Crypto Diversifier App: a User's Guide

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Abstract

The purpose of this document is to assist the user while accessing the Crypto Diversifier App. In a nutshell, the application seeks to provide information for investors or researchers interested in the cryptocurrency market. We divide the app into three separate, complementary dimensions: i) *Time series and correlations*, ii) *Descriptive statistics*, and iii) *Portfolio Optimization*. Overall, the app allows users to analyze the interrelationships, co-movements, and risk and return characteristics of particular assets and portfolios. Importantly, the app provides data not only for cryptocurrencies, but also for other asset classes, such as multi-country stock market indexes and selected commodities.

Link to access the Crypto Diversifier App: http://3.229.60.61/

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1 Overview

Cryptocurrencies represent a recurring discussion topic among academics, professionals, and the general public. This growing and proliferating market – a subset of the so-called market of "digital assets" – offers appealing features, such as operating independently of central banks and using encryption techniques to verify transactions and regulate total supply. Despite the recent crash following the COVID-19 crisis, the numbers of the market are still quite impressive: as of April 2, 2020, the market capitalization for BTC only has reached US$126.3 billion. Together, there are now 5,296 cryptocurrencies with a market capitalization of US$193.2 billion.[1]

Given this particular context, the Crypto Diversifier app is a tool developed in R to facilitate the analysis of worldwide investments considering both traditional assets (e.g., stocks, commodities) and cryptocurrencies. In a nutshell, the user may analyze correlations and patterns in historical data and evaluate the risk and return characteristics of individual assets and portfolios. The body of the web application consists of three pages: *Time Series and Correlations*, *Descriptive Analytics*, and *Portfolio Analysis*. Each one has a fundamental role in portfolio optimization, providing the user with a handful of statistical data and financial simulations to enlighten them on their optimal asset allocation choices. The first two pages describe with a broad range of statistical information how these assets performed in the past. At the same time, the last one runs a portfolio optimization obtaining a Minimum Variance and a Tangency Portfolio.

1.1 Objectives

The objective of our app is to assist researchers, investors, and other agents interested in the cryptocurrency market to:

- Understand the co-movements across cryptocurrencies and among cryptocurrencies and traditional assets in different countries.
- Visualize distributional characteristics – such as skewness and kurtosis – of different cryptocurrencies and infer about its absolute and relative risk.
- Estimate the optimal holding of cryptocurrencies in a portfolio composed of traditional assets in distinct time spams.

In terms of the prospective user, we design the app thinking of someone who has some previous knowledge of financial markets and financial theory. We try to keep the application as simple as possible, but some terms, information, and inferences depend on having some background in financial economics.

[1] https://coinmarketcap.com/.

1.2 Summary of data and its sources

Table 1 summarizes the variables we use in the Crypto Diversifier, stratified by asset classes. Since cryptocurrencies are a relatively new asset class and historical information is still scarce, we choose to use daily data. We also face a trade-off concerning the scope of available series: while much too little information would imply losing essential aspects of the financial market, too much series would pollute the application. We end up with 36 financial-series regarding different countries and different asset classes.

1.3 Disclaimer

It is important to note that the app does not recommend specific products or investments. Instead, it serves merely as a guide for users to assess the potential impact of cryptocurrencies in a portfolio composed of traditional assets. Furthermore, any information or analysis provided in this app comes from the authors' alone and do not represent the view or has the consent of Ripple or FGV EESP. The accuracy, completeness, and validity of any data or analysis within this app are not guaranteed. We accept no liability for any errors, omissions, or representations.

The remaining of the document is structured as follows. In section 2.1, we explore the first set of visual tools, namely, the time series plots and correlation matrices. Section 2.2 shows some examples of analysis with the summary statistics page. Section 2.3.1 is divided in 2 sections. The first one is dedicated to the process of finding optimal weights for assets in a balanced portfolio, and the second one is for Backtesting. The last section presents our concluding remarks.

