Challenge Bradesco - Rafael Eiki Teruya

Part I

Table 1: Returns (%) and Volatility (%) of Selected Assets as of December 31, 2024

Asset	Daily	Monthly	Annual
Panel A: Returns			
Dollar	-0.255%	2.727%	27.374%
IBOVESPA	0.000%	-4.285%	-10.360%
S&P500	-0.428%	-2.499%	23.309%
VIX	-0.287%	28.423%	39.357%
IPCA	0.017%	0.390%	4.831%
Gold Spot	0.716%	-0.970%	27.243%

Asset	Daily	Monthly	Annual
Panel B: Volatility			
Dollar	0.91%	4.66%	10.65%
IBOVESPA	1.22%	4.56%	10.65%
S&P500	0.90%	3.37%	10.51%
VIX	6.86%	69.36%	124.30%
IPCA	0.01%	0.62%	2.15%
Gold Spot	0.80%	3.34%	12.62%

Note: Daily, Monthly, and Annual refer to the respective frequencies as of December 31, 2024.

Table 2: Correlation Heatmap of Assets in 2024 (%)

	Dollar	IBOVESPA	S&P500	VIX	IPCA	Gold Spot
Dollar	100.00	-1.28	-2.58	-3.31	-0.13	5.13
IBOVESPA	-1.28	100.00	26.12	-30.26	-6.81	26.09
S&P500	-2.58	26.12	100.00	-76.69	0.18	23.76
VIX	-3.31	-30.26	-76.69	100.00	0.26	-20.11
IPCA	-0.13	-6.81	0.18	0.26	100.00	-3.61
Gold Spot	5.13	26.09	23.76	-20.11	-3.61	100.00

Part II

The risk of each asset was assessed using the historical daily Conditional Value at Risk (CVaR) at the 5% confidence level. Let L be the portfolio loss random variable and α the confidence level:

$$CVaR_\alpha(L) = E[\, L \mid L \geq VaR_\alpha(L) \,]$$

The CvaR measures the average loss in the worst-case (left-tail) of the return distribution i.e. the average of the worst α% losses. It captures the tail risk, representing the severity of extreme losses beyond the VaR limit, thus allowing a more profound analysis on downside risk.

Table 3: Ranking of Asset Risk Based on 5% daily CVaR

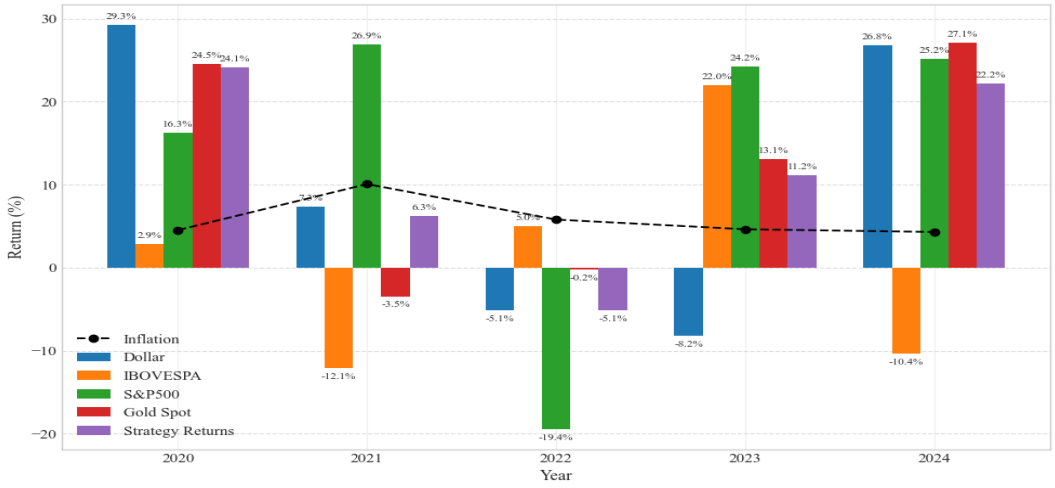
Rank	Asset	CVaR (5%)
1	VIX	-12.52%
2	IBOVESPA	-2.89%
3	S&P500	-2.29%
4	Dollar	-2.15%
5	Gold Spot	-2.00%
6	IPCA	-1.67%

