Comparing Efficient Portfolios of Australian Shares Using Different Risk Measures

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Abstract

It is a fundamental economical concept that to achieve higher investment returns, greater risk must be taken on. It is desirable to achieve a target return while taking on the minimum amount of risk. Utilising portfolio theory it is possible to construct investment portfolios which aim to meet a specified return and have minimal risk. This research determined that investment portfolios constructed by optimising five different risk measures does not result in achieving target wealth; and the risk profile significantly increases. This analysis was conducted over 10 years of returns data for the largest 50 stocks listed on the ASX by market capitalisation as of January 1st, 2022. Research holds random walk theory to hold true, wherein stock returns are independent, thus the dataset was created by randomly sampling from the 10-year observed period to construct a training and testing dataset.

1 Introduction

This research is an application of modern portfolio theory, specifically an extension from mean-variance portfolio theory. Portfolio theory is a method by which to allocate funds for an investment portfolio to minimise risk (Markowitz 1952). Modern portfolio theory defines risk to be variance of investment returns (Loss Reserving and Financial Engineering 2021). This approach is mathematically sound, though has an inherent flaw; penalising a portfolio for variable high returns equally to variable low returns is not reflective of the risk characteristics of the portfolio. More recent approaches to portfolio theory consider many risk measures, each with limitations. By conducting a more thorough analysis of the risk profile of an investment portfolio, investors should have a better understanding of the risks involved with any portfolio and by using multiple risk measures are able to decrease the limitations associated with any one individual risk measure.

It is of interest to determine if investment portfolios constructed to minimise a specific risk, will maintain their risk profile as well as achieve a target wealth. The five risk measures concerned in this report are variance (var), semi-variance (semi-var), value at risk (VaR), tail value at risk (TailVaR) and portfolio beta (β). This research will construct 15 investment portfolios comprised of the largest 50 stocks listed on the Australian Securities Exchange (ASX) by market capitalisation as of January 1st, 2022. Positions in these stocks will be both long and short. The 15 portfolios will be constructed by optimising the five different risk measures and targeting three different wealth values. These portfolios will be applied to a testing dataset to determine the robustness of each risk measure under the three target wealths.

The target wealth values were based upon the average dividend yield for Australian stocks over the observed period (2012-2021). Initially the Australian equity risk premium was to be used, but exploratory analysis of the returns data found that the capital return of most stocks was lower than the risk-free rate, thus the equity risk premium was an unrealistic benchmark for the stocks. The risk-free rate used in this research was the monthly yields on 10-year zero-coupon Australian bonds (RBA 2021). The stock returns were less than the risk-free rate due to the exclusion of dividends in stock prices used to determine returns. This is reflective of the bias towards paying dividends due to differing tax treatments for capital gains and dividends in Australia (RBA 2016)

1.1 Research Questions

- What proportions of stocks are in each of the 15 portfolios and what major differences exist across risk measures and target wealths?
- Do the risk measures exhibit robustness? This will be measured upon three criteria:
    - Do the portfolios meet the required return?
    - Do the portfolios maintain their same level of risk?
    - Do the portfolios maintain their relative risk rank, for their optimised risk measure?

1.2 Statement of Authorship

Zachary Tindale proposed the research and carried out all research tasks under direction by Mark Hayes, the academic supervisor. These tasks included, but were not limited to data cleaning, computation of investment portfolios and their associated risk values and analysis of computed values.

2 Research

2.1 Data Gathering and Cleaning

The stocks to be included in this research were the largest 50 stocks by market capitalisation as of January 1st, 2022. The analysis also required 10 years of monthly returns data. The dataset fitting this requirement was sourced from DatAnalysis premium, Morningstar (Morningstar DatAnalyis Premium 2022). Using Morningstar's stock analysis tool DatAnalysis Premium, monthly *adjusted closing share prices* were recorded in excel. Adjusted share prices are changed for dividends and stock splits, which skew the price of a share, thus analysis over a 10-year-period requires use of adjusted share prices (Morningstar DatAnalyis Premium 2022).

The adjusted closing share prices were converted into forces of interest using the formula:

$$Force\ of\ Interest = \ln\left(\frac{S_t}{S_{t-1}}\right)$$

(Where S_t is the price of a stock at time t and S_{t-1} is the price of a stock at time t-1)

The corresponding risk-free rate was subtracted from each force of interest value. This converts all return values into risk premiums. Risk premium values were then converted to wealths using the formula:

$$Wealth = \exp\left(\mathrm{F}_S - \mathrm{F}_{rf}\right) = \exp(\text{Risk Premium})$$

(Where F_S is a stock's force of interest and F_{rf} is the force of interest of the risk-free asset)

In total there were 120 months of wealth values for each stock. Portfolios will be constructed using the risk premium wealth values. Risk premia are focused upon as this research applies the *Capital Asset Pricing Model (CAPM)*. CAPM is an extension of mean-variance portfolio theory, which enables comparison of assets with the market.

2.2 Manipulation of the Data into Training-Testing Sets

An assumption of this research is that stock returns follow a random walk, thus each period of returns is independent. Utilising this assumption, the monthly risk premiums for each stock were independently selected by generating random numbers using Microsoft Excel's RAND() function alongside the risk premium values, then sorting the randomised numbers from lowest to highest. This would in turn randomise the order of a stock's 120 wealth values. The randomised values were exclusively used to reorder the wealth values to ensure random sampling from the data. From the 120 risk premiums, 72 were sampled without replacement from each stock to produce the training dataset. 72 periods represent 60% of the total data. The remaining 40% (48 periods) of risk premium values for each stock were allocated to the testing dataset. The 60:40 split was chosen to ensure the testing dataset had sufficient data to test the robustness of risk measures.

2.3 Risk Measures Defined

This research considers the robustness of five risk measures and three targeted risk premiums. The five risk measures were variance, semi-variance, value-at-risk, tail-value-at-risk, and portfolio beta. Each risk measure has a different calculation method to derive the associated risk value.

