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# Systemic approach on the dynamics of the stock market

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**Abstract:** The stock market constitutes a highly complex and dynamic system, characterized by multiple interconnected elements and emerging behavioral patterns. This research analyzes the implications of adopting a systemic perspective, which allows modeling the interactions and patterns that arise within the dynamics of the stock market. Through methodologies such as agent-based modeling, systemic network analysis and complex systems theory, it is possible to represent the interconnections between various financial assets and evaluate how fluctuations in a specific asset can propagate and influence other components of the asset. market. Likewise, the importance of integrating approaches such as neural networks and machine learning with systemic analysis is emphasized, allowing the non-linear relationships inherent in financial data to be unraveled and predictive models to be developed with greater precision. This methodological synergy provides a deeper understanding of the underlying dynamics of the stock market. The main objective of this study is to explore how simulation can guide the search for the optimal portfolio, maximizing return and minimizing risk by evaluating hypothetical scenarios and making informed decisions in the field of stock investments.

***Keywords:*** *Harry Markowitz, Portfolio optimization, Return on investment, Risk management, Simulation, Stock market indices.*

## 1. Introduction

The stock market is a complex system that encompasses a wide range of interconnected elements, the understanding of which is crucial to understanding its systemic nature. Internationally, Wall Street stands out as the largest capitalization stock market, accompanied by prominent indices such as the Dow Jones and the Nasdaq. According [1]to Latin America, the panorama is no less relevant, where the Brazilian Stock Exchange (B3) stands out as the largest in the region. Its IBOVESPA index includes various companies, from giants like Petrobras to important banks like Santander. Chile, with its Santiago Stock Exchange, stands out as the only Latin American country with a high human development index. Its main index, the S&P CLX IGPA, reflects a diversity of futures, options and foreign securities [1]. In turn, the Buenos Aires Stock Exchange is presented as a crucial component of the regional financial panorama, with its S & P Merval index that includes important companies in the banking, telecommunications and transportation sectors.

The Lima Stock Exchange (LSE) is an important component of the Peruvian financial system, reflecting the performance of the country's main companies and its key economic sectors. According to a study by [2], there is a significant relationship between the general index of the Lima Stock Exchange and the Gross Domestic Product (GDP) of Peru. This study suggests that economic growth and stock market performance are linked, showing how economic trends are reflected in stock market activity. The cointegration analysis methodology used by Chung Alva allows us to identify this connection, providing relevant information for investors and economists seeking to understand the Peruvian


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financial environment. Thus, the BVL can be seen as a barometer of the country's economic status and a valuable tool for analyzing and projecting future trends [2].

According to [3], in his research he focuses on the characterization of the stratum of companies in the province of Tungurahua, from the perspective of financing mechanisms that are available on the Quito Stock Exchange. As he points out, [4]he created an intelligent system for predicting the daily price of mining shares on the New York Stock Exchange using a hybrid model of neural networks and a support vector regression machine, where its originality stands out since there were no stock market prediction systems. of values which leads to great support in terms of decisions, the development of the research is based on the comparison of previous and current results through established processes to generate the most possible result. In the same way, [5]it created a support system for making investment decisions in the stock market, in which it focuses on finding an optimal investment portfolio, due to the large number of variables that intervene in the process, they also mention that The stock market is important as companies raise capital for various purposes and the system could generate good decision making. It explores how changes in one asset can propagate and affect other assets in the stock market.

Support Vector Machine Model is a model for predicting medium-term actions in the stock market, where it was concluded that the aforementioned models, when evaluated n number of times, give rise to a success rate of 66%. Also, he showed how [6]machine learning techniques can be applied to predict trends in stock market prices. Using machine learning algorithms such as decision trees and neural networks, the stock market plays a fundamental role in economic dynamics, reflecting the expectations and valuations of the companies listed on it. In this context, a study conducted by [7]analyzes the influence of key factors, such as growth potential, capital structure and profitability, on the dividend policy and value of manufacturing companies operating on the Indonesia Stock Exchange. The results highlight the importance of understanding the complex interactions between financial, operational and investment decisions, and their impact on the performance and valuation of companies in the stock market. Stock markets play a fundamental role in the global economy, and their functioning is closely linked to issues of sustainability and good corporate governance. In this sense, a study carried out by [8]analyzes the impact of the characteristics of the board of directors and the ownership structure on the disclosure of information on sustainable development in banks listed on the Amman Stock Exchange. The findings reveal that a large board of directors, with female presence and a Corporate Social Responsibility Committee. This research highlights the importance of adopting sound corporate governance practices and promoting transparency in the disclosure of relevant information to investors and other stakeholders in the context of stock markets.

