

ACST3006_Assignment

Yunbae Chae

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Abstract

There were cases where leaving % figures in plain decimal figures seemed more reasonable. In this way, not all % figures are not in % form and I hope you would inspect with caution and understanding and I only hope this does not confuse the examiner in any way.

There were some instances where it seemed more reasonable to show the answers in the Excel spreadsheet, rather than listing all of them in the report. Since all of the Excel worksheets are screenshot and attached after each relevant section of the questions, the answers are made easily observable for the examiners.

I have aimed to receive a full mark on this assignment, so please remain patient and thorough with my work until the end. I have tried to make things look as simple as possible for your convenience. Please enjoy! :)

Question 1

The optimal risky portfolio

Precisely following the instructions set out in the lectures regarding the Lagrange Function, the calculations should reach (I understand the theory so I will skip to the conclusions to make it as short as possible):

$$Var(R_p) = \frac{C \cdot \{E(R_p)\}^2 - 2B \cdot E(R_p) + A}{D}$$

where

$$\begin{aligned} A &= E(\mathbf{R})'V^{-1}E(\mathbf{R}), \\ B &= E(\mathbf{R})'V^{-1}\mathbf{1} = \mathbf{1}'V^{-1}E(\mathbf{R}), \\ C &= \mathbf{1}'V^{-1}\mathbf{1}, \\ D &= \begin{vmatrix} A & B \\ B & C \end{vmatrix} = AC - B^2, \\ E(R_p) &\neq E(\mathbf{R})^* \end{aligned}$$

$E(R_p)$ is the expected return on efficient portfolio p and $E(\mathbf{R}) = \begin{bmatrix} E(R_1) \\ E(R_2) \end{bmatrix} = \begin{bmatrix} 0.015 \\ 0.008 \end{bmatrix}$.

$$V = \begin{bmatrix} Cov(R_1, R_1) & Cov(R_1, R_2) \\ Cov(R_2, R_1) & Cov(R_2, R_2) \end{bmatrix}, K = \begin{bmatrix} A & B \\ B & C \end{bmatrix}$$

Since a covariance of one value is equivalent to a variance itself, $Cov(R_1, R_1) = \sigma_{R_1}^2 = 0.1^2 = 0.01$. Given $\rho_{R_1, R_2} = 0.4$ and that $Cov(R_1, R_2) = \rho_{R_1, R_2} \cdot \sigma_{R_1} \cdot \sigma_{R_2}$,

$$Cov(R_1, R_2) = Cov(R_2, R_1) = 0.4 \cdot 0.1 \cdot 0.05 = 0.002.$$

$$\therefore V = \begin{bmatrix} 0.01 & 0.002 \\ 0.002 & 0.0025 \end{bmatrix}$$

$$V^{-1} = \frac{1}{0.01 \cdot 0.0025 - 0.002^2} \begin{bmatrix} 0.0025 & -0.002 \\ -0.002 & 0.01 \end{bmatrix} = \begin{bmatrix} 119.0476 & -95.2381 \\ -95.2381 & 476.1905 \end{bmatrix}$$

Breaking down

$$\begin{aligned}
A &= E(\mathbf{R})'V^{-1}E(\mathbf{R}) = [0.015 \quad 0.008] \begin{bmatrix} 119.0476 & -95.2381 \\ -95.2381 & 476.1905 \end{bmatrix} \begin{bmatrix} 0.015 \\ 0.008 \end{bmatrix} \\
&= [0.015 \quad 0.008] \begin{bmatrix} 1.02381 \\ 2.380952 \end{bmatrix} \\
&= 0.034405
\end{aligned}$$

$$\begin{aligned}
B &= E(\mathbf{R})'V^{-1}\mathbf{1} = \mathbf{1}'V^{-1}E(\mathbf{R}) = [1 \quad 1] \begin{bmatrix} 119.0476 & -95.2381 \\ -95.2381 & 476.1905 \end{bmatrix} \begin{bmatrix} 0.015 \\ 0.008 \end{bmatrix} \\
&= [1 \quad 1] \begin{bmatrix} 1.02381 \\ 2.380952 \end{bmatrix} \\
&= 3.404762
\end{aligned}$$