2.3.1 Variance of Portfolio Wealth

The variance of wealth is a means of quantifying the volatility in returns. This is the most widely used risk measure as it is easily calculated and understood by a larger audience (Loss Reserving and Financial Engineering 2021).

$$Variance(W_p) = \sum_{j=1}^{N}\sum_{i=1}^{N} x_i x_j C_{ij}$$

Note that W_p is the wealth of the portfolio, N is the number of stocks (in this case 50), C_{ij} is the covariance between wealth of securities 'i' and 'j' and x_i and x_j represent proportions invested into securities 'i' and 'j' (Loss Reserving and Financial Engineering 2021).

2.3.2 Semi-Variance of Portfolio Wealth

Semi-variance of wealth is a way of understanding the variation in returns which are below the mean.

$$\int_{-\infty}^{\mu} \left(\mu - W_p\right)^2 f(W_p)\, dx$$

μ is the mean portfolio wealth, W_p is portfolio wealth and f(W_p) is the probability function of portfolio wealth (Loss Reserving and Financial Engineering 2021).

2.3.3 Value at Risk

Value at risk represents the maximum potential loss over a given period with a given degree of confidence. This research concerns the 95% confidence amount, thus the shortfall in the lower 5% tail scenario. 5% was used to assess the lower tail wealths, which are not considered by other measures such as variance, semi-variance and portfolio beta.

$$VaR(X) = -t \quad where \quad P(X < t) = p$$

't' represents the loss amount and p (5%) represents the level of confidence (Loss Reserving and Financial Engineering 2021).

Value at risk was determined by finding wealth values for each period and ranking them from smallest to highest. The next step was setting up a cumulative probability column from the smallest to highest value. The value associated at or just below the lowest 5% was subtracted from 1 to get the value at risk.

2.3.4 Tail Value at Risk

Tail value at risk represents the expected loss, given that returns will be worse than a given confidence level.

$$Tail\ VaR = E[\max(L - W, 0)] = \int_{-\infty}^{L} (L - W_p) f(W_p) dx$$

Where L represents a chosen benchmark. For this research the benchmark used was value at risk calculated from 2.3.3 above. The expected shortfall in the lower 5% tail is the tail value at risk value. W_p is portfolio wealth and f(W_p) is the probability function of portfolio wealth (Loss Reserving and Financial Engineering 2021).

Tail value at risk was found using the same method as value at risk, except taking the mean of the wealth values less than or equal to the lowest cumulative 5%.

2.3.5 Portfolio Beta

Portfolio beta is a measure of the risk of the portfolio relative to the market. A risk-free portfolio would have a beta of 0, indicating no risk relative to the market.

$$\beta_p = \frac{Cov(W_p, W_m)}{Var(W_m)}$$

β_p is the portfolio beta, $Cov(W_p, W_m)$ is the covariance between the wealth of the portfolio and the wealth of the market and $Var(W_m)$ is the variance in wealth returned by the market (Investopedia 2021).
Due to the random sampling approach used in data creation, the beta calculation lost much meaning because it requires stock returns to be correlated with the market return. By randomising the selected wealth values into each dataset (training and testing), the beta calculation became meaningless.

2.3.5.1 Market Index

Portfolio beta is a risk measure which is applicable to the dataset as the assumptions follow CAPM, as mentioned in section 2.1. The portfolio beta risk measure requires a market index for calculation. The 'market' used in this research was the S&P/ASX 200 Price Index (XJO index). This is reflective of the changes in wealth for the largest 200 stocks for the observed period. These values were converted into wealth risk premiums and selection was randomised in accordance with the other stock returns. The 50 stocks included in this research are all within the market index (Morningstar DatAnalyis Premium 2022).

2.4 Target Risk Premiums

As mentioned in section 2.1, the capital return of most stocks was lower than the risk-free benchmark over the observed period. The absolute return, including dividend payments is believed to result in an equity risk premium of 4% for a long term (>10 years) investor (RBA 2019). Thus, the target risk premiums used in this research are based upon average dividend yield over the 10-year observed period (RBA 2021). The target risk premium values used are -2.8%, 0% and 2.8% as per annum return values. These returns were converted to wealths using the wealth formula stated in 2.1 (taking the exponential of the return value). These targets as wealths were 0.9724, 1 and 1.0284. The target wealth of 1 is indicative of returning the risk-free rate for every $1 invested, and all wealth values less than 1 fail to achieve the risk-free rate.

By disregarding dividends in stock wealths, it is uncertain how well the dataset reflects true information. Further analysis of dividend yields over the observed period for the 50 stocks would be required to reflect the wealth and risk characteristics of the portfolios more accurately. A dataset inclusive of this information would take more time to construct, which was not possible due to the timeframe of this research project.

2.5 Construction of Initial Portfolios

Utilising Microsoft Excel's solver function, the 15 portfolios were calculated. The solver function minimised the cell which calculated the risk value and held the target return constant by iterating different proportions into the 50 stocks. The proportions were allowed to be positive or negative, indicating a long or short position towards a stock and total proportions summed to 1. It is understood that there are practical issues involved with shorting a stock but given the size and liquidity of the observed stocks this has been ignored, in accordance with the assumptions for mean-variance portfolio theory and CAPM. The optimised risk measure values and stock proportions were recorded for further testing.

2.6 Application of Portfolios on the Testing Dataset

The testing dataset contained the 48 previously unused wealth values for the 50 stocks. The constructed portfolios were applied to this testing dataset to calculate their achieved wealth and risk values. These wealth and risk values will be compared with their initial values to ascertain if the risk measures exhibit robustness.

