments in fixed income versus foreign investments in equities, due to the recovery of profitability indexes at a global level (SBS, 2022, p. 41).

With respect to the Tau=0.02, the risk-free rate has been considered, taking into account that it is the confidence level (95%) of the expected return (5%). The model considers the Sharpe ratio equal to 0.5, as the equilibrium ratio, i.e. the return is half of the risk.

By running the Black Litterman model in the R Studio software, the matrix of the expected adjusted returns of the shares is obtained and with this data the efficient frontier is determined

(Figure 2); considering the 100 most efficient portfolios, the quadratic programming solver was applied and the 5 optimal portfolios were obtained as a result (Table 4). Applying the Sharpe index to these results, we obtain as the optimal portfolio the efficient point 25 and the point 50, the one with the lowest expected return (red point), which coincides with the lowest Sharpe index (0.00775) and the optimal point 50 is the most indicated according to these results.

Table 4. Expected weighted risk and target return of the BL Model

	Efficient point 1	Efficient point 25	Efficient point 50	Efficient point 75	Efficient point 100
mean	0.0001	0.0006	0.0011	0.0017	0.0022
Cov	0.0143	0.0085	0.0184	0.0399	0.0672
CVaR	0.0129	0.0192	0.0365	0.0615	0.096
VaR	0.0002	0.0113	0.0247	0.0397	0.0596
Sharpe	0.00775	0.03125	0.03014	0.02764	0.02292

Source: Lima Stock Exchange. April 18, 2022. Retrieved from https://www.bvl.com.pe/emisores/listado-emisores
Prepared by the authors.

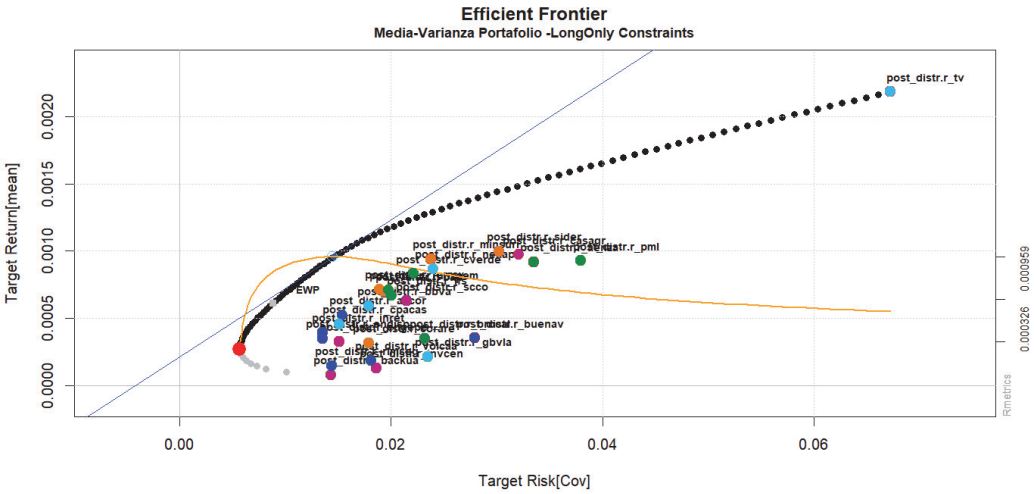

Figure 2. Efficient frontier of the portfolios evaluated with the BL index
Source: Lima Stock Exchange. April 18, 2022. Retrieved from https://www.bvl.com.pe/emisores/listado-emisores
Prepared by the authors.

In order to compare the results of the different models applied, the ratio of return adjusted to expert opinion on expected return (BL/CAPM) was used, observing that the effectiveness of the indicator is higher than the Sharpe BL index in each portfolio (See Figure 3). Therefore, it can be affirmed that the CAPM model and the BL model have a lower predictability index than when we relate the two BL/CAPM results (see Table 5), since the value obtained in the statistical analysis is lower than 0.05, so the alternative hypothesis is accepted.

To test the hypothesis that optimizing the portfolio management models improves the predictability of the expected returns with the indexed shares of the Lima Stock Exchange, the

Shapiro Wilk normality statistical test was used, obtaining a p-value of 0.0001742 (non-parametric) for the BL/CAPM index and a p-value of 0.02724 (non-parametric) for the Sharpe BL index. Therefore, the Wilcoxon index is used to contrast the hypotheses, obtaining that the expected return is predictable, being the Wilcoxon p-value of the BL/CAPM of 0.0000000149 and the Wilcoxon p-value of the Sharpe BL of 0.00000377. It is concluded that the predictability of the BL/CAPM index is more effective, so its use is recommended in order to optimize the portfolio management models.