2 Features of the app

2.1 Time Series and Correlations

Considering the order of the pages on the front page of the app, the first feature here detailed is the Time Series and Correlations. In this section, it is possible to compare historical prices, returns, and volume traded for a set of multiple cryptocurrencies, commodities, and other financial assets for a given time range set by the user. That is, the central panel of this page is a graph detailing how each asset performed historically. It is possible to check patterns or trends visually on information such as price, return, and volume. Right beside it, there is a correlation plot between the assets the user selected for the graph. The type of correlation set as default is the Pearson Correlation. Still, the user also can choose other possibilities, like the Kendall and the Spearman Correlation. One thing to be careful about this analysis is that there are assets (mainly cryptocurrencies) with a shorter time range, so, depending on the choices of the user, the time series and the correlation plot can be somewhat misleading. Due to this difference in the number of available data, there is a button on this page named "Force Listwise deletion" that filters the dataset, maintaining only the data points containing information for all assets

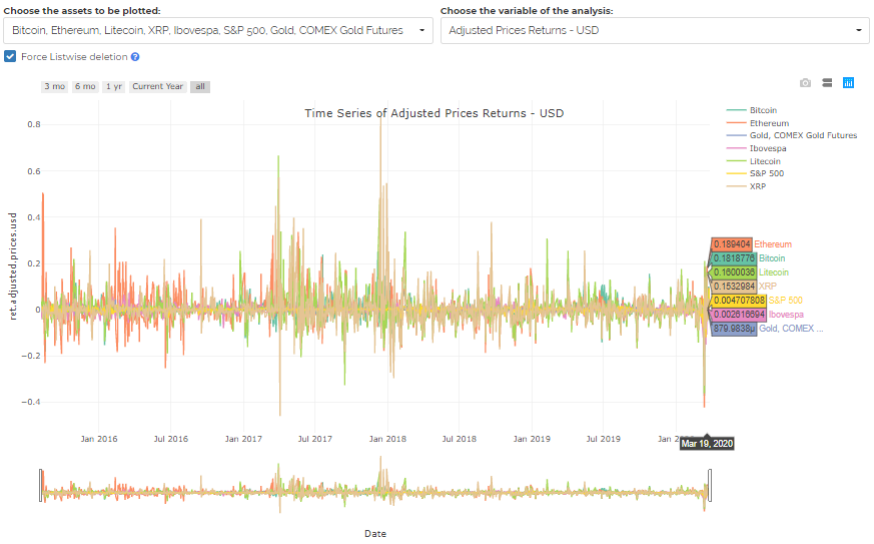
Table 1: Available financial assets and corresponding sources, by asset class.