Although the differences between the stock exchanges of different countries are evident, each one plays a fundamental role in the global framework of the stock market, being influenced by the flow of investments, technological development, and the economic and financial dynamics of the current world. Due to the above, the formulation of the problem is proposed: How to generate a simulation to provide the search for the optimal portfolio in the accurate prediction of the stock market market?

## 2. Method

### *2.1. Modern Portfolio Theory*

Developed by Harry Markowitz, it provides a conceptual framework for building the optimal portfolio. According to this theory, the key to building an efficient portfolio lies in the adequate diversification of assets. By combining assets with low or negative correlations, the total risk of the portfolio can be reduced without significantly sacrificing expected return.

[9]The search for the optimal portfolio involves several stages. First, you need to gather information about the available assets, including their historical returns, volatility, and correlations. This information is used

An optimization model is then applied to find the combination of assets that maximizes the expected return, given an acceptable level of risk. This can be achieved using methods such as linear

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programming, Markowitz theory or more advanced techniques such as the mean-variance model or the efficient frontier. From a systemic perspective, analyzing and predicting the behavior of the complex stock market requires a comprehensive approach encompassing comprehensive data collection, accurate modeling, and effective optimization. Like [10]the stock market, it is essential to collect detailed information about the assets available, including historical returns, volatility and correlations.

*2.2. Modeling of the System to Simulate*

*2.2.1. Historical Data Collection*

They were extracted from secondary sources, such as Apple, AMD, NVIDIA, PBR, data shown in Table 1.

*2.2.2. Creation of the Mathematical Model*

Once the historical data was available, a mathematical model was created to simulate the behavior of the stock market, which was done through the statistical analysis of market prices over time using the normal distribution. Since its parameters, the mean and the variance, have a very important economic meaning.

The mean represents the expected average of historical returns, while the standard deviation (square root of the variance) represents the risk or volatility of an investment. Within an investment portfolio, financial assets are sought that have negative correlations (that is, while one goes up, the other goes down) although in practice this does not occur frequently, so low positive correlations (close to zero) are accepted). Thus, in the search for the optimal portfolio, these correlations tend to be close to zero.

*2.2.3. Parameter Estimation*

The performance of a stock at any time is evaluated using the following formula:

$$r_t = Ln(\frac{P_t + D_t}{P_{t-1}})$$

Where:

$r_t$= stock return at time t

$P_t$= share price at time t

$P_{t-1}$= share price at time t-1

$D_t$= dividend payment.

⇒Since the shares to be studied do not pay dividends, then the formula is reduced to the following expression:

$$r_t = Ln(\frac{P_t}{P_{t-1}})$$

The use of logarithms is necessary in computational models because it is assumed that the returns are continuous compounds, although in practice they are discrete. This is especially relevant when comparing assets using annualized performance. If only monthly performance information is available, the annualized performance can be obtained using the following fórmula:

$$r_{anual} = 12 \times r_{mensual}$$

*2.2.3.1. Variance Calculation*

The variance of the returns is calculated assuming that they are independent and identically distributed random variables.

The calculation is carried out using the following mathematical expression:

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$$\sigma^2 = \frac{1}{N}\sum_{t=1}^{N} (r_t - \underline{r})^2$$

Where:

$N$= total number of data in the returns sample

$\underline{r}$= the sample mean

If annual volatility is required, it is obtained with the following formula:

$$\sigma_{anual} = \sqrt{12} \times \sigma_{mensual}$$

*2.2.3.2. Covariance and Correlation Coefficient*

In the analysis, we calculate covariance to measure the joint variation in the returns of two stocks (A and B). Covariance allows us to evaluate how the returns of both assets behave in relation to each other. From the covariance, we also calculate the correlation coefficient, which quantifies the degree of linear relationship between the returns of the two stocks. This correlation coefficient helps us understand the strength and direction of the relationship between the returns of assets A and B. $Cov(r_A, r_b) = \frac{1}{N}\sum_{t=1}^{N} [r_t^A - \underline{r_A}][r_t^B - \underline{r_B}]$