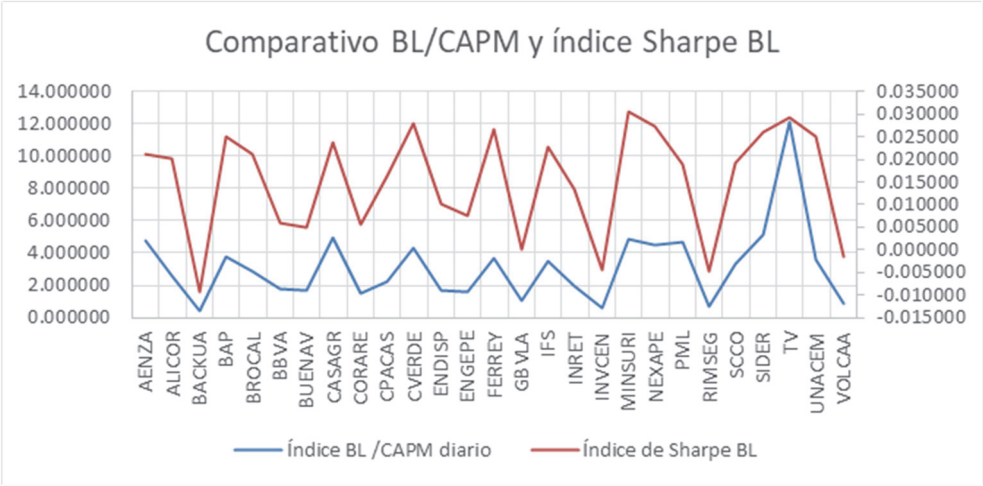

Figure 3. Comparison of the BL/CAPM index and the Sharpe ratio of Black-Litterman returns
Source: Lima Stock Exchange. April 18, 2022. Retrieved from https://www.bvl.com.pe/emisores/listado-emisores
Prepared by the authors.

In Figures 4 and 5, the histogram of the Sharpe index and the BL/CAPM index do not show a normal distribution which is validated by the Shapiro Wilk test, therefore, a non-parametric analysis is performed with the Wilcoxon test.

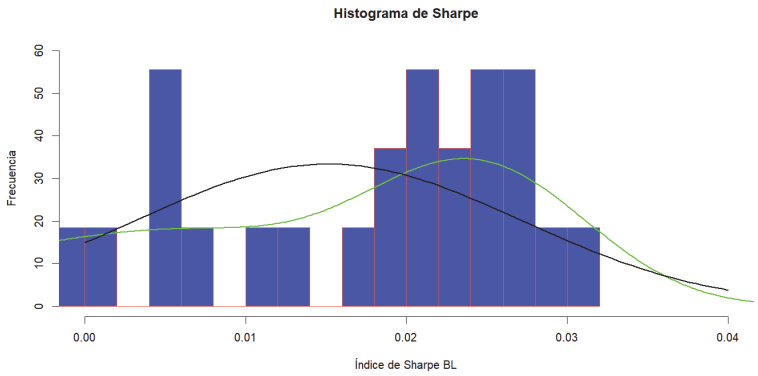

Figure 4. Sharpe ratio histogram of daily ex-post expected adjusted returns.
Source: Lima Stock Exchange. April 18, 2022. Retrieved from https://www.bvl.com.pe/emisores/listado-emisores; Prepared by the authors.