Ticker	**Variable**	**Country**	**Source**
	Panel A - Cryptocurrencies		
BTC	Bitcoin	-	Yahoo Finance
XRP	Ripple	-	Yahoo Finance
ETH	Ethereum	-	Yahoo Finance
LTC	Litecoin	-	Yahoo Finance
BNB	Binance Coin	-	Yahoo Finance
BCH	Bitcoin Cash	-	Yahoo Finance
ADA	Cardano	-	Yahoo Finance
EOS	EOS	-	Yahoo Finance
XLM	Stellar	-	Yahoo Finance
USDT	Tether	-	Yahoo Finance
	Panel B - Stock Market Indexes		
GSPC	S&P500	US	Yahoo Finance
GSPTSE	S&P/TSX Composite Index	Canada	Yahoo Finance
FTSE	FTSE 100	UK	Yahoo Finance
GDAXI	DAX Performance Index	Germany	Yahoo Finance
FCHI	CAC 40	France	Yahoo Finance
BFX	BEL 20	Belgium	Yahoo Finance
IMOEX.ME	MCX	Russia	Yahoo Finance
BVSP	Ibovespa	Brazil	Yahoo Finance
IPSA	S&P/CLX IPSA	Chile	Yahoo Finance
MXX	IPC MEXICO	Mexico	Yahoo Finance
MERV	Merval	Argentina	Yahoo Finance
N225	Nikkei 225	Japan	Yahoo Finance
HSCE	Hang Seng China Enterprises	China	Yahoo Finance
HSI	Hang Seng Index	Hong Kong	Yahoo Finance
KS11	KOSPI Index	South Korea	Yahoo Finance
TWII	TSEC Weighted Index	Taiwan	Yahoo Finance
KLSE	FTSE Bursa Malaysia KLCI	Malaysia	Yahoo Finance
JKSE	Jakarta Composite Index	Indonesia	Yahoo Finance
STI	Straits Times Index	Singapore	Yahoo Finance
BSESN	BSE SENSEX	India	Yahoo Finance
AXJO	S&P/ASX 200 Index	Australia	Yahoo Finance
NZ50	S&P/NZX 50	New Zealand	Yahoo Finance
	Panel C - Commodities		
CME_CG1	COMEX Gold Futures	-	Quandl
ICE_B1	ICE Brent Crude Oil Futures	-	Quandl
CME_CL1	NYMEX Crude Oil Futures	-	Quandl
	Panel D - Riskless asset		
TNX	Treasury Yield 10 Years	U.S.	Yahoo Finance

selected for the plot. To illustrate, let's consider three classes of risky assets to analyze: cryptocurrencies, stock market indexes, and commodities. From these classes, we'll choose, for instance, Bitcoin (BTC), Ripple (XRP), Ethereum (ETH), Litecoin (LTC), Ibovespa (BVSP), S&P500 (GSPC) and COMEX Gold Futures (CME_CG1). Because some assets have more extended historical data than others, we'll check the *Force Listwise Deletion* button to consider complete-cases only. Suppose we are interested in getting some visual insights about the US-Dollars

adjusted returns of these assets. The first graph in the **Time Series and Correlations** page shows the results. We printed the results in Figure 1.

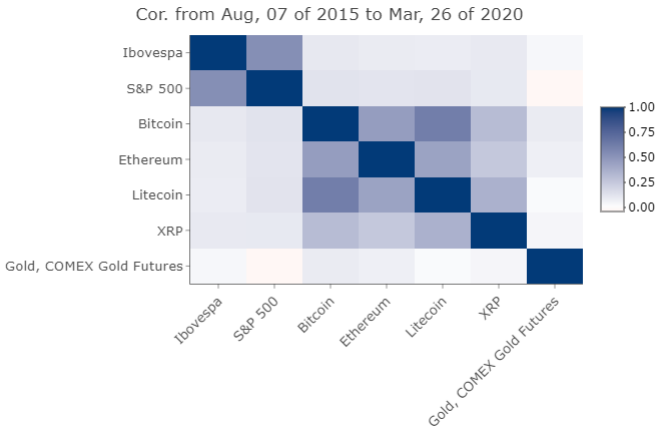
Figure 1: Time Series and Correlation Example



We can see that there are some extreme values in the sample, both positive and negative. In 12/14/2017, for instance, ripple's return in dollars reached more than 80% in a day! You can check that by navigating your mouse on the plot. In fact, by doing this, you can check the daily returns on any date you like, for all assets. Now we know that most of these outliers in the data come from cryptocurrencies. Indeed, the next section will show us a tool that confirms this first visual evidence.

Another interesting information we can obtain from this page is the correlation among assets, which is a powerful tool for asset allocation purposes. That happens because the risk of a portfolio depends not only on the risk of its individual assets, but also on the correlation between them. As an example, Figure 2 shows the Pearson correlation matrix for the selected assets.