$$\begin{aligned}
C &= \mathbf{1}'V^{-1}\mathbf{1} = [1 \quad 1] \begin{bmatrix} 119.0476 & -95.2381 \\ -95.2381 & 476.1905 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \end{bmatrix} \\
&= [1 \quad 1] \begin{bmatrix} 23.80952 \\ 380.9524 \end{bmatrix} \\
&= 404.7619
\end{aligned}$$

$$\begin{aligned}
D &= AC - B^2 = 0.034405 \cdot 404.7619 - 3.404762^2 \\
&= 2.333333
\end{aligned}$$

$$\begin{aligned}
Var(R_p) &= \frac{C \cdot \{E(R_p)\}^2 - 2B \cdot E(R_p) + A}{D} \\
&= \frac{404.7619 \cdot \{E(R_p)\}^2 - 2 \cdot 3.404762 \cdot E(R_p) + 0.034405}{2.333333}.
\end{aligned}$$

The portfolio return that minimizes $Var(R_p)$ is the $E(R_p)$ that finds $\frac{d Var(R_p)}{d E(R_p)} = 0$. The efficient frontier only considers $E(R_p) > E(R_p^G)$ where

$$\Rightarrow \frac{d Var(R_p)}{d E(R_p)} = \frac{404.7619 \cdot 2}{2.333333} \cdot E(R_p) - \frac{2 \cdot 3.404762}{2.333333} = 0$$

$$E(R_p^G) = \frac{2 \cdot 3.404762}{2.333333} \cdot \frac{2.333333}{404.7619 \cdot 2} = 0.008412$$

$$\sigma_{R_p^G} = \sqrt{\frac{404.7619 \cdot 0.008412^2 - 2 \cdot 3.404762 \cdot 0.008412 + 0.034405}{2.333333}} = 0.049705$$

Confirming the minimum variance at $E(R_p^G)$:

$$\frac{d^2 \text{Var}(R_p)}{d E(R_p)^2} = \frac{2C}{D} = 346.9388 > 0$$

The capital allocation line

Omitting theory and proof, the Capital Allocation Line (for the optimal risky portfolio) is given by

$$E(R_p) = E(R_p^Z) + \frac{D\sigma_{R_p^*}}{C E(R_p^*) - B} \times \sigma_{R_p}$$

where $E(R_p^Z) = 0.004$ (given) and R_p^* refers to the tangency portfolio $\begin{bmatrix} \sigma_{R_p} \\ E(R_p) \end{bmatrix}$.

Solving for the tangency portfolio,

$$E(R_p^Z) = \frac{B E(R_p^*) - A}{C E(R_p^*) - B}$$

$$0.004 = \frac{3.404762 \cdot E(R_p^*) - 0.034405}{404.7619 \cdot E(R_p^*) - 3.404762}$$

$$E(R_p^*) = 0.01164$$

$$\sigma_{R_p^*} = \sqrt{\frac{404.7619 \cdot 0.01164^2 - 2 \cdot 3.404762 \cdot 0.01164 + 0.034405}{2.333333}} = 0.06540948$$

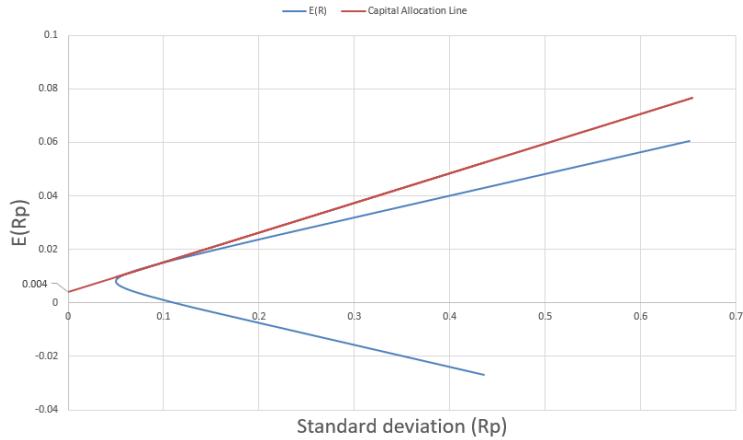
The Capital Allocation Line is now

$$E(R_p) = 0.004 + \frac{2.333333 \cdot 0.06540948}{404.7619 \cdot 0.01164 - 3.404762} \times \sigma_{R_p} = 0.004 + 0.1168026 \cdot \sigma_{R_p}$$