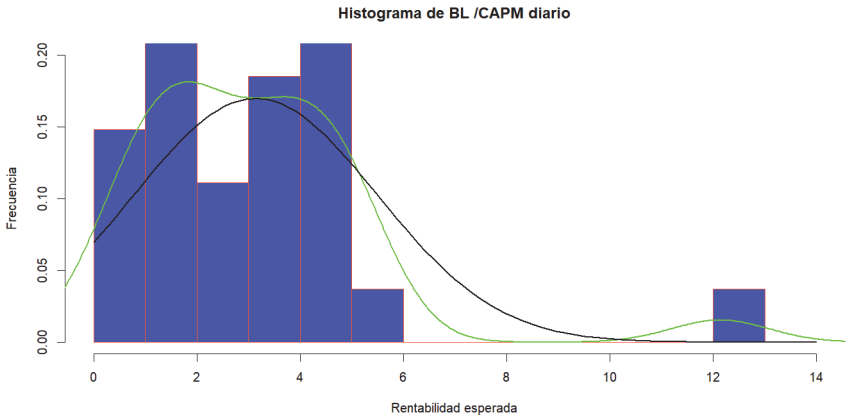

Figure 5. Histogram of daily expected returns of the CAPM model
Source: Lima Stock Exchange. April 18, 2022. Retrieved from https://www.bvl.com.pe/emisores/listado-emisores
Prepared by the authors.

Table 5. Comparison of the CAPM and Black Litterman

Asset	CAPM daily	CAPM annual (%)	Black Litterman Index daily	Black Litterman Index annual	BL /CAPM daily	BL /CAPM annual	Sharpe BL
AENZA	0.00019166	0.07142531	0.00092005	0.39244959	4.80049	5.49454	0.0210634
ALICOR	0.00019971	0.07453401	0.00052524	0.20808646	2.63008	2.79183	0.0202380
BACKUA	0.00021361	0.07992661	0.00007999	0.02921275	0.37445	0.36549	0.0093686
BAP	0.00018616	0.06930606	0.00069762	0.28538332	3.74752	4.11773	0.0250549
BROCAL	0.00020999	0.07851868	0.00059425	0.23845751	2.82990	3.03695	0.0212483
BBVA	0.00019875	0.07416361	0.00034875	0.13374745	1.75474	1.80341	0.0058099
BUENAV	0.00020887	0.07808510	0.00035243	0.13525077	1.68731	1.73209	0.0049535
CASAGR	0.00019549	0.07290472	0.00097198	0.41870137	4.97200	5.74313	0.0236249
CORARE	0.00020836	0.07788568	0.00031535	0.12020025	1.51349	1.54329	0.0056578
CPACAS	0.00020327	0.07591159	0.00045900	0.17963312	2.25814	2.36635	0.0161778
CVERDE	0.00019379	0.07224714	0.00083174	0.34891807	4.29204	4.82951	0.0279401
ENDISP	0.00020670	0.07724234	0.00035083	0.13459773	1.69731	1.74254	0.0101060
ENGEPE	0.00020780	0.07766817	0.00032710	0.12494909	1.57414	1.60876	0.0075020
FERREY	0.00019620	0.07317787	0.00071801	0.29484383	3.65962	4.02914	0.0266822
GBVLA	0.00021282	0.07961832	0.00021636	0.08099612	1.01665	1.01730	0.0001007
IFS	0.00019249	0.07174479	0.00067098	0.27312051	3.48587	3.80683	0.0228294
INRET	0.00020262	0.07566076	0.00039593	0.15315931	1.95405	2.02429	0.0134465
INVCEN	0.00021364	0.07993743	0.00013110	0.04832440	0.61364	0.60453	0.0044588
MINSURI	0.00019294	0.07192177	0.00094066	0.40281340	4.87532	5.60072	0.0305544
NEXAPE	0.00019437	0.07247093	0.00086827	0.36675619	4.46715	5.06074	0.0273037
PML	0.00020017	0.07471145	0.00092806	0.39646983	4.63649	5.30668	0.0188115
RIMSEG	0.00021227	0.07940525	0.00014736	0.05447805	0.69420	0.68608	0.0046311
SCCO	0.00019019	0.07086032	0.00062905	0.25406192	3.30747	3.58539	0.0193345
SIDER	0.00019493	0.07268739	0.00099945	0.43279054	5.12731	5.95413	0.0259746
TV	0.00018006	0.06696259	0.00218455	1.19367941	12.13232	17.82606	0.0293127
UNACEM	0.00019731	0.07360866	0.00071215	0.29211740	3.60924	3.96852	0.0252027
VOLCAA	0.00021191	0.07926301	0.00018612	0.06929243	0.87831	0.87421	0.0015368

Source: Lima Stock Exchange. April 18, 2022. Retrieved from https://www.bvl.com.pe/emisores/listado-emisores
Prepared by the authors.