3 Results

Initial Measure	Optimised Value	Target Wealth	Achieved Wealth	Variance	Semi-Variance	VaR (5%)	TailVaR (5%)	Beta
Variance	**0.00009**	0.9724	0.9856	**0.02089**	0.00081	0.08151	0.88968	-0.13583
Semi-Variance	**0.00036**	0.9724	0.9900	0.00172	**0.00083**	0.10564	0.89013	-0.17896
Value at Risk	**0.04591**	0.9724	0.9895	0.00901	0.00023	**0.04525**	0.95360	-0.14965
Tail Value at Risk	**0.95351**	0.9724	0.9863	0.01444	0.00039	0.06931	**0.92959**	-0.14188
Beta	**0.00000**	0.9724	0.9882	0.00423	0.00183	0.11523	0.88414	**0.10260**
Variance	**0.00010**	1.0000	0.9874	**0.00290**	0.00056	0.07127	0.92780	-0.03563
Semi-Variance	**0.00003**	1.0000	0.9842	0.00382	**0.00110**	0.09117	0.89618	0.07460
Value at Risk	**0.01721**	1.0000	0.9920	0.00181	0.00067	**0.07424**	0.91856	0.25095
Tail Value at Risk	**0.97954**	1.0000	0.9911	0.00121	0.00053	0.06765	**0.92985**	0.22876
Beta	**0.00000**	1.0000	0.9922	0.00121	0.00052	0.06927	0.92106	**0.36284**
Variance	**0.00067**	1.0284	0.9892	**0.06252**	0.00412	0.19346	0.79926	0.06784
Semi-Variance	**0.00083**	1.0284	0.9946	0.01323	**0.00503**	0.20923	0.77400	0.58810
Value at Risk	**0.02634**	1.0284	0.9992	0.02048	0.00523	**0.20439**	0.78193	0.71344
Tail Value at Risk	**0.98591**	1.0284	1.0007	0.01550	0.00536	0.18114	**0.81771**	0.70419
Beta	**0.00000**	1.0284	0.9991	0.01328	0.00429	0.18456	0.80194	**1.02446**

Table 1: Wealth and Risk Values on the 15 Portfolios

Table 1 contains the wealth and risk values achieved by the 15 portfolios on the training and testing dataset. This enables quick comparison between the optimised portfolio's risk values, shown in bold in the second column and the risk values exhibited on the testing dataset, with the corresponding risk measure indicated in blue. Appendix 1 displays the proportions invested into each of the 50 stocks for the 15 portfolios.

3.1 Analysis of Portfolio Proportions

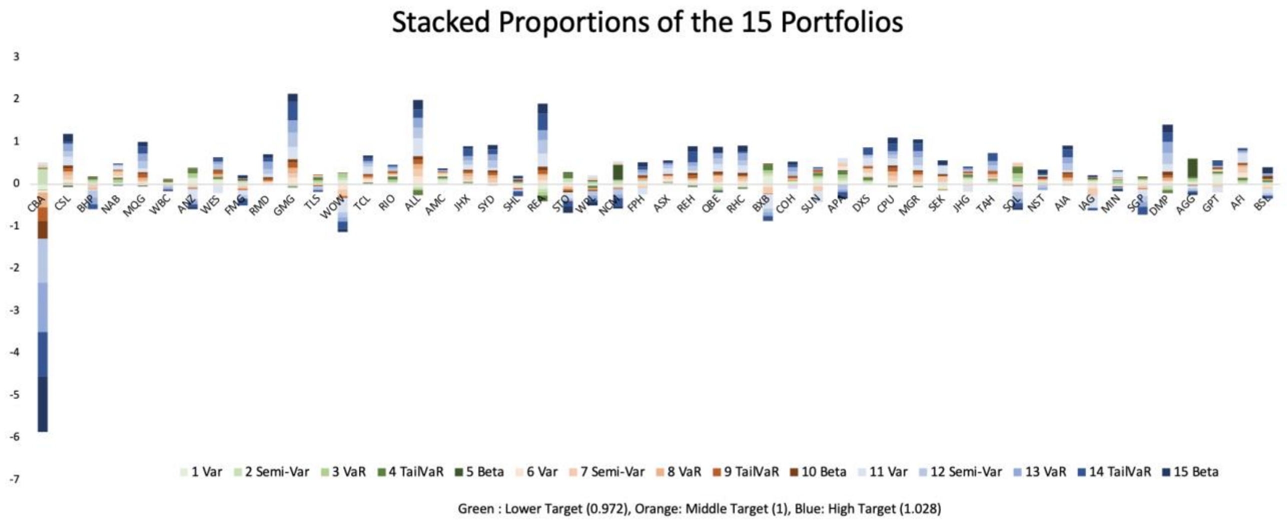

Figure 1: Stock Proportions of the 15 Portfolios

Figure 1 shows the proportions invested into each of the 50 stocks by the 15 portfolios. The target wealths are indicated by different colours, green for the lower target, orange for the middle and blue for the higher target. Values below the x-axis are indicative of short positions and positive values indicate long positions. CBA (Commonwealth Bank of Australia) was the most shorted (by magnitude), followed by WOW (Woolworths) and then BXB (Brambles Lt.). The largest long positions were GMG (Good Man Group), ALL (Aristocrat Leisure) and REI (Ring Energy). These proportions are reflective of the iterative process utilised in calculations to minimise risk measures and not a reflection of market sentiment. By comparing the long and short positions of the three target wealths the middle and higher target portfolios have mostly the same positions (long or short) but in different proportions. These positions are almost always the inverse of the lower target. This is an interesting finding as it indicates a different strategy was utilised to achieve the lower wealth, which from Table 1 can be seen to have a lower risk.