The graph is supplied in the attached Excel screenshot. Regarding the other portfolios for scenarios of -100%, 0%, 50% and 100% correlation, all the relevant values and graphs are also supplied.



Risk free	0.004 Asset 1 re	0.015 Asset 2 return	0.008	V:	0.01	0.0025	V^~1:	133.3333	-133.333333	E(R):	0.015
Cor	0.5 sd	0.1 sd	0.05 Cov	0.0025	0.0025	0.0025	-133.333	533.333333		0.008	
Proportion in Risky Asset 1	Proportion in Risky Asset 2	E(R)	Var(R)*0.5	Capital Allocation Line							
-50.0%	600.0%	600.0%	-0.027	0.435889894	0.052364358						
-150.0%	250.0%	250.0%	-0.0025	0.139194109	0.019444345						
-80.0%	180.0%	180.0%	0.0024	0.085440037	0.013480038						
-70.0%	170.0%	170.0%	0.0031	0.078581168	0.012719009						
-60.0%	160.0%	160.0%	0.0038	0.072111026	0.012001111						
-50.0%	150.0%	150.0%	0.0045	0.066143783	0.011339013						
-40.0%	140.0%	140.0%	0.0052	0.060827625	0.010749156						
-30.0%	130.0%	130.0%	0.0059	0.056347138	0.010252022						
-20.0%	120.0%	120.0%	0.0066	0.052915026	0.00987121						
-10.0%	110.0%	110.0%	0.0073	0.050744458	0.009630374						
0.0%	100.0%	100.0%	0.008	0.050744458	0.009547772						
10.0%	90.0%	90.0%	0.0087	0.050744458	0.009630374						
20.0%	80.0%	80.0%	0.0094	0.052915026	0.00987121						
30.0%	70.0%	70.0%	0.0101	0.056347138	0.010252022						
40.0%	60.0%	60.0%	0.0108	0.060827625	0.010749156						
50.0%	50.0%	50.0%	0.0115	0.066143783	0.011339013						
60.0%	40.0%	40.0%	0.0122	0.072111026	0.012001111						
70.0%	30.0%	30.0%	0.0129	0.078581168	0.012719009						
80.0%	20.0%	20.0%	0.0136	0.085440037	0.013480038						
90.0%	10.0%	10.0%	0.0143	0.092601296	0.014274618						
100.0%	0.0%	0.0%	0.015	0.1	0.015955545						
110.0%	-10.0%	-10.0%	0.0157	0.107587174	0.015937383						
120.0%	-20.0%	-20.0%	0.0164	0.115325626	0.016796006						
250.0%	-150.0%	-150.0%	0.0255	0.22220486	0.02865484						
750.0%	-650.0%	-650.0%	0.0605	0.651440711	0.076280895						