4. Discussion

Several authors conclude that the Black-Litterman model has more predictability than other models such as the Markowitz model (efficient frontier) and the CAPM model. Similar results were obtained in this research referring to shares rated by the Lima Stock Exchange indexes (Sotelo Rojas, 2015; Cabezas, Ramos and Vidal, 2020; Medina and Cáceres, 2016; Franco-Arbelaez et al. 2011 and Giraldo *et al*. 2015).

Álvarez-Franco, Restrepo-Tobón, Velásquez-Giraldo (2017) use the models of Nelson and Siegel; Diebold and Li; Duffie and Kan to analyze the variations of returns in the Colombian market. In this study, the Markowitz, Sharpe, CAPM and Black -Litterman models were used obtaining similar results.

Vargas Sanchez (2012) with the S&P500 (USA) database used the Treynor-Black; Sharpe models, obtaining as results that the Sharpe ratio 2.9, total portfolio return (assets and liabilities) of 20.10%, a higher return of 7.55% measured through the 2M indicator is achieved. In the results obtained, in order to achieve the new CAL Line, the structure of the risky portfolio is necessarily composed of 81.7% of the selected shares with abnormal returns and 18.3% composed of shares with normal returns, so that the investment strategy is concentrated on securities with high levels of unsystematic risk (active portfolio). To find the optimal portfolio, the efficient frontier of the CAPM and Black-Litterman indices was taken into account. Considering the systemic risk and the expected return ex-post to the experts' opinion.

Montenegro (2018), uses the CAPM and Markowitz models and the Ecuindex index, obtaining as a result that the liquidity of the stock market in Ecuador is affected by the low participation of popular economic sectors. In this study, the descriptive analysis identifies the lack of liquidity in the Lima Stock Exchange market due to the low participation of economic actors in Peru.

Núñez and León (2019) use the Markowitz model of the Efficient Frontier, obtaining as results that the optimal portfolio consists of a low percentage in equities and a higher weight in fixed income, nominal rate and real rate with the choice of short-term instruments. In this study, an analysis of the optimal portfolio was carried out with only variable income of the shares rated in the Lima Stock Exchange.

Duvoba (2005) applies the Capital Asset Pricing Model (CAPM) and the Markowitz method, concluding that the quantitative results were uncertain in the Colombian and international market, and that the application of the optimal portfolio will depend on the efficiency of the Colombian capital market in the future. In this study, in the LSE market, shares also have a high degree of uncertainty due to the lack of liquidity, and the analysis of expected returns adjusted for systemic risk and expert opinion was performed.

Jisma, Mohan & Thomas (2023); Unni, Ongsakul & Madhu (2022) obtain as a result a better risk-return ratio of expected returns using the Markowitz efficient frontier and the Black-Litterman model including the opinion of the specialists of the electricity sector. In the Indonesian market, Subekti, R., Abdurakhman, & Rosadi, D. (2022) analyze and adjust the results to the Shariah principle and the impact of COVID-19 using the CAPM, the Markowitz Efficiency Frontier and the Black-Litterman model. The Markowitz, CAPM and Black-Litterman models were used in the study, obtaining optimization in the predictability of the profitability of the portfolios.

Colasanto, Grilli, Santoro & Villani (2022) and Gómez, Trujillo & Quimbayo (2022) use the Black-Litterman model to optimize portfolio performance by considering polarized Bert feelings and diffused logic in the valuation of Views. Sahamkhadam, Stephan & Östermark (2022), using the Black-Litterman model, analyze the copulae vines to determine the symmetry and asymmetry of the tails determining better performance of the portfolios in terms of lower tail risk and higher risk-adjusted returns. The Markowitz, CAPM and Black-Litterman models were used in the study, obtaining optimization in the predictability of the profitability of the portfolios.

Li, Uysal & Mulvey (2022) use a successive convex program algorithm model to improve the prediction of results, considering the Sharpe, Bayes-Stein and Black -Litterman indexes. Stoilov,

Stoilova, K., & Vladimirov, M. (2022) create an algorithm to optimize market parameters and in that way are used to measure expert opinion by comparing them with historical results. The Markowitz, CAPM and Black-Litterman models were used in the study, obtaining optimization in the predictability of the profitability of the portfolios.