Figure 2: Time Series and Correlation Example

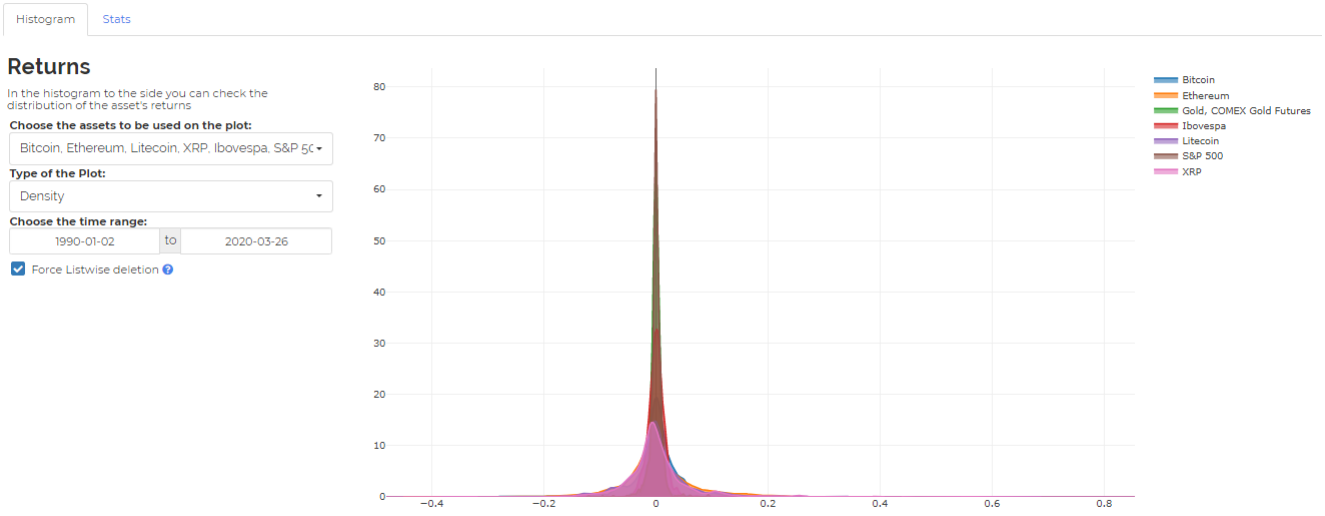


We can see that intra-class correlations are larger than multi-class correlations. Cryptocurrencies have co-moves more with other cryptos than with stock indices or future price of gold. At the same time, S&P500 and Ibovespa have a high correlation, but each one has a low association with the other assets. Again, you can check the numbers by passing the cursor over the figure.

2.2 Descriptive statistics

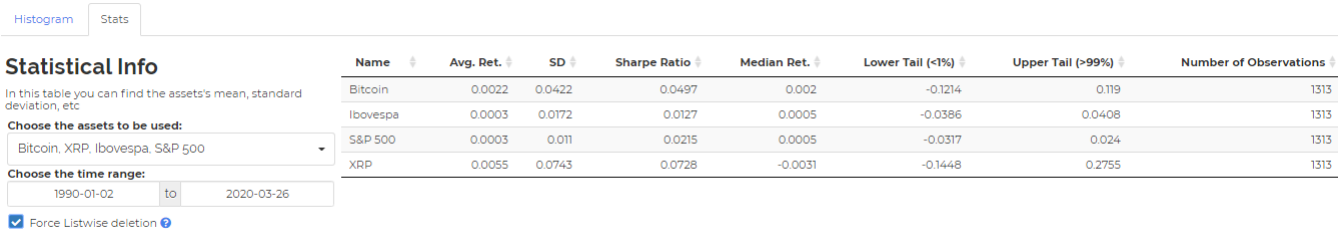
Now focusing on aggregating these time series data, a second feature of the app describes the historical behavior of the assets and is called Descriptive Statistics. On this page, the user can choose many assets as they want for any time range and compare the distribution of the assets returns. These distributions can be plotted simultaneously in the same graph, being a Density Plot or a Histogram. Also, besides the main plot, in the Stats tab, this aggregate data can be shown in a table format, where the user can choose those same assets and analyze their mean returns, standard deviation, Sharpe ratio, and other useful stats. On this page, just like on the Time Series and Correlation, there is the "Force Listwise deletion" button on both tabs because of the different ranges for each financial asset. For instance, let's consider the same seven assets from the last section. In the Histogram page, we can see the distribution of each asset through density functions. There are some extreme values, both positive and negative, for cryptocurrencies. Stock market indices, however, seem to have a much higher probability for near-null daily returns.