3.1.1 Comparison Between Target Wealths

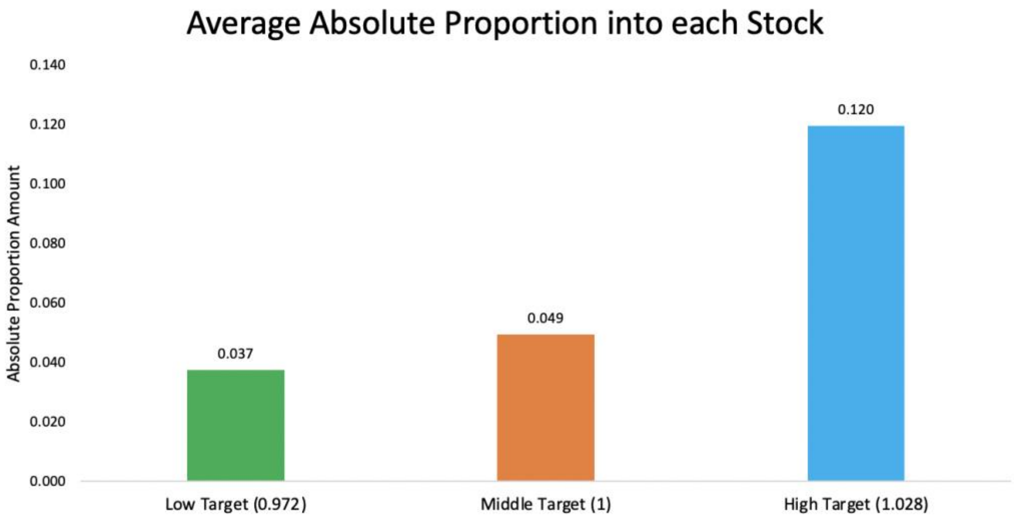

Figure 2: Average Absolute Proportion Allocated to Stocks by Target

As there was more blue in Figure 1 than other colours, it suggests that larger magnitudes of investment in both short and long positions were exhibited in the higher target wealth portfolios. This could suggest that to meet the required return, greater risk was taken through greater exposure to the securities. This indicates economic consistency which is a good result. Figure 2 shows this relationship more clearly. Portfolios exhibit greater exposure to the stocks as the target wealth was increased. The average absolute proportions invested were 0.037, 0.049, 0.120 (3dp) from the lowest target wealth to the highest.

3.1.2 Comparison Between Risk Measures

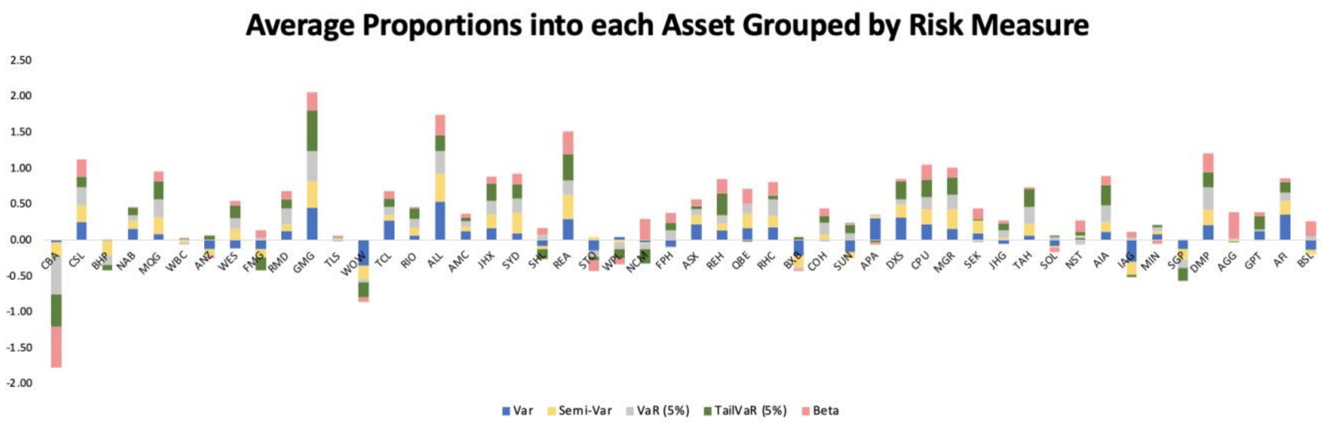

Figure 3: Average Proportion Allocated to Stocks by Risk Measure

Figure 3 displays the average proportions into each stock grouped by risk measure. It shows there are small differences in absolute proportions between the risk measures. This is shown clearly in Appendix 2 'Average Absolute Proportions Grouped by Risk Measure', with the highest average absolute proportion at 0.080 (3dp) and the lowest at 0.057 (3dp). This difference of 0.023 is much smaller than the average absolute proportions compared between target wealths (0.082), shown in Figure 2.

Figure 3 also shows that for 43 stocks, most or all risk measures shared the long or short position, with only 7 stocks displaying a split between long and short positions. This suggests that to minimise the risk measures from the training dataset, the proportion into each asset was the largest difference between the risk measures, rather than alteration of which stocks were long or short.

3.2 Analysis of Robustness of Risk Measures

To assess if the optimised portfolios exhibit robustness on the testing dataset the portfolios characteristics will be assessed. Assessed characteristics include achieved wealth, risk values for the testing dataset and determination of whether the portfolios maintain the lowest risk for their initially optimised risk measure.