The authors, Fuhrer & Hock (2023); Sun, Wu & De (2023); Han, & Li (2023) and Teplova, Evgeniia, Munir & Pivnitskaya (2023) start from the importance of Bayesian analysis used in the Black-Litterman model to calculate expected returns considering risk and expert opinion, and through econometric adjustments manage to obtain better results by including multiple covariance analysis in the risk calculation. The Markowitz, CAPM and Black-Litterman models were used in the study, obtaining optimization in the predictability of the profitability of the portfolios.

5. Conclusions

In this study the database obtained from the Lima Stock Exchange has been used, considering those variable income assets that are indexed to April 13, 2022.

The econometric models applied to define the investment portfolios were the Markowitz efficient frontier model, then the CAPM, and finally the Black-Litterman model. With these results we applied the Sharpe index in order to determine the best portfolio considering the highest return and the lowest risk. It can be stated that the expected return is predictable, with the Wilcoxon p-value of the BL/CAPM of 0.0000000149 and the Wilcoxon p-value of the Sharpe BL of 0.00000377, and it can be concluded that the predictability of the BL/CAPM index is more effective, because the dispersions are smaller.

Applying the Markowitz model the optimal portfolio consists of the following weights: 21.14% in Unión de Cervecerías Peruanas Backus y Johnston SAA, 1.57% in Sociedad Minera el Brocal SAA, 4.03% Compañía de Minas Buenaventura SAA, 14.48% Corporación Aceros Arequipa SA, 0.37% Sociedad Minera Cerro Verde SAA, 3. 96% Enel Distribución Perú SAA, 5.03% Enel Generación Perú SAA, 21.06% Inretail Perú Corp, 0.63% Inversiones Centenario SAA, 3.27% Minsur SA, 4.96% Rimac Seguros y Reaseguros, 6.43% Southern Copper Corporation, 2.32% Empresa Siderurgica del Peru SAA and 10.97% Volcan Compañia Minera SAA.

Applying the Black-Litterman model, the optimal portfolio consists of the following weights: 10.8% in Aenza SAA (formerly Graña y Montero SAA), 10.54% in Casa Grande SAA, 7.33% Sociedad Minera Cerro Verde SAA, 0.88% Ferreycorp SAA, 17.79% Minsur SA, 10.59% Nexa Resources Peru SAA, 9.32% Panoro Minerals LTD, 14.29% Empresa Siderurgica del Peru SAA, 15.79% Trevali Mining Corporation and 2.67% Unacem Corp SAA.

For the comparison, the ratio of the CAPM and Black-Litterman models was used, obtaining the BL/CAPM index and comparing it with the Sharpe BL index.

To improve the predictability of portfolio management models, the BL/CAPM index is more effective than the Sharpe index in terms of the ex-post expected returns of each asset which is tested using the Shapiro Wilk normality test and the Wilcoxon test, with the Wilcoxon p-value of the BL/CAPM of 0.0000000149 and the Wilcoxon p-value of the Sharpe BL of 0.00000377 indicating that the BL/CAPM index has better predictability.

References

Álvarez-Franco, S. I., Restrepo-Tobón, D. A., & Velásquez-Giraldo, M. (2017). Medición del valor en riesgo de portafolios de renta fija usando modelos multifactoriales dinámicos de tasas de interés. Estudios Gerenciales, 33(142), 52-63. https://doi.org/10.1016/j.estger.2017.02.003

Black, F., & Litterman, R. (1992). Global Portfolio Optimization. Financial Analysts Journal, 48(5), 28-43. https://www.jstor.org/stable/4479577

Bolsa de Valores de Lima, (2022). Listado de emisores. [en línea]. [Consulta: 8 agosto 2022]. Disponible en: https://www.bvl.com.pe/emisores/https:/www.bvl.com.pe/emisores/listado-emisores

Cabezas Estrella, M. O., Ramos Peralta, R., & Vidal Cuba, J. A. (2020). Aplicación del modelo de Black-Litterman para describir las estrategias de las AFP peruanas en los portafolios de ETFs: 2014-2018. https://repositorio.esan.edu.pe///handle/20.500.12640/2012

Colasanto, F., Grilli, L., Santoro, D., & Villani, G. (2022). BERT's sentiment score for portfolio optimization: A fine-tuned view in black and litterman model. Neural Computing and Applications, 34(20), 17507-17521. https://doi.org/10.1007/s00521-022-07403-1

Congreso de la República. (2020). Comisión especial multipartidaria encargada de evaluar, diseñar y proponer el proyecto de ley para la reforma integral del sistema previsional peruano. http://www.congreso.gob.pe/comisiones2020/CEM-sistema-previsional/sobrelacomision/plan-trabajo/

Diebold, F. X. y Li, C. (2006). Forecasting the term structure of government bondyields. Journal of Econometrics, 130(2), 337–364.