Figure 3: Portfolio Analysis Example - Portfolio weights



We also can check the descriptive statistics themselves in the subpage *stats*.

Figure 4: Portfolio Analysis Example - Portfolio weights



Name	Avg. Ret.	SD	Sharpe Ratio	Median Ret.	Lower Tail (<1%)	Upper Tail (>99%)	Number of Observations
Bitcoin	0.0022	0.0422	0.0497	0.002	-0.1214	0.119	1313
Ibovespa	0.0003	0.0172	0.0127	0.0005	-0.0386	0.0408	1313
S&P 500	0.0003	0.011	0.0215	0.0005	-0.0317	0.024	1313
XRP	0.0055	0.0743	0.0728	-0.0031	-0.1448	0.2755	1313

2.3 Portfolio analysis

The functionality of the app concerned on portfolio optimization – in a mean-variance sense – is called Portfolio Analysis. Here, the user can choose any set of assets she wants for any period, and, giving a risk-free rate of their choice (the default is the U.S. 10 year treasury bond yield), the app runs a portfolio optimization following the Markowitz model. Specifically, the output comprises i) the optimal weights of each asset to obtain the Tangency Portfolio, and ii) the optimal weights for the Global Minimum Variance Portfolio. Further, in the central panel, there is a plot containing the Efficient Frontier, just as the scatter plot all individual assets. Assuming the investor may not only invest in risky but also in a riskless asset, the upward sloping line from the risk-free rate (S.D. = 0) and contiguous to the Tangency Portfolio is known as the Capital Market Line (CML). Under the Markowitz's model assumptions, this line represents the risk-return trade-off in the capital market: to increase expected returns,

an investor will have to take higher risk necessarily. The other tab of this page performs a backtest that shows how the optimal portfolio and the minimum variance portfolio would have performed over time, comparing their returns with a selected benchmark. Also, the user can choose the "Naive Portfolio" option, which equal weight to every asset on the portfolio, and the "Rebalance Portfolio" option, which includes the portfolios with weights changing over time. In what follows, we briefly describe the approaches used in this page.

2.3.1 The Optimal Portfolio

Following the Markowitz approach, the problem of finding the optimal combination of assets can be addressed by choosing the weights (w) for each asset that maximize the Sharpe Ratio subject to a set of constraints as follows:

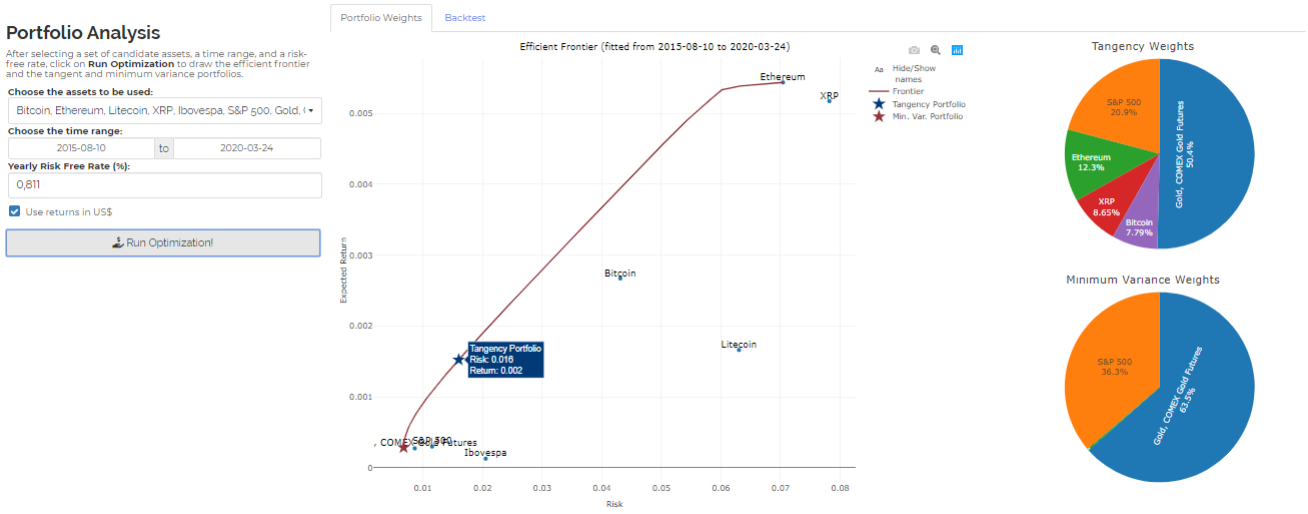
$$\begin{aligned} Max_w \quad & \frac{\mu^T w - r_f}{(w^T \Sigma w)^{(1/2)}} \\ \text{s.t.} \quad & Aw = b \\ & w \geq D. \end{aligned} \tag{1}$$

Where μ^T is a vector of mean returns, r_f is the risk-free rate, and Σ is the variance-covariance matrix of assets returns. When A and b are unit vectors, and D is greater than or equal to zero, those constraints signal the "full investment" and "no short sales" constraints. In other words, it means that the whole budget should be allocated on those assets and that we do not leverage our investments, so the weights of the assets are all non-negative.

By concatenating the portfolios that offer the highest return for each level of risk, we get the so-called *Efficient Frontier*. Portfolios that lie above the efficient frontier are not feasible, while portfolios that lie below it are considered sub-optimal because, for the same level of risk, it is possible to find another combination of assets that gives a higher expected return. The portfolio to the far left of the efficient frontier is called the Minimum Variance Portfolio because, among all feasible combinations, it is the one with the lowest risk, measured in terms of standard deviation. The tangency portfolio will be the one with the highest excess return (relative to a risk-free ratio, which is often the rate of return of government bonds, such as the US Treasury bond (T-Bond)) per unit of risk, that is the highest Sharpe Ratio.

For illustration, we select our seven assets (Bitcoin, Litecoin, Ethereum, Ripple, Ibovespa, S&P500, and Future Gold). The time range default selects the period in which the returns, in US dollars, for all assets are available. In this case, it ranges from 08/10/2015 to 03/24/2020. We run the optimization using an arbitrary annual risk-free rate of 0.81% and obtain the following results.

Figure 5: Portfolio Analysis Example - Portfolio weights



The figure on the left shows the efficient frontier, together with risk and return estimates for the tangency portfolio, the minimum variance portfolio, and the individual assets. Except for Ethereum, note that all individual assets lie under the efficient frontier. The mean daily return of the optimal portfolio is 1.6%, while it's risk is 0.2%. On the right side, the weights of each asset in the tangency and minimum variance portfolio are displayed. The tangency portfolio is composed of 50% Gold Futures, 20.9% S&P500, 12.3% Ethereum, 8.65% XRP, and 7.79% Bitcoin.

On the other hand, the portfolio that has the minimum level of risk, which is the combination of risky assets as left as possible in the frontier and is composed of only two assets: 36.3% of S&P500 and 63.5% of future gold. The message is pretty clear. If one wants to minimize risk (variance), she shouldn't allow these cryptocurrencies to enter the portfolio. However, it seems that cryptocurrencies can play a role in adding high return for each unit of risk that she is willing to take.