*2.2.3.4. Correlation Coefficient*

$$\rho = \frac{Cov(r_A, r_b)}{\sigma_A \, \sigma_B}$$

*2.2.4. Simulation*

*2.2.4.1. Calculation of Continuous Returns*

**Table 1.**
Continuous returns.

| **Continuous returns** | | | |
|---|---|---|---|
| **Manzana** | **AMD** | **NVIDIA** | **PBR** |
| 2.37% | 5.11% | 4.70% | -2.14% |
| 0.47% | 0.06% | -0.13% | 4.06% |
| -1.49% | -3.07% | -4.43% | 1.97% |
| 0.68% | -0.77% | -0.46% | -2.06% |
| -0.25% | 1.51% | 0.54% | -2.81% |
| 2.03% | 1.38% | 1.36% | 0.97% |
| 1.14% | 3.14% | 2.51% | -3.96% |
| -2.09% | 0.39% | 2.13% | 2.98% |
| 2.64% | 5.32% | 5.39% | 2.11% |
| 1.34% | 4.05% | 4.68% | 1.64% |
| 1.50% | 1.84% | 1.36% | -0.26% |
| -0.81% | -3.34% | -4.13% | -1.39% |
| -0.74% | -0.64% | -1.72% | 1.47% |
| -0.89% | -2.65% | -2.93% | 6.24% |
| 3.37% | 5.22% | 7.33% | 1.76% |
| 0.36% | 2.04% | 1.08% | 2.66% |
| 3.23% | 3.01% | 0.99% | 3.34% |
| -0.62% | 2.42% | 1.52% | 6.44% |

**Note:** The formula of the return of one stock per day of the four indices is used. The data shown is referential, more than 200

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daily data are evaluated in a range of 2 years (2022-2023).

**Table 2.**
Daily expected performance.

| | Expected performance | | | |
|---|---|---|---|---|
| | **Manzana** | **amd** | **NVIDIA** | **PBR** |
| Expected profitability | 0.12% | 0.17% | 0.41% | 0.27% |
| Risk-volatility | 1.85% | 3.37% | 3.60% | 3.03% |
| Relative risk | 15,567 | 20,394 | 8,747 | 11,209 |
| Annualized return | 30.00% | 41.69% | 103.76% | 68.08% |
| Annualized risk | 29.42% | 53.56% | 57.17% | 48.07% |
| Holdings | 25% | 25% | 25% | 25% |
| Lower limits | 0% | 0% | 0% | 0% |
| Upper limits | twenty% | twenty% | twenty% | twenty% |

**Note:** Basically, the relative risk is the coefficient of variation that will be the ratio between risk and profitability, that is, the riskiest asset was the one with the greatest relative risk. For the annualized return, 252 days are taken, which are the business days in the stock market. The participations would be the % of investment that you want to execute in each of the indices, and there are also investment limits that could be legal or corporate according to the AFP, they would be 20%.

### *2.2.4.2. Variance and Covariance Matrix*

**Table 3.**
Calculation of the feasible return-risk area.

| **Variance and covariance matrix** | | | | |
|---|---|---|---|---|
| | **Manzana** | **AMD** | **NVIDIA** | **PBR** |
| Manzana | 0.000342194 | 0.00037264 | 0.00040603 | 2.8007E-05 |
| AMD | 0.000372642 | 0.00113395 | 0.00097572 | 3.6786E-06 |
| NVIDIA | 0.000406034 | 0.00097572 | 0.00129174 | 1.8204E-05 |
| PBR | 2.80068E-05 | 3.6786E-06 | 1.8204E-05 | 0.00091334 |

**Note:** Let's remember that the main diagonal is the variance and the downward diagonal is the covariance.

### *2.2.4.3. Calculation of Historical Returns*

**Table 4.**
Historical returns.

| **Manzana** | **amd** | **NVIDIA** | **PBR** | **Historical portfolio performance** |
|---|---|---|---|---|
| 2.37% | 5.11% | 4.70% | -2.14% | 2.51% |
| 0.47% | 0.06% | -0.13% | 4.06% | 1.12% |
| -1.49% | -3.07% | -4.43% | 1.97% | -1.75% |
| 0.68% | -0.77% | -0.46% | -2.06% | -0.65% |
| -0.25% | 1.51% | 0.54% | -2.81% | -0.25% |
| 2.03% | 1.38% | 1.36% | 0.97% | 1.44% |
| 1.14% | 3.14% | 2.51% | -3.96% | 0.71% |
| -2.09% | 0.39% | 2.13% | 2.98% | 0.85% |
| 2.64% | 5.32% | 5.39% | 2.11% | 3.86% |
| 1.34% | 4.05% | 4.68% | 1.64% | 2.93% |
| 1.50% | 1.84% | 1.36% | -0.26% | 1.11% |
| -0.81% | -3.34% | -4.13% | -1.39% | -2.42% |
| -0.74% | -0.64% | -1.72% | 1.47% | -0.41% |
| -0.89% | -2.65% | -2.93% | 6.24% | -0.05% |
| 3.37% | 5.22% | 7.33% | 1.76% | 4.42% |

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| | | | | |
|---|---|---|---|---|
| 0.36% | 2.04% | 1.08% | 2.66% | 1.54% |
| 3.23% | 3.01% | 0.99% | 3.34% | 2.64% |

**Note:** Basically, the historical profitability of the portfolio corresponds to the sum product of the returns on the participations, which would be 25% each.