Risk free	0.004	Asset 1 re	0.015	Asset 2 return	0.008		V:	0.01	0.005	V^-1:	#NUM!
Cor	1 sd		0.1 sd		0.05 Cov	0.005		0.005	0.0025		
Proportion in Risky Asset	Proportion in Risky Asset			Capital Allocation Line							
in Risky Asset 1	n in Risky Asset 2	E(R)	Var(R)^0.5								
-500.0%	600.0%	-0.027	0.2	#NUM!							
-150.0%	250.0%	-0.0025	0.025	#NUM!							
-80.0%	180.0%	0.0024	0.01	#NUM!							
-70.0%	170.0%	0.0031	0.015	#NUM!							
-60.0%	160.0%	0.0038	0.02	#NUM!							
-50.0%	150.0%	0.0045	0.025	#NUM!							
-40.0%	140.0%	0.0052	0.03	#NUM!							
-30.0%	130.0%	0.0059	0.035	#NUM!							
-20.0%	120.0%	0.0066	0.04	#NUM!							
-10.0%	110.0%	0.0073	0.045	#NUM!							
0.0%	100.0%	0.008	0.05	#NUM!							
10.0%	90.0%	0.0087	0.055	#NUM!							
20.0%	80.0%	0.0094	0.06	#NUM!							
30.0%	70.0%	0.0101	0.065	#NUM!							
40.0%	60.0%	0.0108	0.07	#NUM!							
50.0%	50.0%	0.0115	0.075	#NUM!							
60.0%	40.0%	0.0122	0.08	#NUM!							
70.0%	30.0%	0.0129	0.085	#NUM!							
80.0%	20.0%	0.0136	0.09	#NUM!							
90.0%	10.0%	0.0143	0.095	#NUM!							
100.0%	0.0%	0.015	0.1	#NUM!							
110.0%	-10.0%	0.0157	0.105	#NUM!							
120.0%	-20.0%	0.0164	0.11	#NUM!							
250.0%	-150.0%	0.0255	0.175	#NUM!							
750.0%	-650.0%	0.0605	0.425	#NUM!							
		0	#NUM!								

Question 2

Question 2 i

Please refer to the attached screenshot of the Excel file.

For correlations and covariances among the risky assets, I put them in a matrix form. These figures exist for every pair, so the number of figures would need to be $\binom{19}{2}=171$. They take up quite a large area, so please understand some complexity.

The means, standard deviations, correlations, and variances/ covariances among the risky assets are all listed nicely in the Excel screenshot. Since there is a large number of answers, I have not listed them in the report. Please refer to the Excel screenshot and you will find all of them there nicely listed.

Also, there is an additional screenshot to show the function that I used to find the covariance between the risky assets. As it was emphasized in the announcement, COVARIANCE.S() was used.