3.2.1 Wealth Achieved by the Portfolios

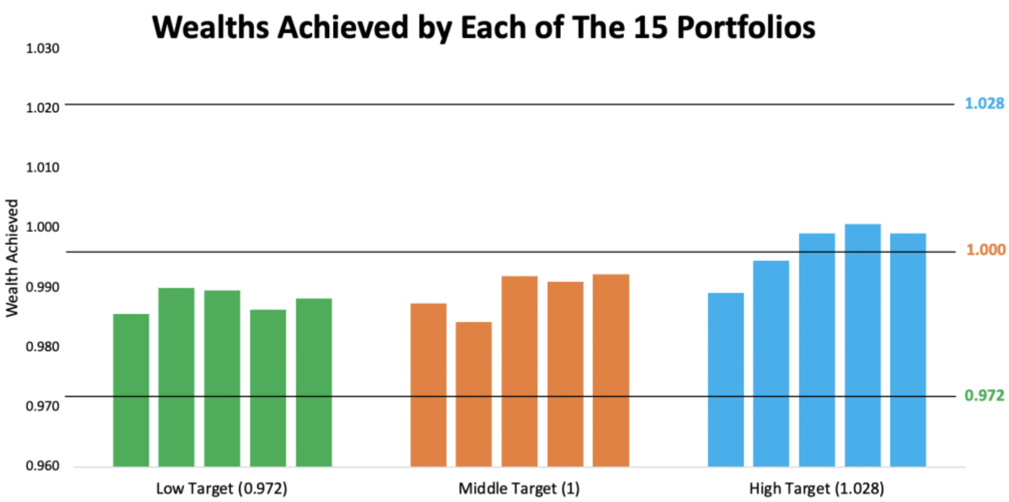

Figure 4: Wealth Achieved by Each Portfolio

The primary aim of any investor is to achieve a financial goal. The three target wealths are reflective of different possible aims. If a portfolio fails to meet the desired wealth an alternative approach which does achieve the wealth is preferable. From the chart above, the five portfolios aiming for the lower target achieved their purpose while the middle and higher target portfolios failed. This indicates that the risk measures were not robust for the middle and higher wealth targets.

3.2.2 Economic Consistency

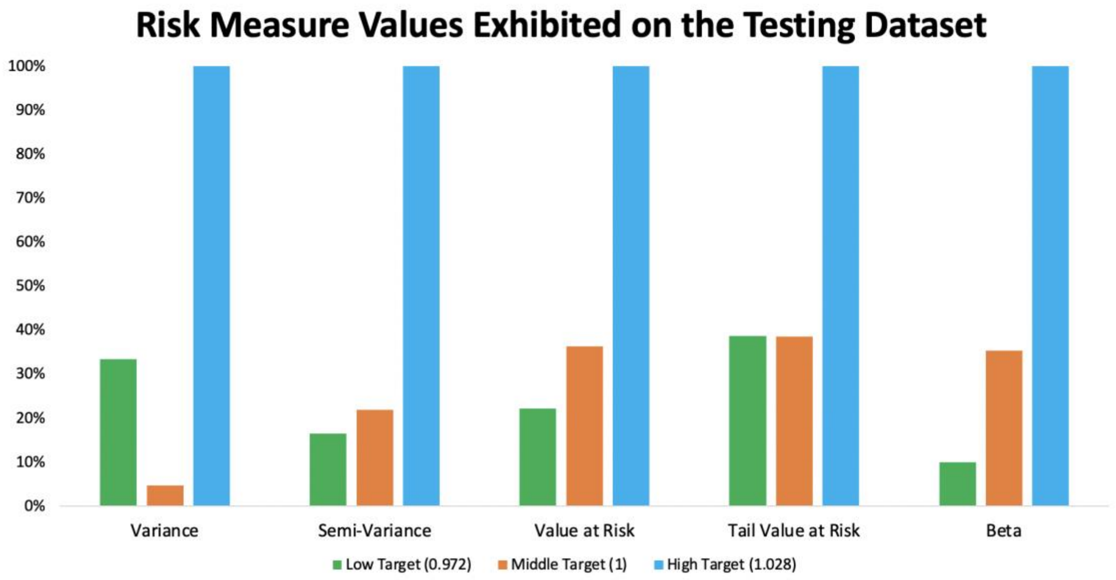

Figure 5: Risk Measure Values on the Testing Dataset

For economic consistency to hold true, the portfolios targeting higher returns must be taking on more risk to do so. The chart to the right displays the risk measure values as percentages of the portfolios targeting the highest wealth. The data demonstrates economic consistency for all risk measures except for variance and tail value at risk. Variance is a significant outlier as this indicates that the portfolio targeting the lowest wealth took on greater risk than the portfolio targeting the middle wealth. This is not economically consistent and thus suggests that the risk measure is not robust. This is an interesting result, given that variance is the most used risk measure in portfolio optimisation. The tail value at risk portfolios displayed the same effect but to a lesser degree. The portfolio targeting the middle wealth took on less risk to achieve a higher return. This is illogical and is evidence suggesting tail value at risk is not robust. Figure 5 shows that portfolios targeting the higher wealth took on more than twice as much risk. This is a significant finding as these portfolios achieved an average of 0.007 (3dp) higher wealth, representing an increase of 0.72%, for more than twice the amount of risk.

3.2.3 Comparison Between Training and Testing Risk Values

	Lower Target (0.9724)				
Portfolio	1	2	3	4	5
Initial Measure	Variance	Semi-Variance	Value at Risk	Tail Value at Risk	Beta
Optimised value	0.00009	0.00036	0.04591	0.95351	0.00000
Testing value	0.02089	0.00083	0.04525	0.92959	0.10260
% Change	23145%	129%	-1%	-3%	-1.6786E+17
	Middle Target (1)				
Portfolio	6	7	8	9	10
Initial Measure	Variance	Semi-Variance	Value at Risk	Tail Value at Risk	Beta
Optimised value	0.00010	0.00003	0.01721	0.97954	0.00000
Testing value	0.00290	0.00110	0.07424	0.92985	0.36284
% Change	2939%	3238%	331%	-5%	-5.93607E+17
	Higher Target (1.0284)				
Portfolio	11	12	13	14	15
Initial Measure	Variance	Semi-Variance	Value at Risk	Tail Value at Risk	Beta
Optimised value	0.00067	0.00083	0.02634	0.98591	0.00000
Testing value	0.06252	0.00503	0.20439	0.81771	1.02446
% Change	9265%	508%	676%	-17%	-1.67601E+18

Table 2: Comparison Between Training and Testing Risk Values

The portfolios exhibited much higher risk on the testing dataset comparatively to the training dataset. This is evidence against robustness, as the portfolios are not maintaining their risk profile. It should be noted that higher tail value at risk values are indicative of lower risk, as the wealth achieved is greater. One portfolio did decrease its risk on the testing dataset. This portfolio minimised value at risk and targeted the lowest wealth category. By exhibiting lower risk on the testing data value at risk, while targeting the lower wealth, displays evidence of robustness. The beta portfolios had insignificant values due to the method used to create the two datasets.

