BT2201 Finance Project

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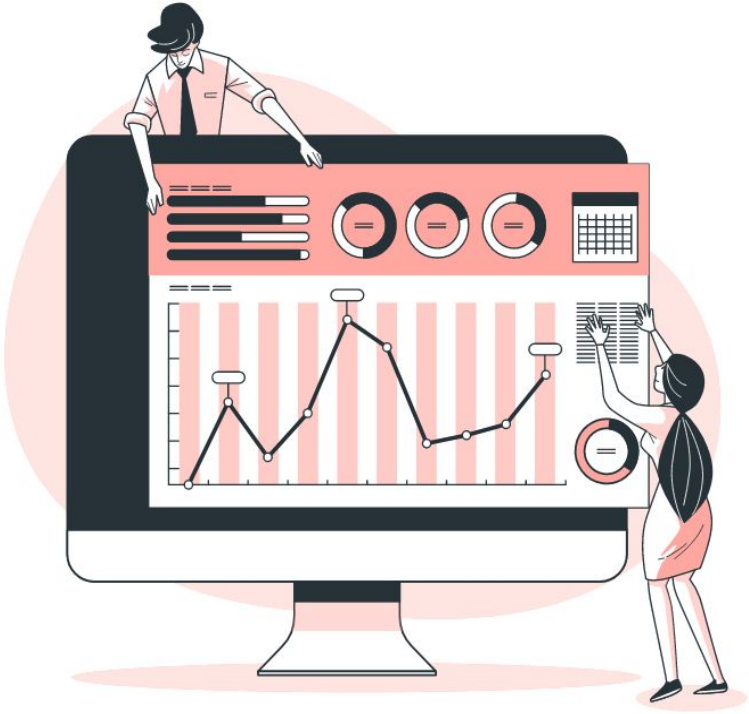

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ETF Details

Considerations: Expense Ratio, Coverage, Holdings

ETF	Benchmark	Expense Ratio/%	Sector	Region	Major Holdings
AGG US	Bloomberg US Aggregate	0.03	Bond	US	BlackRock Funds, US Treasury Notes
SCHP	Bloomberg US Treasury Inflation Protected Notes (TIPS)	0.05	Bond	US	US Treasury Notes
VCSH	Bloomberg US Corporate	0.04	Corporate Bonds	Global Developed Markets	US Dollar, Boeing Company, Apple Inc., Bank of America Corporation
BNDX	Bloomberg Global Aggregate x USD Float Adjusted RIC Capped	0.07	Bond	Global	Japan, France, Germany, Italy government bonds
VWOB	Bloomberg USD Emerging Markets Govt. RIC Capped Bond	0.20	Bond	Global Emerging markets	Qatar, Saudi Arabia, Indonesia
1306 JT	Topix Gross Total Return Index	0.04	Mid/Small Cap	Japan	Toyota Motor Corp, Sony Corp, Softbank Group Corp

Considerations: Expense Ratio, Coverage, Holdings

ETF	Benchmark	Expense Ratio/%	Sector	Region	Major Holdings
VOO US	S&P 500	0.03%	Large Cap	US	APPL, MSFT, AMZN, TSLA
VO US	CRSP US Mid Cap	0.04	Mid- Cap	US	Palo Alto Networks, Pioneer Natural Resources Company
VSS	FTSE Global ex Small Cap Net Tax(US RIC) Index	0.07	Large/Mid-Cap/ Small	Global	US Dollar, Vanguard Cash Management, First Quantum Minerals
VGK	FTSE Developed Europe All Cap Net Tax(US RIC) Index	0.08	Large-Cap	Europe	Nestle SA, Roche Holding AG, Novartis AG
VWO	FTSE Custom Emerging Markets All Cap China A Inclusion Net Tax (US RIC)	0.08	Large-Cap	Global Emerging Markets	Taiwan SemiConductor, Tencent Holdings, Alibaba
1343 JT	TSE REIT Index	0.12	REITS	Japan	Nippon Building Fund, Japan REIT Group, Japan Metropolitan Fund Inv.

Considerations: Expense Ratio, Coverage, Holdings

ETF	Benchmark	Expense Ratio/%	Sector	Region	Major Holdings
VNQ US	MSCI US Investable Market Real Estate 25/50	0.12	REIT	US	Vanguard Real Estate II Index Fund, Prologis Inc, American Tower Corporation
VNQI US	S&P Global ex-US Property Index	0.12	Large/Mid-Cap REITS	Global	Vonovia SE, Goodman Group, Mitsui Fudosan Co. , Mitsubishi Estate Company
IAU US	LBMA Gold Price PM	0.25	Commodity	-	Gold
BCI	Aberdeen Bloomberg All Commodity ETF	0.25	Commodity	Global	Gold FUTR, Crude Future, Natural Gas Future, Corn Future