Another interesting finding in this analysis is that Ibovespa and Litecoin played no relevant role. Their weights were zero on both portfolios. However, one should be alert that these results may be (and, in fact, they are) extremely sensitive to the time range of analysis and the assets considered. It is for the user's leisure to check the consistency of these findings.

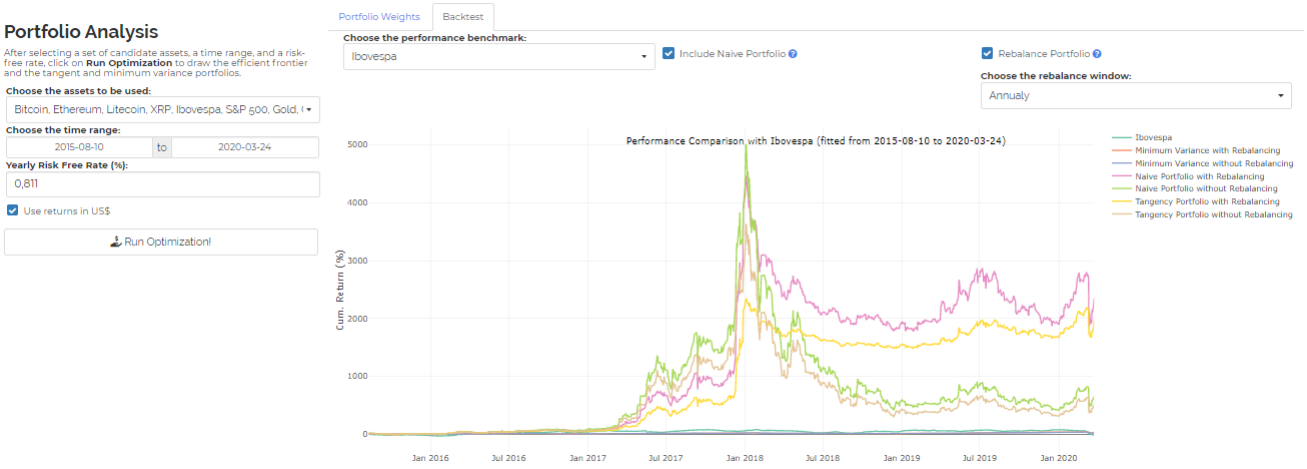
2.3.2 Backtesting

In simple words, backtesting refers to the process of analyzing, with historical data, what would have happened to your portfolio if you adopted a strategy A or B. Note that choosing a strategy, in the context of our app, means choosing weights for the assets. For instance, suppose that you find that choosing weights by maximizing the

Sharpe Ratio might be too complex or that it involves a high degree of uncertainty. Thus, you may want to take a more agnostic approach by simply choosing equal weights to all assets you are considering. This is often called the naive portfolio. How well would you perform compared to the alternative of choosing the optimal portfolio or to a benchmark of your preference?

Moreover, suppose that you invested $200 on January 1, 2010, in assets 1 and 2 at a 50% share, that is, $100 in each. Now suppose that, after one year, asset 1 grew about 10% and asset 2 about 50%. In other words, on January 1, 2011, you have $260 ($110 + $150), which means that now assets 1 and 2 weight 42% and 58%, respectively. You may think that now your portfolio is too concentrated in asset 2 and decide to sell part of your asset 2 to buy more of asset 1 and restore the 50% share for each, that is now you have $130 allocated in each asset. This is called **rebalancing**. Rebalancing can be done in whatever periodicity you like: daily, monthly, quarterly, yearly, and it's usually done for balancing risk and return from times to times. However, how well would you perform by doing such rebalancing instead of letting the ups and downs in the assets lead the weights in your portfolio? We thought about these questions to provide answers in the Crypto Diversifier app. Again, we select our seven assets in the backtest page for illustration. By including together with the optimal and minimum variance portfolios, a naive portfolio with weights 1/7 for each asset, and also allowing for annual rebalancing, we can check which strategy worked best. Results are presented in Figure 6