3.2.4 Risk Rank Consistency

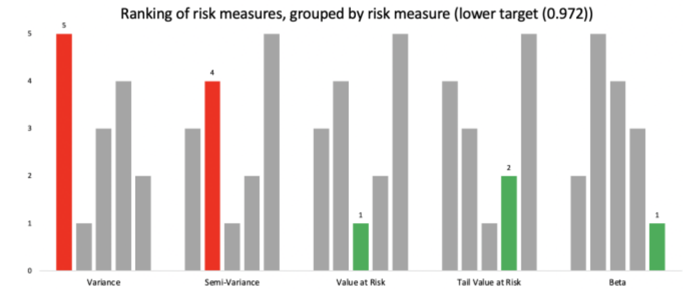

Figure 6: Performance Ranking of Risk Measures on The Lower Target Wealth

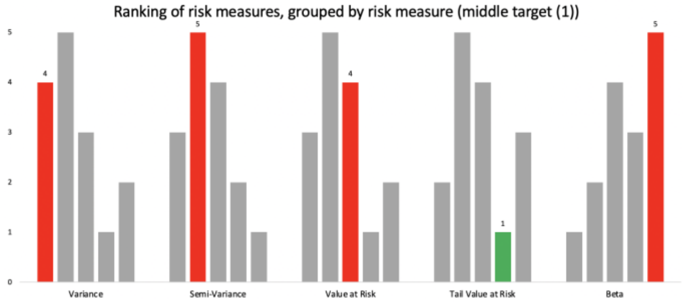

Figure 7: Performance Ranking of Risk Measures on The Middle Target Wealth

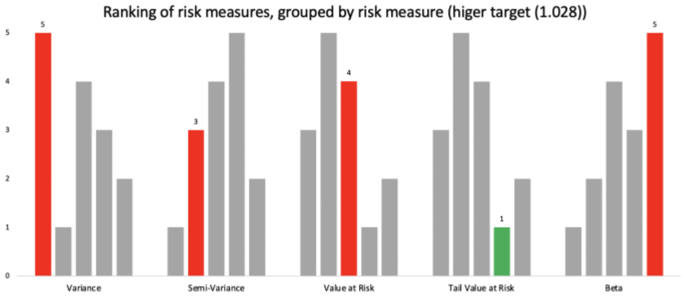

Figure 8: Performance Ranking of Risk Measures on The Higher Target Wealth

Figures 6-8 show how well each risk measure did at maintaining its risk ranking. Each portfolio optimised a risk measure on the training dataset, and then was applied to the testing dataset to determine a new risk value. The constructed portfolios should exhibit the lowest risk relative to their initially optimised risk measure, and thus achieve a rank of 1 on both datasets. For the risk measures to be considered robust, portfolios must maintain their relative risk rank. Evidence of robustness would occur if a risk measure was able to maintain a rank of 1 for its respective risk measure for all target wealths.

Tail value at risk was the only risk measure to almost meet this criterion, with the others showed no evidence of robustness regarding this metric. All other risk measures had instances of being ranked 4^{th} or 5^{th} in the risk measure initially optimised for that portfolio's construction. This implies that a portfolio specifically constructed to minimise a certain type of risk has no ability to minimise this risk in the future, rather the data suggests such a portfolio would perform worse than other portfolios which had initially disregarded it.

3.2.5 Comparison to an Equal Weighted Portfolio

	Achieved Wealth	Variance	Semi-Variance	VaR (5%)	TailVaR (5%)	Beta
Training	0.98594	0.00013	0.00008	0.03328	0.96529	-0.00519
Testing	**0.98881**	**0.00049**	**0.00005**	**0.02773**	**0.96790**	**0.03522**
% Change	0.29%	293.22%	-32.79%	-16.66%	0.27%	-779.09%

Table 3: Risk Values of an Equal Weighted Portfolio

Table 3 shows the risk values exhibited by an equal weighted portfolio on the training and testing dataset. An equally weighted portfolio will gain exposure to all stocks, thus should achieve the return of the market while decreasing its risk by diversifying away specific risk. The risk values exhibited on the testing dataset are lower than all other portfolios, while achieving the lower target wealth. This is economically consistent. The equally weighted portfolio also exhibits decreased risk relative to semi-variance, value at risk and tail value at risk. This suggests that the diversified, long only portfolio exhibited greater robustness than any of the risk measure constructed portfolios.

4 Conclusion

By optimising investment portfolios upon a training dataset of independent wealth values for specific risk measures and targeting specific wealths portfolios were constructed with different proportions of stocks. These stock distributions were more different between the three target wealths, than between the five risk measures. This was economically consistent as larger risk was taken on to achieve the higher wealth targets, through greater magnitude positions into the stocks. This was reflected in much larger risk measure values for the portfolios targeting the higher wealths. The portfolios targeting the lower wealth had an average position which was the inverse of the position of the middle and higher target wealths, as shown in Figure 1.

The risk measures were not robust as the portfolios optimised using the risk measures failed to meet the requirements. These requirements were achieving the target wealth, maintaining risk characteristics, and maintaining risk ranking, relative to other portfolios in the same target wealth category. There appeared to be greater robustness of risk measures in the lower target wealth category, though these portfolios still failed to maintain their risk characteristics and variance and semi-variance failed to maintain their relative risk rank for this target wealth. An equal weighted portfolio achieved a similar wealth to the portfolios targeting the lower wealth target and achieved lower risk measures than the optimised portfolios did upon the testing dataset.