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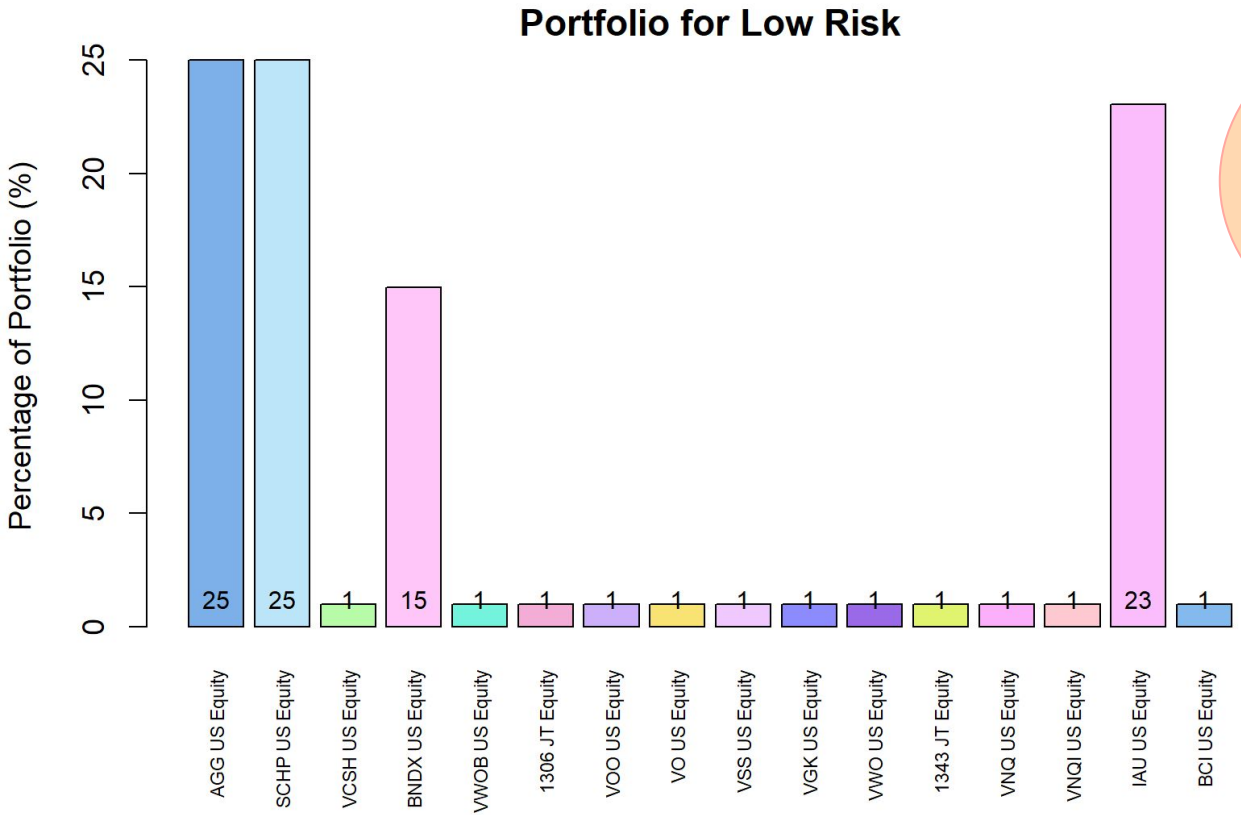
Overview of Portfolios