	15	Stock	Stock	Stock	Stock	Stock	Stock	US Portfolio	US Portfolio	US Portfolio	US Portfolio	US Portfolio	Country Port	US Riskfree							
	49	Barrick	Hanson	IBM	Nokia	Telefonos	YPF	Small-Growth	Small-Neutral	Small-Value	Big-Growth	Big-Neutral	Big-Value	Australia	Hong Kong	Italy	Japan	Norway	US	US Riskfree	
Covariances:																					
Stock	Barrick	1.06%	0.28%	0.08%	0.17%	0.22%	0.30%	-0.14%	-0.09%	-0.07%	-0.05%	-0.04%	-0.02%	-0.09%	0.03%	-0.02%	-0.11%	-0.10%	-0.06%	0.00%	
Stock	Hanson	0.28%	1.00%	0.19%	0.28%	0.17%	0.24%	-0.09%	-0.04%	-0.04%	-0.04%	-0.03%	-0.02%	0.03%	0.04%	-0.05%	0.07%	-0.08%	-0.04%	0.00%	
Stock	IBM	0.08%	0.19%	0.88%	0.54%	0.33%	0.30%	-0.01%	-0.02%	-0.04%	-0.03%	-0.03%	-0.05%	-0.04%	0.05%	-0.07%	-0.04%	-0.08%	-0.03%	0.00%	
Stock	Nokia	0.17%	0.28%	0.54%	1.89%	0.47%	0.29%	-0.10%	-0.12%	-0.16%	-0.06%	-0.12%	-0.08%	-0.10%	-0.14%	-0.07%	-0.03%	-0.25%	-0.09%	0.00%	
Stock	Telefonos	0.22%	0.17%	0.33%	0.47%	0.83%	0.36%	0.00%	-0.03%	-0.05%	-0.03%	-0.05%	-0.05%	-0.04%	-0.07%	-0.02%	-0.11%	-0.07%	-0.14%	-0.03%	0.00%
Stock	YPF	0.30%	0.24%	0.30%	0.29%	0.36%	1.07%	0.01%	-0.04%	-0.07%	0.05%	-0.01%	0.01%	0.05%	0.02%	0.01%	-0.06%	0.03%	0.00%	0.00%	
1 US Portfolio	Small-Growth	-0.14%	-0.09%	-0.01%	-0.10%	0.00%	0.01%	0.65%	0.38%	0.34%	0.28%	0.18%	0.15%	0.24%	0.32%	0.31%	0.19%	0.32%	0.30%	0.00%	
2 US Portfolio	Small-Neutral	-0.09%	-0.04%	-0.02%	-0.12%	-0.03%	-0.04%	0.38%	0.27%	0.25%	0.17%	0.16%	0.13%	0.23%	0.19%	0.11%	0.23%	0.19%	0.00%		
3 US Portfolio	Small-Value	-0.07%	-0.04%	-0.04%	-0.16%	-0.05%	-0.07%	0.34%	0.25%	0.25%	0.15%	0.15%	0.14%	0.21%	0.17%	0.10%	0.22%	0.17%	0.00%		
4 US Portfolio	Big-Growth	-0.05%	-0.04%	-0.03%	-0.06%	-0.03%	0.05%	0.28%	0.17%	0.15%	0.23%	0.16%	0.14%	0.20%	0.17%	0.13%	0.16%	0.22%	0.00%		
5 US Portfolio	Big-Neutral	-0.04%	-0.03%	-0.03%	-0.12%	-0.05%	-0.01%	0.18%	0.16%	0.15%	0.16%	0.19%	0.17%	0.20%	0.13%	0.08%	0.18%	0.17%	0.00%		
6 US Portfolio	Big-Value	-0.02%	-0.02%	-0.05%	-0.08%	-0.04%	-0.01%	0.15%	0.13%	0.14%	0.14%	0.17%	0.19%	0.10%	0.16%	0.11%	0.07%	0.15%	0.15%	0.00%	
7 Country Port	Australia	-0.09%	0.03%	-0.04%	-0.10%	-0.07%	0.01%	0.24%	0.16%	0.15%	0.15%	0.12%	0.10%	0.25%	0.24%	0.15%	0.17%	0.22%	0.16%	0.00%	
8 Country Port	Hong Kong	0.03%	0.04%	0.05%	-0.14%	-0.02%	0.05%	0.32%	0.23%	0.21%	0.20%	0.20%	0.16%	0.24%	0.61%	0.15%	0.22%	0.26%	0.22%	0.00%	
9 Country Port	Italy	-0.02%	-0.05%	-0.07%	-0.11%	0.02%	0.31%	0.19%	0.17%	0.13%	0.11%	0.15%	0.15%	0.04%	0.09%	0.24%	0.18%	0.00%			
10 Country Port	Japan	-0.11%	0.07%	-0.04%	-0.03%	-0.07%	0.01%	0.19%	0.11%	0.10%	0.13%	0.08%	0.07%	0.17%	0.22%	0.09%	0.35%	0.16%	0.13%	0.00%	
11 Country Port	Norway	-0.10%	-0.08%	-0.08%	-0.25%	-0.14%	-0.06%	0.32%	0.23%	0.22%	0.16%	0.18%	0.15%	0.22%	0.26%	0.16%	0.46%	0.20%	0.00%		