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6 Appendices

Appendix 1

Proportions of Each Stock in The 15 Portfolios

Initial Measure	CBA	CSL	BHP	NAB	MQG	WBC	ANZ	WES	FMG	RMD	GMG	TLS	WOW	TCL	RIO	ALL	AMC
1 Variance	-0.1309	-0.0259	0.0207	0.0137	-0.0322	0.0219	0.1388	0.0920	0.0235	0.0021	0.0018	-0.0015	0.0988	0.0077	0.0357	-0.0692	0.0862
2 Semi-Variance	0.3559	-0.0149	0.0479	0.0235	0.0197	0.0111	0.0163	0.0122	0.0453	-0.0138	-0.0450	0.0504	0.0596	-0.0019	0.0181	-0.0426	0.0193
3 Value at Risk	-0.0296	-0.0041	0.0452	0.0646	0.0002	0.0195	0.0920	0.0210	0.0148	0.0049	-0.0213	0.0481	0.0908	0.0092	0.0502	-0.0297	0.0255
4 Tail Value at Risk	0.0129	0.0198	0.0418	0.0362	-0.0048	0.0454	0.1164	0.0347	0.0079	0.0007	0.0063	0.0520	-0.0016	0.0103	0.0656	-0.0898	0.0390
5 Beta	0.0234	-0.0153	0.0138	0.0140	-0.0026	0.0121	0.0190	0.0067	0.0021	0.0003	-0.0160	0.0113	0.0212	0.0028	0.0129	-0.0194	0.0083
6 Variance	-0.0378	0.0819	-0.0046	0.0500	0.0279	0.0021	-0.0421	-0.0373	-0.0414	0.0391	0.1480	-0.0010	-0.1194	0.0890	0.0212	0.1752	0.0409
7 Semi-Variance	0.0688	0.1107	-0.0882	0.0745	0.0274	-0.0183	-0.0401	0.0101	-0.0702	-0.0033	0.0926	0.0432	-0.1312	0.0011	0.0242	0.1758	0.0313
8 Value at Risk	-0.3453	0.0822	-0.0274	0.0319	0.0745	-0.0175	-0.0186	0.0605	-0.0006	0.0367	0.1294	-0.0278	-0.0293	0.0439	0.0253	0.1167	0.0322
9 Tail Value at Risk	-0.3300	0.0788	-0.0070	0.0299	0.0867	-0.0045	-0.0024	0.0738	-0.0315	0.0368	0.1332	-0.0177	-0.0358	0.0419	0.0454	0.1064	0.0008
10 Beta	-0.4220	0.0759	0.0074	0.0078	0.0458	0.0120	-0.0047	0.0244	0.0354	0.0400	0.0777	0.0133	-0.0100	0.0339	0.0106	0.0863	0.0206
11 Variance	0.0579	0.1925	-0.0303	0.0864	0.0889	-0.0178	-0.2311	-0.1701	-0.1076	0.0771	0.2979	-0.0012	-0.3423	0.1725	0.0062	0.4261	-0.0052
12 Semi-Variance	-1.0321	0.1380	-0.1607	0.0252	0.1766	-0.0230	-0.0429	0.1367	-0.0945	0.1197	0.3246	-0.0721	-0.1182	0.0792	0.0567	0.2525	0.0159
13 Value at Risk	-1.1753	0.1693	-0.1547	-0.0261	0.1768	-0.0400	-0.0926	0.0627	0.0123	0.1718	0.3031	-0.0142	-0.1000	0.0588	0.0482	0.2321	0.0121
14 Tail Value at Risk	-1.0403	0.0450	-0.1069	0.0370	0.1698	-0.0343	-0.0564	0.0643	-0.1556	0.0894	0.4293	-0.0286	-0.1737	0.0673	0.0451	0.1972	0.0165
15 Beta	-1.3145	0.1886	-0.0180	-0.0169	0.0979	-0.0042	-0.0547	0.0332	0.0664	0.0805	0.1942	-0.0003	-0.0705	0.0618	-0.0084	0.2201	0.0218