Low Risk

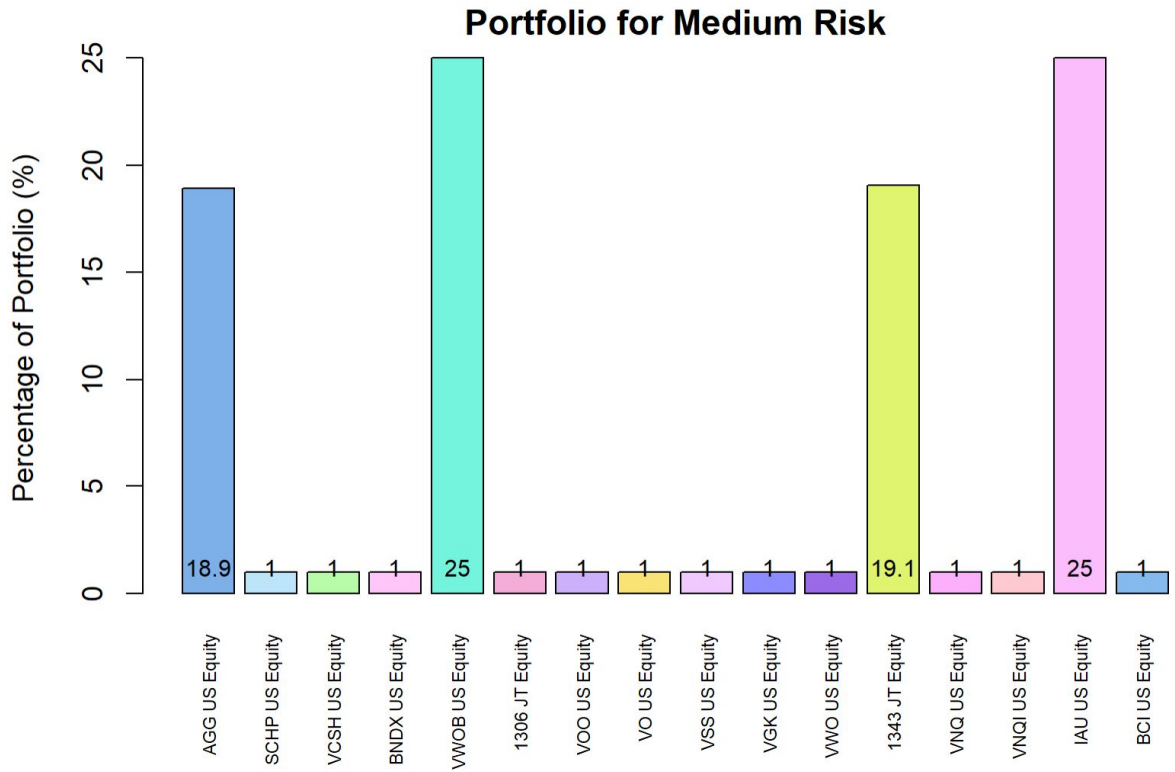


Bonds: 67%
Equities: 9%
Gold & Commodities: 24%

Low Risk Portfolio

Annual expected returns	Volatility	Sharpe Ratio
5.75%	0.105	0.535

Medium Risk

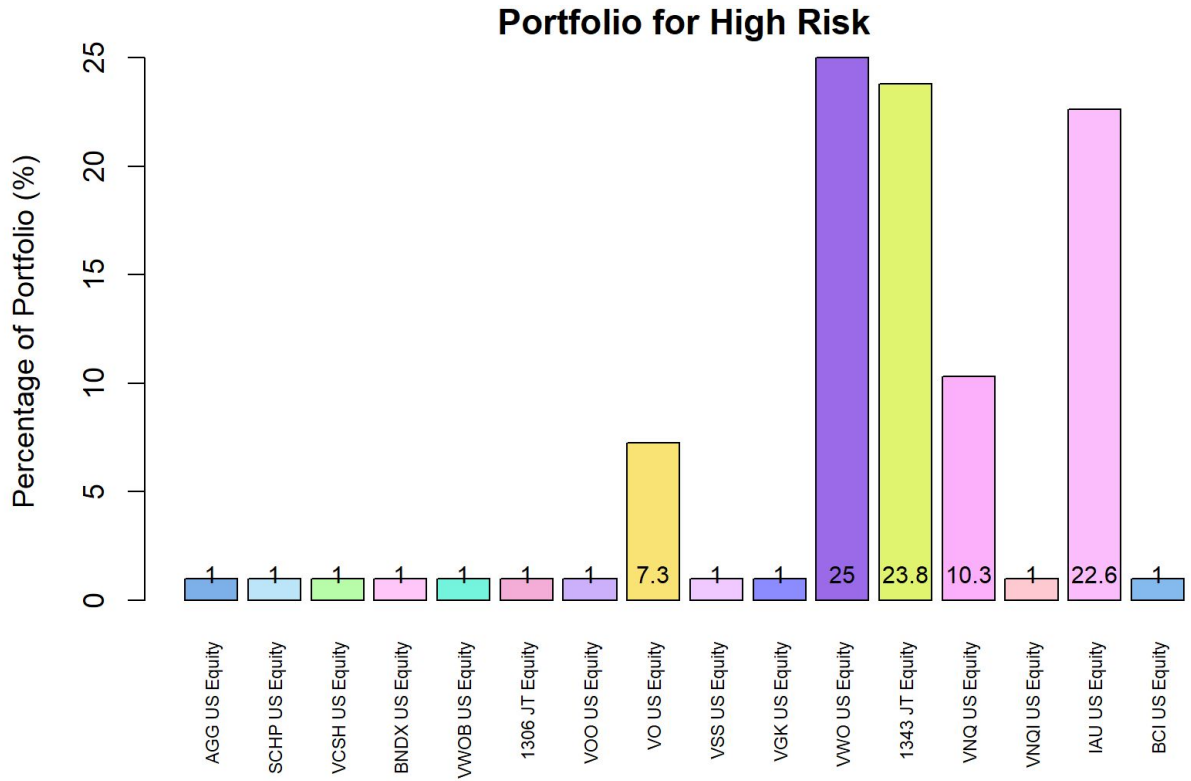


Bonds: 46.9%
Equities: 27.1%
Gold & Commodities: 26%

Medium Risk Portfolio

Annual expected returns	Volatility	Sharpe Ratio
8.08%	0.129	0.613

High Risk



Bonds: 5%
Equities: 71.4%
Gold & Commodities: 23.6%

High Risk Portfolio

Annual expected returns	Volatility	Sharpe Ratio
11.0%	0.193	0.562

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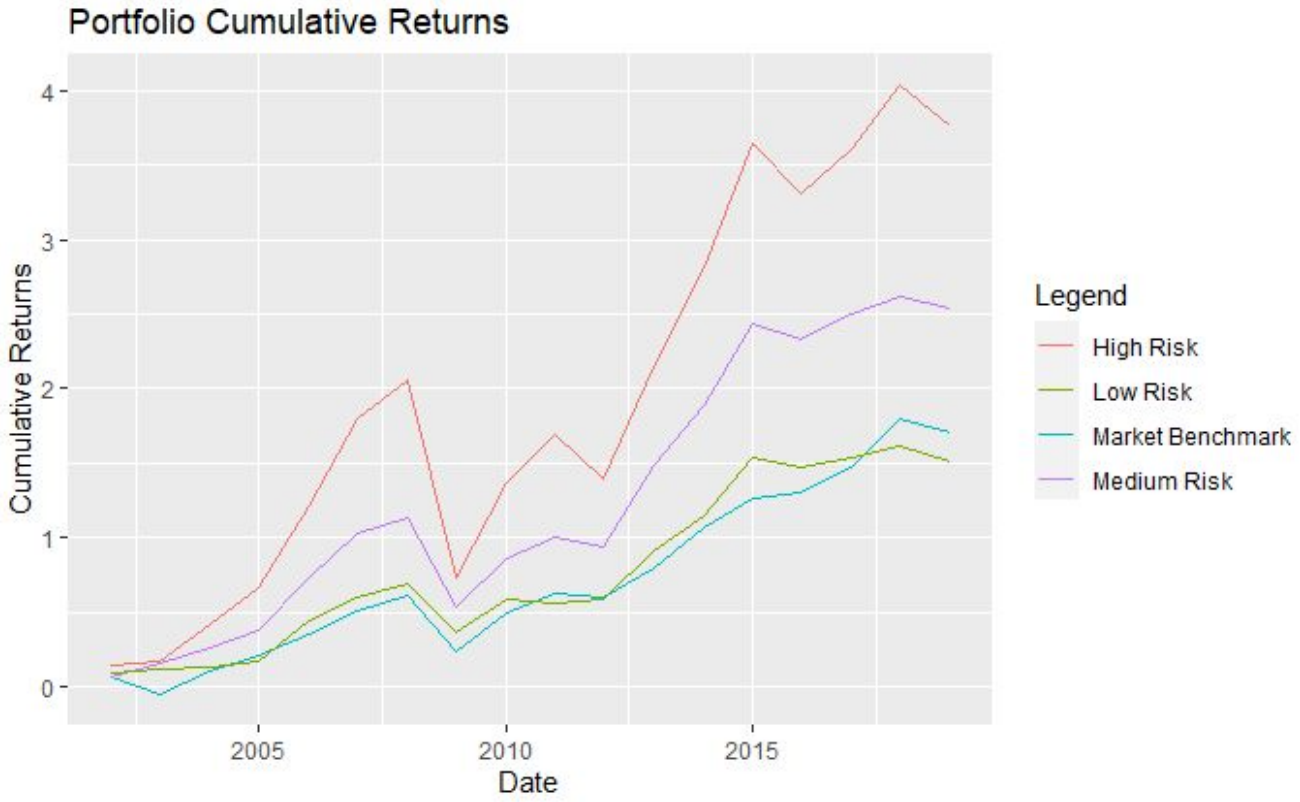
Performance against market