We simulate portfolio risk optimization with the Risk Simulator tool.

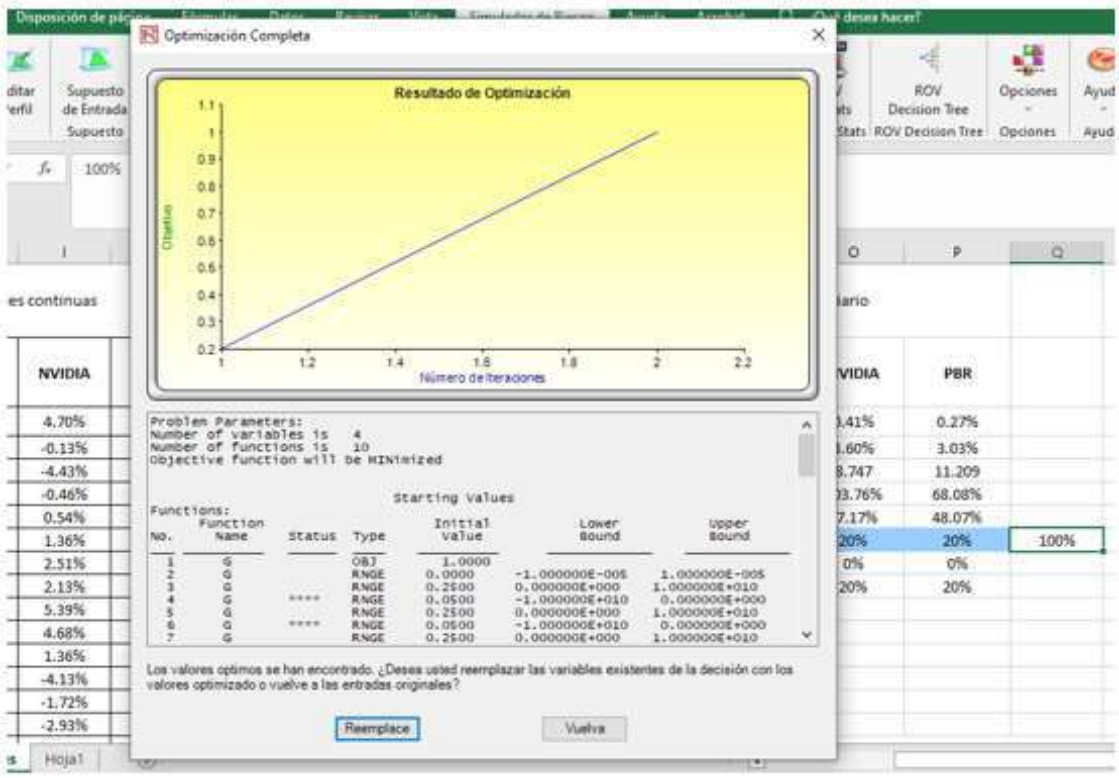


**Figure 1.**
Replacement of portfolio risk values.
**Note:** The probability distribution gives the historical information for the profitability of the four indices, it will not have a single value, it will have an expected value of many, which will be generated with the help of Monte Carlo.

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| | |
|---|---|
| Rentabilidad portafolio | 60.88% |
| Riesgo portafolio | 0.85% |
| | |
| Indice de Sharpe | 6793.11% |
| Omega de Keating | -1.348966272 |

**Figure 2.**
Previous values.

| | L | M | N | O | P | Q |
|---|---|---|---|---|---|---|
| | Riesgo-Volatilidad | 1.85% | 3.37% | 3.60% | 3.03% | |
| | Riesgo Relativo | 15.567 | 20.394 | 8.747 | 11.209 | |
| | Rentabilidad anualizada | 30.00% | 41.69% | 103.76% | 68.08% | |
| | Riesgo anualizado | 29.42% | 53.56% | 57.17% | 48.07% | |
| | Participaciones | 20% | 20% | 20% | 20% | 100% |
| | Limites Inferiores | 0% | 0% | 0% | 0% | |
| | Limites Superiores | 20% | 20% | 20% | 20% | |
| | 0.000229775 | | | | | |
| | Rentabilidad portafolio | 48.71% | | | | |
| | Riesgo portafolio | 0.68% | | | | |
| | Indice de Sharpe | 6695.16% | e riesgo que es 3.32% en peru / reisgo de portafolio | | | |
| | Omega de Keating | -1.348966272 | | | | |

**Figure 3.**
Values after replacement.
**Note:** The risk was minimized, because it shows that our profitability is optimal.