Initial Measure	JHX	SYD	SHL	REA	STO	WPL	NCM	FPH	ASX	REH	QBE	RHC	BXB	COH	SUN	APA	DXS
1 Variance	-0.0164	-0.0079	-0.0482	-0.1059	0.0443	-0.0337	-0.0635	0.0695	0.0239	0.0447	-0.0670	-0.0583	0.1881	0.0669	0.1165	0.0857	0.0306
2 Semi-Variance	0.0153	0.0043	0.0162	-0.0748	0.0991	0.0237	0.0632	0.0047	-0.0056	-0.0275	-0.0506	-0.0135	0.0645	-0.0068	0.0352	0.0547	0.0285
3 Value at Risk	0.0126	0.0009	0.0122	-0.0924	-0.0028	0.0454	0.0346	-0.0004	0.0172	-0.0075	-0.0292	-0.0090	0.0739	0.0085	0.0450	0.0827	0.0386
4 Tail Value at Risk	0.0123	-0.0035	0.0140	-0.1039	0.1046	-0.0581	0.0139	-0.0010	0.0095	-0.0165	-0.0228	-0.0109	0.1267	0.0050	0.0590	0.0803	0.0574
5 Beta	0.0033	-0.0027	0.0031	-0.0231	0.0325	0.0232	0.3505	-0.0014	0.0039	-0.0086	-0.0101	-0.0083	0.0161	0.0015	0.0106	0.0186	0.0105
6 Variance	0.0534	0.0318	-0.0289	0.0959	-0.0481	0.0134	-0.0107	-0.0312	0.0701	0.0447	0.0527	0.0569	-0.0710	-0.0040	-0.0559	0.0991	0.1042
7 Semi-Variance	0.0799	0.1034	-0.0188	0.0953	-0.0263	0.0416	0.0337	-0.0678	0.0500	0.0050	0.1353	0.0625	-0.1430	-0.0235	-0.1066	0.0877	0.0805
8 Value at Risk	0.0758	0.0642	0.0240	0.0517	-0.0476	-0.0305	-0.0154	0.0590	0.0273	0.0401	0.0292	0.0600	-0.0168	0.0518	0.0214	-0.0046	0.0249
9 Tail Value at Risk	0.0517	0.0683	-0.0264	0.0791	-0.0334	-0.0330	-0.0208	0.0290	0.0134	0.0766	0.0199	0.0315	-0.0141	0.0286	0.0402	-0.0155	0.0448
10 Beta	0.0329	0.0471	0.0325	0.0945	-0.0353	-0.0149	-0.0053	0.0443	0.0307	0.0601	0.0638	0.0598	0.0024	0.0363	0.0153	-0.0028	0.0145
11 Variance	0.1254	0.0715	-0.0090	0.3027	-0.1438	0.0604	0.0436	-0.1347	0.1181	0.0451	0.1751	0.1769	-0.3380	-0.0764	-0.2331	0.1151	0.1813
12 Semi-Variance	0.0941	0.1666	-0.0447	0.3165	-0.0327	-0.0990	-0.1278	0.0599	0.0828	0.1181	0.1216	0.1106	-0.0853	0.0965	-0.0149	-0.1084	0.0620
13 Value at Risk	0.1065	0.1421	0.0387	0.2401	-0.0379	-0.1091	-0.0877	0.0690	0.0442	0.0842	0.1327	0.1812	-0.0887	0.1066	0.0214	-0.0586	0.0076
14 Tail Value at Risk	0.1751	0.1273	-0.1153	0.3875	-0.1189	-0.0417	-0.1908	0.0813	0.0204	0.2422	-0.0238	0.0273	-0.0771	0.0632	0.0198	-0.1024	0.1596
15 Beta	0.0589	0.1019	0.0576	0.2450	-0.1469	-0.0852	-0.0563	0.0933	0.0523	0.1411	0.1522	0.1403	-0.0332	0.0694	0.0057	-0.0489	0.0034

Initial Measure	CPU	MGR	SEK	JHG	TAH	SOL	NST	AIA	IAG	MIN	SGP	DMP	AGG	GPT	AFI	BSL
1 Variance	-0.0068	-0.0176	-0.1169	0.1038	0.0436	0.0601	0.0033	0.0355	0.0699	-0.0535	0.0766	-0.0376	0.0513	0.2035	0.0167	0.0157
2 Semi-Variance	-0.0178	-0.0326	0.0273	0.0396	0.0024	0.0759	0.0475	-0.0120	0.0146	0.0075	0.0225	-0.0771	0.0266	0.0220	0.0325	0.0295
3 Value at Risk	-0.0135	-0.0029	-0.0047	0.0226	0.0541	0.1180	-0.0043	0.0014	0.0173	0.0791	0.0262	-0.0226	0.0529	0.0222	0.0376	-0.0147
4 Tail Value at Risk	-0.0154	-0.0024	-0.0070	0.0490	0.0077	0.1425	-0.0004	-0.0018	0.0145	-0.0048	0.0202	-0.0574	0.0388	0.0440	0.0602	0.0533
5 Beta	-0.0092	-0.0019	-0.0035	0.0107	0.0118	0.0208	-0.0041	-0.0013	0.0048	0.0214	0.0136	-0.0162	0.4313	0.0074	0.0091	-0.0091
6 Variance	0.0723	0.0501	0.0290	-0.0167	0.0212	-0.0295	0.0110	0.0371	-0.1028	0.0259	-0.0418	0.0662	0.0005	0.0426	0.1155	-0.0450
7 Semi-Variance	0.1283	0.1192	0.1290	-0.0333	0.0217	0.0729	0.0496	-0.0060	-0.1739	0.0023	-0.0435	0.0172	0.0025	-0.0696	0.1272	-0.0410
8 Value at Risk	0.0943	0.0578	-0.0259	0.0299	0.0814	0.0137	-0.0082	0.0801	-0.0015	0.0073	-0.0219	0.0716	-0.0158	-0.0001	0.0394	0.0168
9 Tail Value at Risk	0.0900	0.0561	0.0121	0.0254	0.0543	-0.0188	0.0242	0.0890	0.0029	0.0142	-0.0186	0.0608	-0.0199	0.0340	0.0388	0.0109
10 Beta	0.0624	0.0450	0.0479	0.0161	0.0125	-0.0091	0.0497	0.0430	0.0291	-0.0092	0.0072	0.0778	-0.0067	0.0225	0.0194	0.0624
11 Variance	0.1541	0.1207	0.1783	-0.1409	-0.0013	-0.1228	0.0184	0.0388	-0.2806	0.1083	-0.1627	0.1730	-0.0523	-0.1217	0.2183	-0.1075
12 Semi-Variance	0.0920	0.1826	0.0215	0.0226	0.1372	-0.1680	-0.0692	0.1581	-0.0103	0.0324	-0.1247	0.2723	-0.0485	0.0303	0.0333	-0.0586
13 Value at Risk	0.0867	0.1484	0.0001	0.0488	0.0973	-0.0938	-0.0569	0.1436	0.0133	-0.0377	-0.1269	0.2636	-0.0194	-0.0013	0.0395	0.0582
14 Tail Value at Risk	0.1771	0.1842	0.0158	0.0244	0.1915	-0.1043	0.0321	0.1942	-0.0475	0.0293	-0.1715	0.2150	-0.0291	0.1040	0.0494	-0.0631
15 Beta	0.1481	0.0956	0.1041	0.0082	-0.0027	-0.0680	0.1097	0.0895	0.0473	-0.0681	-0.0188	0.1944	-0.0607	0.0276	0.0182	0.1480

Appendix 2

Average Absolute Proportions Grouped by Risk Measure