Market Performance

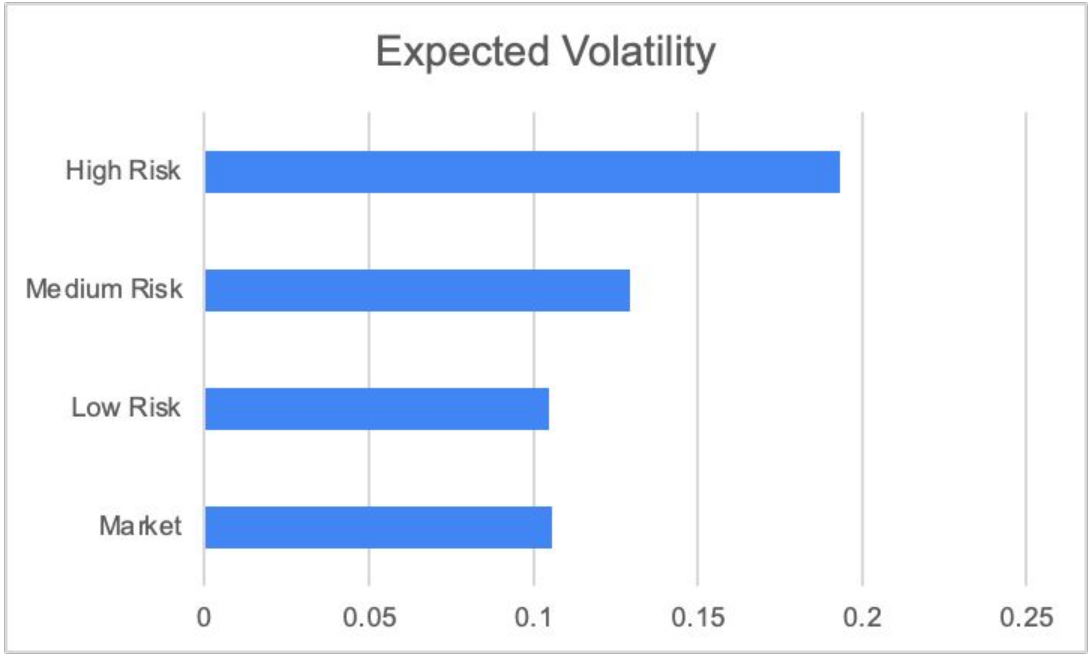
Annual expected returns	Volatility	Sharpe Ratio
6.23%	0.106	0.576

Benchmark against market portfolio



Comparing returns

Comparing volatility



Low Risk Portfolio Beta

```
Call:
lm(formula = minvarreturns ~ testfull$mkt)

Residuals:
      Min        1Q    Median        3Q       Max
-0.119500 -0.049629 -0.000753  0.026188  0.143857

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)   0.01368    0.02096   0.653 0.523298
testfull$mkt  0.70426    0.17471   4.031 0.000967 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.07601 on 16 degrees of freedom
Multiple R-squared:  0.5039,    Adjusted R-squared:  0.4728
F-statistic: 16.25 on 1 and 16 DF,  p-value: 0.000967
```

High Risk Portfolio Beta

```
Call:
lm(formula = maxreturnreturns ~ testfull$mkt)

Residuals:
     Min       1Q   Median       3Q      Max
-0.13054 -0.06385 -0.01047  0.05356  0.19994

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.008447   0.024979   0.338     0.74
testfull$mkt 1.631314   0.208228   7.834 7.27e-07 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.09059 on 16 degrees of freedom
Multiple R-squared:  0.7932,    Adjusted R-squared:  0.7803
F-statistic: 61.38 on 1 and 16 DF,  p-value: 7.268e-07
```

Medium Risk Portfolio Beta

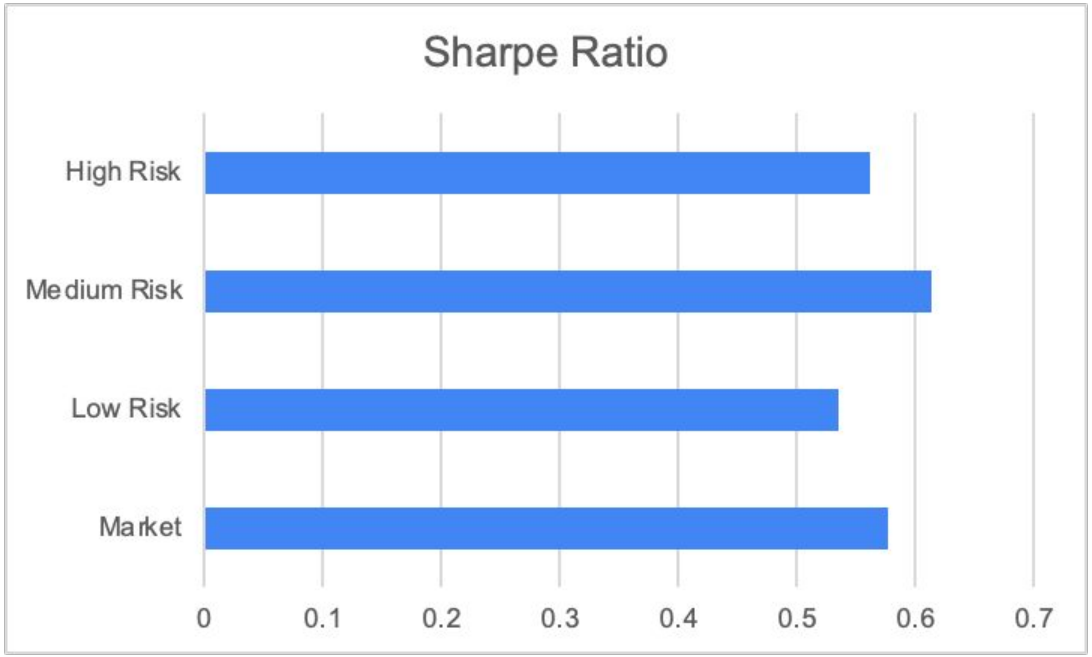
```
Call:
lm(formula = tangencyreturns ~ testfull$mkt)

Residuals:
     Min       1Q   Median       3Q      Max
-0.11401 -0.04355 -0.01559  0.03040  0.16617

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)   0.02053    0.02261   0.908    0.377
testfull$mkt  0.96806    0.18847   5.136 9.95e-05 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.082 on 16 degrees of freedom
Multiple R-squared:  0.6225,    Adjusted R-squared:  0.5989
F-statistic: 26.38 on 1 and 16 DF,  p-value: 9.95e-05
```