Dubova, I. (2005). La validación y aplicabilidad de la teoría de portafolio en el caso colombiano. Cuadernos de Administración, 18(30), 241-279. http://www.scielo.org.co/scielo.php?script=sci_abstract&pid=S0120-35922005000200011&lng=en&nrm=iso&tlng=es

Duffie, D. y Kan, R. (1996). A yield-factor model of interest rates. Mathematical Finance, 6(4), 379–406.

Fuhrer, A., & Hock, T. (2023). Uncertainty in the Black–Litterman model: Empirical estimation of the equilibrium. Journal of Empirical Finance, 72, 251-275. https://doi.org/10.1016/j.jempfin.2023.03.009

Franco-Arbeláez, L. C., Avendaño-Rúa, C. T., & Barbutín-Díaz, H. (2011). Modelo de Markowitz y Modelo de Black-Litterman en la Optimización de Portafolios de Inversión. TecnoLógicas, 26, 71-88. http://www.scielo.org.co/scielo.php?script=sci_abstract&pid=S0123-77992011000100005&lng=en&nrm=iso&tlng=es

Giraldo Cárdenas, L., Díaz Zapata, J. M., Arboleda Ríos, S. M., Galarcio Padilla, C. L., Lotero Botero, J. E., & Isaza Cuervo, F. (2015). Modelo de selección de portafolio óptimo de acciones mediante el análisis de Black-Litterman. Revista ingenierías (Medellín, Colombia), 14(27), 111-130. https://doi.org/10.22395/rium.v14n27a7

Gomero Gonzales, N. A. (2014). Portafolios de activos financieros utilizando el modelo de Sharpe y Treynor. Quipukamayoc, 22(41), 135-146. https://doi.org/10.15381/quipu.v22i41.10078

Gómez, Y. A. F., Trujillo, J. F. M., & Quimbayo, C. A. Z. (2022). Optimal portfolio selection using the black-litterman model with fuzzy views. [Sélection optimale de portefeuille à l'aide du modèle Black-Litterman avec des views floues; Selección óptima de portafolios usando el modelo Black-Litterman con views difusas] Lecturas De Economia, (97), 363-393. https://doi.org/10.17533/udea.le.n97a346171

Han, Y., & Li, J. (2023). The impact of global economic policy uncertainty on portfolio optimization: A Black–Litterman approach. International Review of Financial Analysis, 86 https://doi.org/10.1016/j.irfa.2022.102476

Investing.com, (s.f.). S&P Lima General (SPBLPGPT). Recuperado el 13 de abril del 2022 de https://www.investing.com/indices/lima-stock-exchange-general

Jisma, M., Mohan, V., & Thomas, M. S. (2023). Risk-return optimised energy asset allocation in transmission-distribution system using tangency portfolio and Black–Litterman model. IET Energy Systems Integration, https://doi.org/10.1049/esi2.12102

Li, X., Uysal, A. S., & Mulvey, J. M. (2022). Multi-period portfolio optimization using model predictive control with mean-variance and risk parity frameworks. European Journal of Operational Research, 299(3), 1158-1176. https://doi.org/10.1016/j.ejor.2021.10.002

Markowitz, H. (1952). Portfolio Selection*. The Journal of Finance, 7(1), 77-91. https://doi.org/10.1111/j.1540-6261.1952.tb01525.x

Medina Astete, C., & Cáceres Hilario, G. M. (2016). Construcción y gestión de portafolios mediante el modelo Black-Litterman: una aplicación a las AFP en Perú durante el período 2007-2015. https://tesis.pucp.edu.pe/repositorio/handle/20.500.12404/7238

Montenegro, E. (2018). Rendimiento y riesgo de portafolios de inversiones en el mercado de valores ecuatoriano. Prospectivas UTC «Revista de Ciencias Administrativas y Económicas», 1(1), 42-55. http://investigacion.utc.edu.ec/revistasutc/index.php/prospectivasutc/article/view/114

Nelson, C. R. y Siegel, A. F. (1987). Parsimonious modelling of the yield curves. Journalof Business, 60(4), 473–489.