Figure 6: Portfolio Analysis Example - Backtesting



As you can see, the Naive portfolio would have delivered the highest cumulated rate of return in that period. The second highest portfolio return would be that from the Tangency Portfolio with rebalancing, followed by the Naive Portfolio without Rebalancing, the Tangency Portfolio without rebalancing, the Minimum Variance Portfolio with Rebalancing, the Minimum Variance Portfolio without Rebalancing and Ibovespa. Note that in this case, rebalancing provides higher returns for all portfolios. To summarize that information, the bottom part of the page shows some summary statistics for each of the portfolios. These are displayed in Figure 7

Figure 7: Portfolio Analysis Example - Backtesting

Name	Avg. Ret.	SD	Sharpe Ratio	Median Ret.	Lower Tail (<1%)	Upper Tail (>99%)
Ibovespa	-0.7827	3.1523	-0.2483	0.0001	-0.0741	0.0583
Minimum Variance with Rebalancing	-0.9886	9.4009	-0.1052	0.0006	-0.0187	0.0181
Minimum Variance without Rebalancing	-0.6663	2.4238	-0.2749	0.0007	-0.0183	0.018
Naive Portfolio with Rebalancing	192.5023	10.8772	17.6978	0.003	-1.819	1.8923
Naive Portfolio without Rebalancing	3.179	12.3664	0.2571	-0.0001	-2.2704	2.4391
Tangency Portfolio with Rebalancing	86.5443	5.236	16.5288	0.0015	-0.7686	0.8489
Tangency Portfolio without Rebalancing	-0.986	14.5315	-0.0679	-0.0004	-2.1871	1.8162

3 Limitations

There are several limitations to the app that worth discussing. Among them, we highlight:

- *Limited number of assets and asset classes*: for the sake of conciseness, we chose a limited number of assets and asset classes to include in the app. For example, we do not provide a proxy for corporate bonds, real estate, or private equity/venture capital investments. Focusing on multi-country analyses comes with the cost of diminishing the number of available asset classes.[2]

- *Expected returns as a function of past performances*: in the Portfolio Optimization feature, we use past returns as a proxy for future returns. As one should note, future outcomes may differ significantly from past returns. Therefore, the user should take such limitation in mind when analyzing any result from the optimization procedure.

- *The standard Markowitz model of portfolio selection is just one out of many other possibilities*: the Markowitz model for portfolio selection is still widely used and has many virtues. However, it also has its shortcomings: for example, it assumes that stock returns follow a normal distribution, which is frequently not corroborated by the data. More sophisticated models add higher-order moments like skewness (third moment) and kurtosis (fourth moment) in the return characteristics. Similarly, other optimization models could be considered, such as the Black-Litterman (BL) Model. Finally, we build on the standard covariance matrix to estimate the relative riskiness of an asset. There is an extensive literature testing more sophisticated techniques to measure the risk structure among assets, including dynamic covariance specifications.

[2]In fact, it is a strategical decision we took based on two factors. The first one is conciseness concerns and trying to keep things as simple as possible. The second one is that we do not have institutional knowledge necessary to provide other investment classes (e.g., real estate) for a large sample of countries.

4 Concluding remarks

In short, the Crypto Diversifier App shows statistical information, data visualizing features, and the optimal asset allocation following the classical mean-variance framework. By putting ten of the most liquid cryptocurrencies into the universe of the traditional assets, the app allows users to assess how they behave, how they co-move, and how portfolios may benefit (or not) from including cryptocurrencies.

As a final and vital remark, the app does not constitute, under whichever circumstance, any investment recommendation or advice of our part. It is the user's responsibility to use the information provided in the Crypto Diversifier cautiously, as one out of multiple factors involving real-world investment decisions. That said, the app works as a guide that hopefully will help users to understand the behavior of cryptocurrencies and its potential role in asset allocation.