Comparing Sharpe Ratios



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Appendix

Portfolio Construction Process

- Data cleaning and manipulation
  - To account for the exchange rate JPYUSD changes, taking into consideration that there are US ETFs in the portfolio, we mutated the daily returns of each US ETF through the equation:

    Currency Accounted returns = (1+daily returns)*(1+JPYUSD returns) - 1

  - To manipulate our data for portfolio optimisation in R, we then converted our returns into an time series object, which then allowed us to find the yearly geometric returns for each ETF in the portfolio.

Portfolio Construction Process

	mkt	rf	AGG US Equity	SCHP US Equity
2001-12-31	0.06649724	0.0001463167	0.101706546	0.08935238
2002-12-31	-0.11215371	0.0005551092	-0.005226801	0.05171745
2003-12-31	0.16839124	0.0004120871	-0.061233960	-0.02156482
2004-12-31	0.09251594	0.0003751140	-0.006588657	0.03815481
2005-12-30	0.12074471	0.0004121510	0.173296013	0.17990141
2006-12-29	0.11611596	0.0021551581	0.050515771	0.01529592

	VCSH US Equity	BNDX US Equity	VWOB US Equity	1306 JT Equity
2001-12-31	0.19959965	0.10717871	0.14101733	0.01176471
2002-12-31	-0.05108981	-0.03598708	0.02820919	-0.17829457
2003-12-31	-0.11686321	-0.07552222	0.13680720	0.25613208
2004-12-31	-0.00628774	0.00752676	0.07004455	0.10918137
2005-12-30	0.35373079	0.20949474	0.27083002	0.45315277
2006-12-29	0.02659136	0.04341680	0.11486169	0.03127730

	VOO US Equity	VO US Equity	VSS US Equity	VGK US Equity
2001-12-31	0.2188594	0.2992020	0.1800537	0.2047633
2002-12-31	-0.2971264	-0.2286476	-0.1603647	-0.2736456
2003-12-31	0.1613335	0.2239772	0.4681771	0.2214153
2004-12-31	0.0612918	0.1493192	0.2445964	0.1279667
2005-12-30	0.2036238	0.3075809	0.4433798	0.2532602
2006-12-29	0.1706475	0.1519765	0.2124201	0.3454118

	VWO US Equity	1343 JT Equity	VNQ US Equity	VNQI US Equity
2001-12-31	0.3974656	-0.0748600	0.15557763	0.14672958
2002-12-31	-0.1513569	0.2739261	-0.06486847	-0.08918043
2003-12-31	0.4064956	0.1637695	0.23425166	0.31111881
2004-12-31	0.2061741	0.3197815	0.25572406	0.33428380
2005-12-30	0.5231878	0.1208753	0.28431062	0.34327039
2006-12-29	0.3080363	0.2899283	0.36802756	0.46793148

Portfolio Construction Process

- Portfolio construction and optimisation
  - We ran individual regression to obtain individual β_{OLS} of each ETF and find the respective μ_{CAPM} and total risk.
  - By having our μ_{CAPM} and total risk we are then able to obtain our weights for the portfolio.