*2.2.4.4. Calculation of the Optimal Portfolio Maximizing Risk*

**Table 5.**
Optimal portfolio according to indicator.

| Briefcase | Manzana | AMD | NVIDIA | PBR | Risk | Cost effectiveness | ES | okay |
|---|---|---|---|---|---|---|---|---|
| 1 | Twenty% | Twenty% | Twenty% | Twenty% | 1% | 49% | 66.9515627 | -1.34896627 |

**Note:** It is observed that the profitability of the portfolio is high, the portfolio risk is 1%, Sharpe IS index (it is taken by evaluating the expected return - a risk-free rate that is 3.32% in Peru on the portfolio risk), Omega Keating OK (correlation coefficient).

## 3. Results and Discussion

After simulating the selection of investment portfolios in 4 stock indices (Apple, AMD, NVIDIA, PBR), we have obtained the following results:
Relative Risk of Indices:

- Apple: 15,567
- AMD: 20,394

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- NVIDIA: 8,747
- PBR: 11,209

Annualized Returns of the Indices:

- Apple: 30.00%
- AMD: 41.69%
- NVIDIA: 103.76%
- PBR: 68.08%

Relative Risk is a measure that indicates the relationship between the risk and return of each index. A higher Relative Risk value implies greater risk compared to return.

Considering the initial investment participations of 25% in each of the indices, the historical profitability of the portfolio was calculated. Below, we present the results obtained:

- Portfolio Profitability: 60.88%
- Portfolio Risk: 0.85%

Portfolio Risk indicates the level of risk associated with the set of investments in the selected indices. In this case, a low risk has been obtained, which indicates lower volatility compared to individual indices.

On the other hand, Portfolio Profitability shows the performance obtained by the set of investments. With a profitability of 60.88%, optimal profitability has been achieved in this simulation.

It should be noted that the established investment limits are 20% for each index, according to the corresponding legal regulations or corporate policies.

These results are the product of the simulation carried out using the data and parameters mentioned. It is recommended to keep in mind that results may vary depending on different factors and market conditions.

The simulation carried out to evaluate the selection of investment portfolios in the Apple, AMD, NVIDIA and PBR stock indices has yielded interesting results. The analysis of the Relative Risk and Annualized Return of each index provides valuable information for decision making in portfolio construction.

According to the results obtained, it is observed that the index with the highest Relative Risk is AMD, which indicates that it has greater volatility in relation to its profitability. This implies that investing in AMD carries a higher risk compared to the other indices evaluated.

On the other hand, it is highlighted that NVIDIA is the index with the highest annualized return, which indicates a significant performance in the period considered. This information is relevant for those investors seeking to maximize their long-term profits.

Building an investment portfolio based on modern portfolio theory, as proposed by Harry Markowitz, involves diversifying assets to minimize risk and maximize returns. In this sense, it is important to consider the results obtained in the simulation to determine the optimal weights of each index in the portfolio.

It is relevant to mention that the simulation results are based on historical data and assume that the past behavior of the indices will be repeated in the future. However, the stock market is subject to unpredictable changes and events that can affect asset performance. Therefore, it is advisable to constantly monitor the portfolio and adjust the weightings based on market conditions and the evolution of the indices.

The references provided offer additional information on topics related to the stock market, stock market crashes, and stock price prediction. These resources can serve as a complement to better understand the financial context and make informed decisions.

In summary, the results of investment portfolio simulation provide valuable information for building a diversified and balanced portfolio. However, it is important to note that investing in the stock market carries inherent risks and past performance does not guarantee future results. It is recommended

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to continue monitoring and adjusting the portfolio according to market conditions and the evolution of the indices.

## 4. Conclusions

The simulation made it possible to evaluate the relative risk of the Apple, AMD, NVIDIA and PBR stock indices. It was observed that AMD presented the highest relative risk, which implies greater volatility compared to the other investment options. This information is relevant for investors who wish to make decisions considering their risk tolerance.

By obtaining the annualized profitability the simulation showed that NVIDIA showed the highest annualized profitability, indicating significant profit potential. This information can be useful to investors looking to maximize their long-term returns.

The simulation results can be used to build a diversified and balanced investment portfolio. Modern portfolio theory, proposed by Harry Markowitz, suggests that by combining assets with different levels of risk and return, an optimal balance can be obtained. In this case, investors can assign weights to each index in the portfolio based on the simulation results and their own investment objectives.



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