Part III

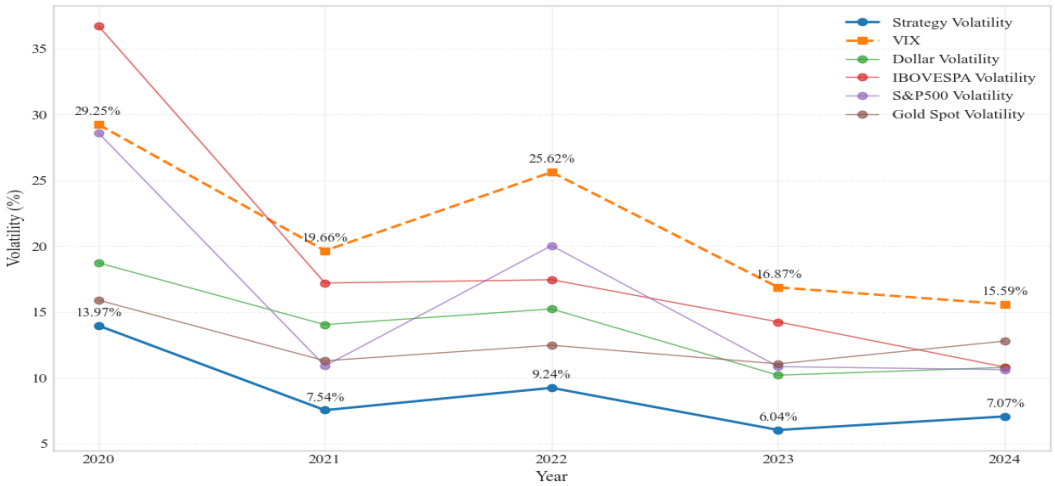
The implemented method was based on the paper *Building Diversified Portfolios that Outperform Out-of-Sample* by Miguel López de Prado (2016) that introduced the Hierarchical Risk Parity methodology. HRP was develop to adress three major problems of quadratic optimizers used in traditional methods such as Markowitz's CLA, that being: underperfomance out-of-sample, instability and concentration. This methodology does not require the inversion of a positive-definite covariance matrix, thus avoiding errors caused by numerically ill-conditioned matrices. It introduces the concept of hierarchy and applies graph theory and machine learning techniques, being divided into three stages: **tree clustering**, **quasi-diagonalization** and **recursive bisection**. It organizes the investment into a tree structure, that ensures weight stability and intuitive top-down allocations by diversifying across clusters of investments at multiple hierarchical levels.

Table 4: Annual Asset Performance, Market Volatility, and HRP Portfolio Metrics (2020–2024)

Year	Dollar	IBOV	S&P500	Gold Spot	VIX (avg)	Inflation	Strategy Return	Strategy Vol.	HRP Weight
2020	29.26%	2.88%	16.26%	24.53%	29.25%	4.52%	24.09%	13.97%	27.07%
2021	7.31%	-12.14%	26.89%	-3.46%	19.66%	10.06%	6.26%	7.54%	35.51%
2022	-5.13%	4.97%	-19.44%	-0.21%	25.62%	5.78%	-5.13%	9.24%	11.64%
2023	-8.22%	21.95%	24.23%	13.07%	16.87%	4.62%	11.17%	6.04%	25.78%
2024	26.77%	-10.37%	25.18%	27.09%	15.59%	4.29%	22.18%	7.07%	—



(a) Annual Returns of Assets and Strategy (2020–2024)



(b) Volatility and VIX Comparison (2020–2024)

Figure 1: Performance and Risk Metrics.

Part IV

The portfolio yielded a return of **69.91%** with an average annual volatility of **8.77%**, given the amount invested, the final value would be **R$169,911.67**. The method used has several benefits, Lopez's paper indicates a superior out-of-sample variance, improved risk-adjusted returns and resilience to shocks. In addition, while methods like Markowitz's tend to heavily concentrate weights on few assets in order to minimize in-sample risk, HRP delivers a less concentrated allocation. Computationally, HRP does not require invertibility or positive-definitiveness of the covariance matrix, thus improving robustness. However, HRP can possibly generate an arbitrary asset cluster that not necessarily corresponds to any meaningful market relationship. Improvements could be made by incorporating expected returns into this approach, leading to a more return oriented strategy. Further metrics we could use to evaluate the strategy: **Sharpe Ratio** and **Max Drawdown**. In relation to analysis, it would be interesting to evaluate the strategy's market regime sensitivity i.e. the perfomance across calm and stressed markets (stress-testing).