$$w*=f(\mu,\Sigma)$$

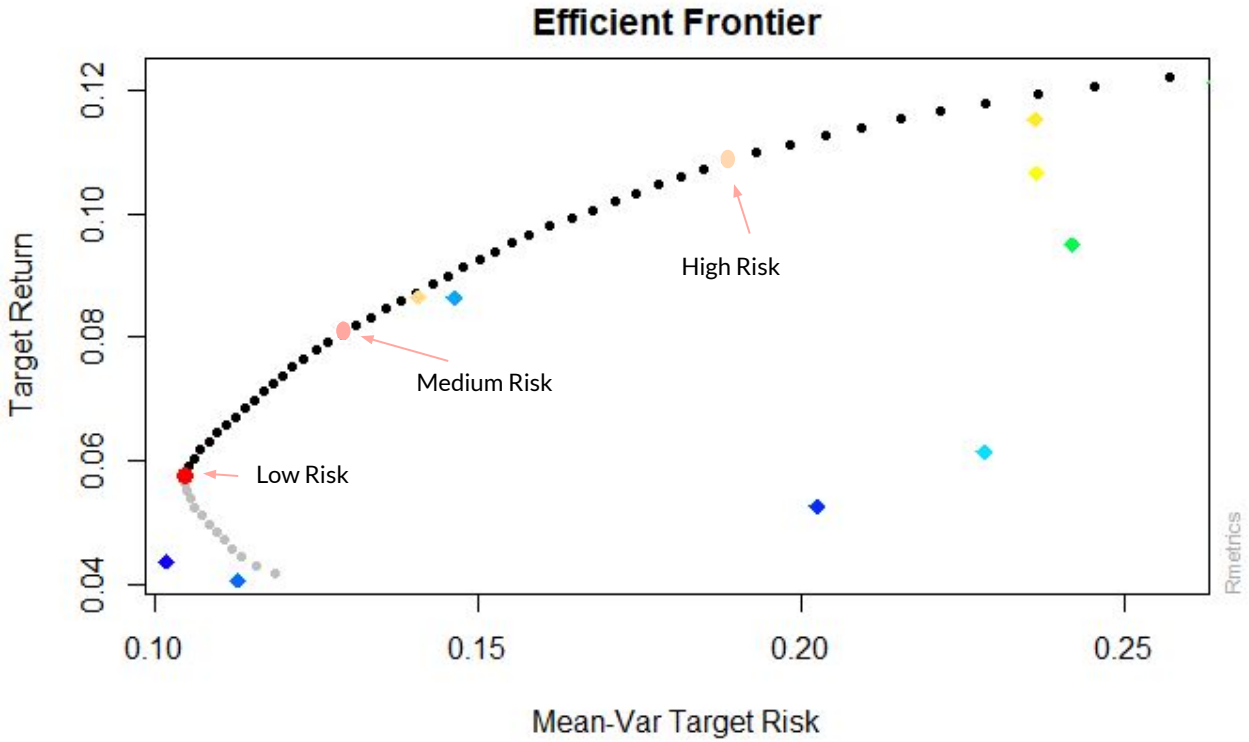
  - From the equation, we can use the covariance matrix and the μ_{CAPM} to find the weights of our portfolio. However, inspecting the covariance matrix led us to find that some of the ETF returns are highly correlated to each other, making determinant of the matrix to be equal to 0, thus making it non invertible. This prevents us from finding reasonable weights using $w*=f(\mu,\Sigma)$. Thus, we added constraints to include all the ETFs provided.
  - This was done through the use of the R packages PerformanceAnalytics and fPortfolio.

Portfolio Construction Process

- Portfolio construction and optimisation
  - To form our 3 portfolios, we sought for points along the efficient frontier.
  - These are the points which gave the minimum variance portfolio, the tangency portfolio and the maximum returns portfolio.
  - In order to maximise diversification, we have set minimum weights for each ETF in the portfolio to be 1%.
  - Diversification is done to minimise idiosyncratic risk.
  - Ideally, the portfolio constructed should only be left with its systematic risk.
  - Hence, the investor will be compensated with higher return for every unit of risk taken on.

Portfolio Construction Process

Efficient Frontier



Portfolio Construction Process

Min Variance Portfolio

```
Title:
 MV Minimum Variance Portfolio
 Estimator:         covEstimator
 Solver:            solveRquadprog
 Optimize:          minRisk
 Constraints:       minW maxW

Portfolio Weights:
 AGG US Equity SCHP US Equity VCSH US Equity BNDX US Equity
        0.2500         0.1674         0.0100         0.2126
VWOB US Equity 1306 JT Equity  VOO US Equity   VO US Equity
        0.0100         0.0100         0.0100         0.0100
 VSS US Equity  VGK US Equity  VWO US Equity 1343 JT Equity
        0.0100         0.0100         0.0100         0.0100
 VNQ US Equity VNQI US Equity  IAU US Equity  BCI US Equity
        0.0100         0.0100         0.2500         0.0100

Covariance Risk Budgets:
 AGG US Equity SCHP US Equity VCSH US Equity BNDX US Equity
        0.2020         0.1553         0.0179         0.1973
VWOB US Equity 1306 JT Equity  VOO US Equity   VO US Equity
        0.0129         0.0146         0.0189         0.0209
 VSS US Equity  VGK US Equity  VWO US Equity 1343 JT Equity
        0.0211         0.0201         0.0237         0.0132
 VNQ US Equity VNQI US Equity  IAU US Equity  BCI US Equity
        0.0195         0.0225         0.2257         0.0143

Target Returns and Risks:
  mean    Cov   CVaR    VaR
0.0620 0.0964 0.1777 0.0365
```

Portfolio Construction Process

Tangency Portfolio

```
Title:
 MV Tangency Portfolio
 Estimator:         covEstimator
 Solver:            solveRquadprog
 Optimize:          minRisk
 Constraints:       minW maxW

Portfolio Weights:
 AGG US Equity SCHP US Equity VCSH US Equity BNDX US Equity
        0.0671         0.2500         0.0100         0.0100
VWOB US Equity 1306 JT Equity  VOO US Equity   VO US Equity
        0.1622         0.0100         0.0100         0.0572
 VSS US Equity  VGK US Equity  VWO US Equity 1343 JT Equity
        0.0100         0.0100         0.0100         0.1135
 VNQ US Equity VNQI US Equity  IAU US Equity  BCI US Equity
        0.0100         0.0100         0.2500         0.0100

Covariance Risk Budgets:
 AGG US Equity SCHP US Equity VCSH US Equity BNDX US Equity
        0.0395         0.1803         0.0133         0.0068
VWOB US Equity 1306 JT Equity  VOO US Equity   VO US Equity
        0.1779         0.0125         0.0159         0.1029
 VSS US Equity  VGK US Equity  VWO US Equity 1343 JT Equity
        0.0195         0.0176         0.0211         0.1542
 VNQ US Equity VNQI US Equity  IAU US Equity  BCI US Equity
        0.0174         0.0206         0.1880         0.0127

Target Returns and Risks:
  mean    Cov   CVaR    VaR
0.0796 0.1173 0.2544 0.0382
```