Núñez Mora, J. A., & León Alvarado, M. A. (2019). Determinación de un portafolio de referencia para las SIEFORE Básicas a través de un modelo de riesgo-rendimiento que optimiza la tasa de reemplazo. EconoQuantum, 57-82. https://doi.org/10.18381/eq.v16i1.7159

Ortegón Rojas, J. A., & Torres Castro, F. A. (2016). El mercado integrado latinoamericano, MILA. Estado del arte. Cuadernos Latinoamericanos de Administración, 12(23), 7-15. https://doi.org/10.18270/cuaderlam.v12i23.2111

Prima AFP, G.C. (2022). Memoria Anual 2021. Disponible en: https://www.prima.com.pe/public-zone/files/2022/pdf/Memoria-Anual-2021.pdf

Sahamkhadam, M., Stephan, A., & Östermark, R. (2022). Copula-based Black–Litterman portfolio optimization. European Journal of Operational Research, 297(3), 1055-1070. https://doi.org/10.1016/j.ejor.2021.06.015

SBS (2022). Memoria anual SBS 2021, [Consulta: 25 agosto 2022]. Superintendencia de Banca y Seguros. Disponible en: https://www.sbs.gob.pe/Portals/0/Memoria-SBS-2021.pdf.

Sharpe, W. F. (1964). Capital Asset Prices: A Theory of Market Equilibrium Under Conditions of Risk*. The Journal of Finance, 19(3), 425-442. https://doi.org/10.1111/j.1540-6261.1964.tb02865.x

SMV. (2011). Alianza del Pacífico. Superintendencia del Mercado de Valores. Recuperado de: chttps://www.smv.gob.pe/Frm_VerArticulo?data=668A68657A853BFCA8DDFA4A3E641E338F44DDE048E62F62EB071C6ADD26971EF28A117933

Sotelo Rojas, A. F. (2015). Administración y gestión de portafolios de renta variable una aplicación comparativa de los modelos de optimización de Markowitz y de expectativas Black-Litterman [Recurso electrónico]. Buenos Aires Universidad de Buenos Aires. Facultad de Ciencias Económicas. Escuela de Estudios de Posgrado. http://catalogosuba.sisbi.uba.ar/vufind/Record/KOHA-FCE-UBA:175997

Subekti, R., Abdurakhman, & Rosadi, D. (2022). The efficiency frontier of markowitz and black-litterman model: A case study on the shariah-compliant stock in jakarta islamic index. Paper presented at the AIP Conference Proceedings, , 2575 https://doi.org/10.1063/5.0108225

Subekti, R., Abdurakhman, & Rosadi, D. (2022). Toward the Black–Litterman with shariah-compliant asset pricing model: A case study on the indonesian stock market during the COVID-19 pandemic. International Journal of Islamic and Middle Eastern Finance and Management, 15(6), 1150-1164. https://doi.org/10.1108/IMEFM-12-2020-0633

Sun, Y., Wu, Y., & De, G. (2023). A novel black-litterman model with time-varying covariance for optimal asset allocation of pension funds. Mathematics, 11(6) https://doi.org/10.3390/math11061476

Teplova, T., Evgeniia, M., Munir, Q., & Pivnitskaya, N. (2023). Black-litterman model with copula-based views in mean-CVaR portfolio optimization framework with weight constraints. Economic Change and Restructuring, 56(1), 515-535. https://doi.org/10.1007/s10644-022-09435-y

Treynor, J. L., & Black, F. (1973). How to Use Security Analysis to Improve Portfolio Selection. The Journal of Business, 46(1), 66-86. https://www.jstor.org/stable/2351280

Unni, A. C., Ongsakul, W., & Madhu, N. (2022). Fuzzy incorporated Black–Litterman model for renewable energy portfolio optimization. Electrical Engineering, 104(6), 4279-4288. https://doi.org/10.1007/s00202-022-01618-0

Vargas Sánchez, A. (2012). GESTIÓN ACTIVA DE PORTAFOLIOS MEDIANTE LA APLICACIÓN DEL MODELO DE TREYNOR - BLACK. Revista Investigación & Desarrollo, 1(12). https://www.upb.edu/revista-investigacion-desarrollo/index.php/id/article/view/51