Portfolio Construction Process

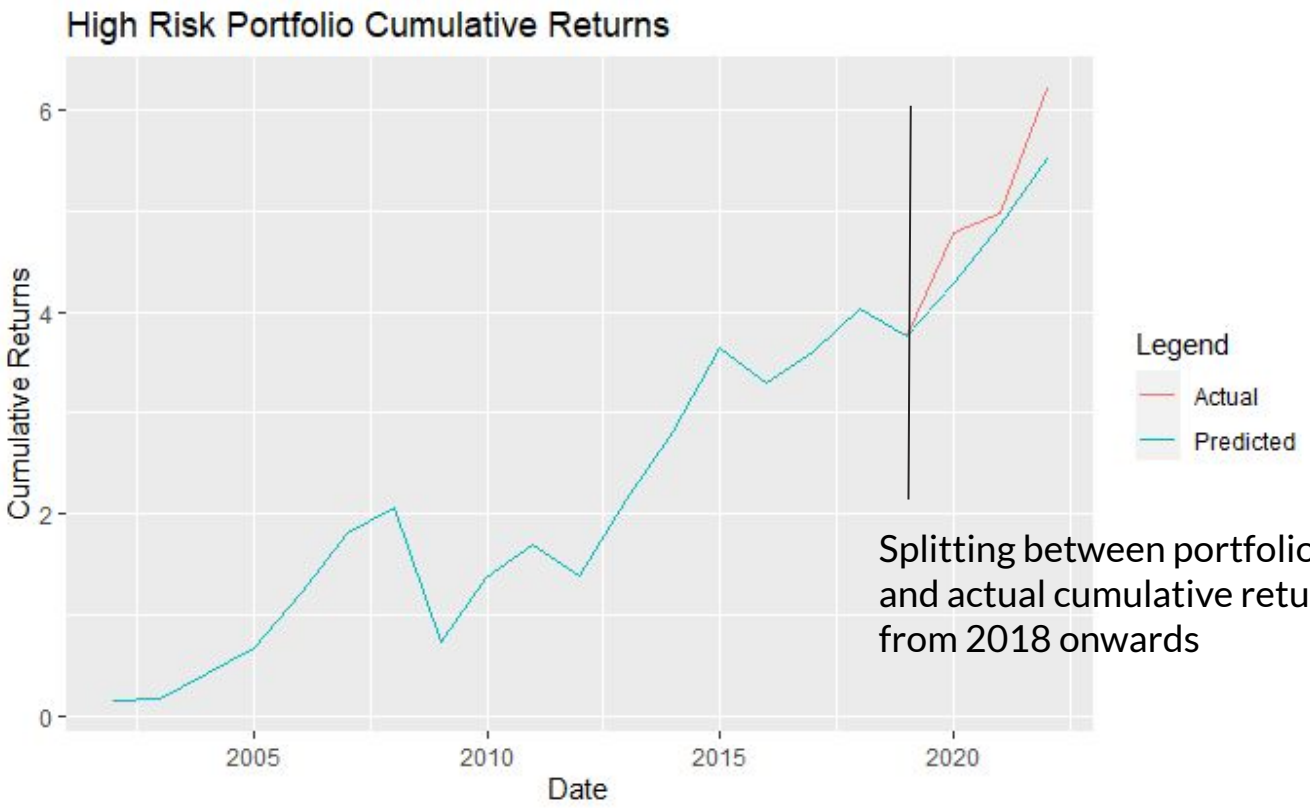
Max Returns Portfolio

```
Title:
 MV Return Maximized Efficient Portfolio
 Estimator:         covEstimator
 Solver:            solveRquadprog
 Optimize:          minRisk
 Constraints:       minW maxW

Portfolio Weights:
 AGG US Equity SCHP US Equity VCSH US Equity BNDX US Equity
        0.0100         0.0100         0.0100         0.0100
VWOB US Equity 1306 JT Equity  VOO US Equity   VO US Equity
        0.0410         0.0100         0.0100         0.2500
 VSS US Equity  VGK US Equity  VWO US Equity 1343 JT Equity
        0.0100         0.0100         0.0365         0.1195
 VNQ US Equity VNQI US Equity  IAU US Equity  BCI US Equity
        0.2029         0.0100         0.2500         0.0100

Covariance Risk Budgets:
 AGG US Equity SCHP US Equity VCSH US Equity BNDX US Equity
        0.0038         0.0045         0.0087         0.0044
VWOB US Equity 1306 JT Equity  VOO US Equity   VO US Equity
        0.0298         0.0094         0.0121         0.3385
 VSS US Equity  VGK US Equity  VWO US Equity 1343 JT Equity
        0.0143         0.0130         0.0529         0.1166
 VNQ US Equity VNQI US Equity  IAU US Equity  BCI US Equity
        0.2648         0.0145         0.1042         0.0084

Target Returns and Risks:
  mean    Cov   CVaR    VaR
0.1100 0.1710 0.3690 0.0631
```

Portfolio Construction Process

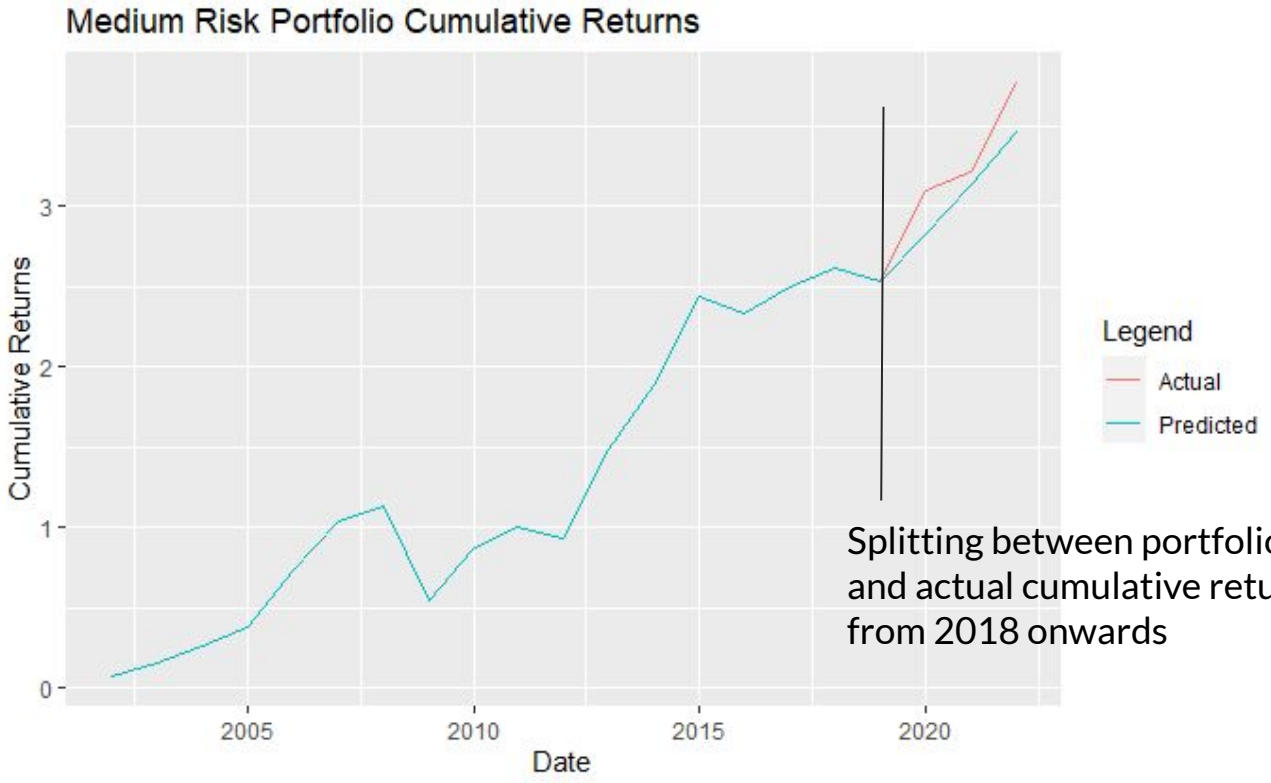
- Portfolio backtesting
  - For our data we have split it into T1 (from 2001 - 2018) and T2 (from 2018 - 2021). Using our portfolio weights we ran it with our in-sample data T1.
  - Thereafter, using the expected returns as of 2018, we forecasted it for the next three years (2018 - 2021) to obtain predicted cumulative returns.
  - By running our weights against the out-of-sample data T2, we would then obtain the actual cumulative returns from 2018 - 2021.
  - Hence, by comparing the cumulative returns from the actual and the predicted, we are able to determine the performance of our portfolio models.
  - Judging from the performance of our portfolio models, we would then rebalance our portfolios against the in-sample data T1 and repeat the backtesting process.

Backtesting of High Risk Portfolio



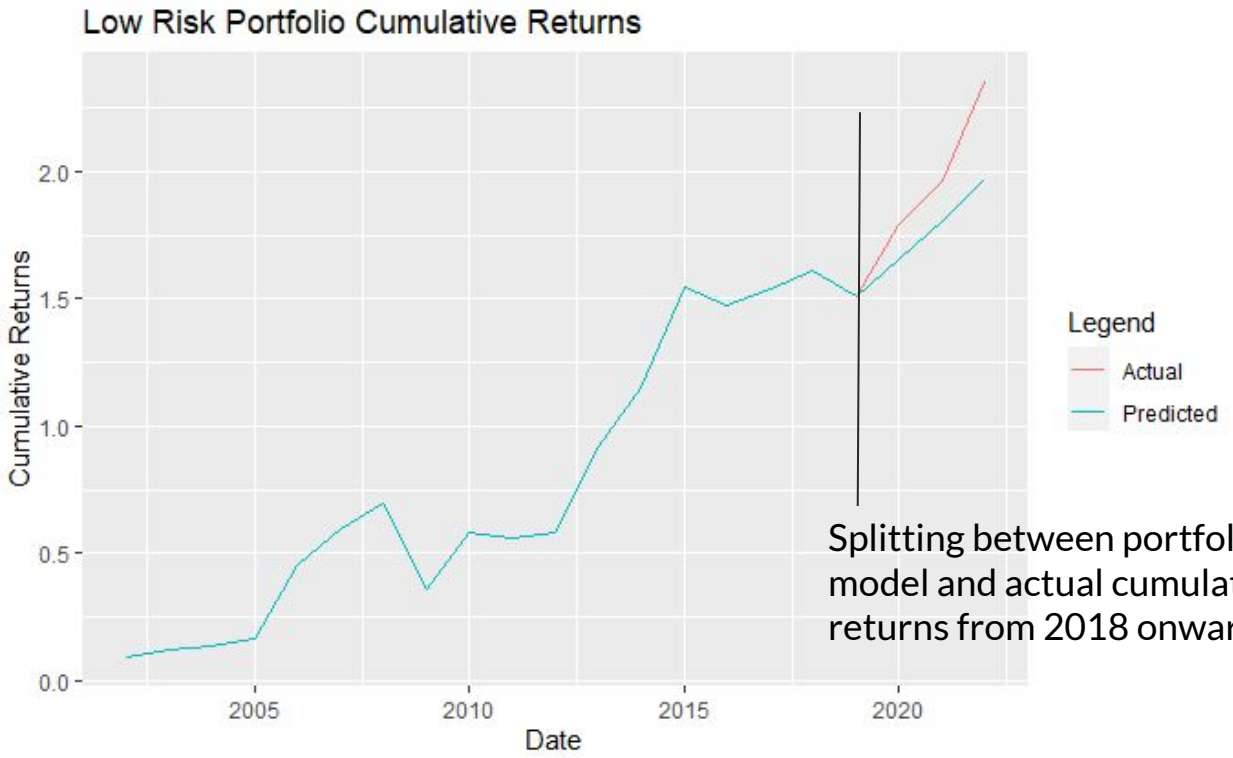
Splitting between portfolio model and actual cumulative returns from 2018 onwards

Backtesting of Medium Risk Portfolio



Splitting between portfolio model and actual cumulative returns from 2018 onwards

Backtesting of Low Risk Portfolio



Splitting between portfolio model and actual cumulative returns from 2018 onwards

Thank you