12 Country Port	US	-0.06%	-0.04%	-0.03%	-0.09%	-0.03%	0.03%	0.30%	0.19%	0.17%	0.22%	0.17%	0.15%	0.16%	0.22%	0.18%	0.13%	0.20%	0.21%	0.00%	
13 US Riskfree	US Riskfree	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Correlations:																					
5		Stock	Stock	Stock	Stock	Stock	Stock	US Portfolio	US Portfolio	US Portfolio	US Portfolio	US Portfolio	Country Port	US Riskfree							
6		Barrick	Hanson	IBM	Nokia	Telefonos	YPF	Small-Growth	Small-Neutral	Small-Value	Big-Growth	Big-Neutral	Big-Value	Australia	Hong Kong	Italy	Japan	Norway	US	US Riskfree	
7		Correlations:																			
8		Stock	Barrick	100.00%	26.80%	7.76%	11.99%	23.62%	28.47%	-17.34%	-16.18%	-13.29%	-10.39%	-9.57%	-3.58%	-17.22%	3.57%	-2.93%	-14.86%	-13.43%	-5.39%
9	Stock	Hanson	26.80%	100.00%	19.97%	20.24%	19.26%	22.87%	-10.62%	-7.91%	-8.21%	-7.88%	-7.27%	-4.78%	5.20%	5.45%	-8.35%	11.57%	-11.19%	-9.18%	-3.10%
10	Stock	IBM	7.76%	19.97%	100.00%	41.77%	38.50%	31.25%	-1.62%	-3.39%	-7.92%	-6.69%	-6.84%	-11.95%	-8.09%	6.31%	-11.36%	-7.50%	-13.31%	-6.22%	9.31%
11	Stock	Nokia	11.99%	20.24%	41.77%	100.00%	37.28%	20.37%	-8.86%	-16.26%	-9.30%	-19.65%	-13.16%	-15.02%	-13.11%	-8.25%	-3.68%	-26.69%	-13.49%	7.22%	
12	Stock	Telefonos	23.62%	19.26%	38.50%	37.28%	100.00%	38.86%	-0.10%	-6.74%	-11.92%	-7.26%	-13.05%	-10.45%	-34.71%	-2.42%	-18.51%	-12.44%	-23.19%	-8.30%	9.51%
13	Stock	YPF	28.47%	22.87%	31.25%	20.37%	38.68%	100.00%	0.74%	-7.56%	-12.84%	9.46%	-2.87%	-1.66%	2.11%	5.80%	2.66%	1.91%	-8.96%	5.26%	-18.39%
14	US Portfolio	Small-Growth	-17.34%	-10.62%	-1.62%	-8.86%	-0.10%	0.74%	100.00%	91.27%	84.04%	72.30%	52.47%	41.36%	60.71%	51.19%	60.15%	39.85%	57.88%	81.09%	-5.50%
15	US Portfolio	Small-Neutral	-16.18%	-7.91%	-3.39%	-16.26%	-6.74%	-7.56%	91.17%	100.00%	96.43%	65.94%	68.44%	58.74%	61.53%	57.07%	56.49%	34.26%	65.24%	78.58%	-2.96%
16	US Portfolio	Small-Value	-13.29%	-8.21%	-7.92%	-22.89%	-11.92%	-12.84%	84.04%	96.43%	61.63%	69.97%	62.62%	59.69%	52.77%	54.07%	33.05%	65.25%	74.84%	-5.88%	
17	US Portfolio	Big-Growth	-10.39%	-7.88%	-6.69%	-9.30%	-7.26%	9.46%	72.30%	65.94%	61.63%	100.00%	75.85%	66.78%	61.40%	52.29%	55.43%	45.03%	50.42%	97.03%	3.34%
18	US Portfolio	Big-Neutral	-9.57%	-7.27%	-6.84%	-19.65%	-13.05%	-2.87%	52.47%	68.44%	69.97%	75.85%	100.00%	90.88%	54.41%	57.36%	45.91%	32.94%	61.04%	82.49%	5.59%
19	US Portfolio	Big-Value	-3.58%	-4.78%	-11.95%	-13.16%	-10.45%	-1.66%	41.36%	58.74%	62.62%	66.78%	90.88%	100.00%	47.09%	47.26%	39.13%	25.49%	50.74%	72.64%	7.63%
20	Country Port	Australia	-17.22%	5.20%	-8.09%	-15.02%	-14.71%	2.11%	60.71%	61.53%	59.69%	61.40%	54.41%	47.09%	100.00%	60.98%	48.79%	57.00%	65.18%	68.13%	-16.46%
21	Country Port	Hong Kong	3.57%	5.45%	6.31%	-13.11%	-2.42%	5.80%	51.19%	57.07%	52.77%	52.29%	57.36%	47.26%	60.98%	100.00%	30.55%	46.54%	48.70%	59.83%	-6.59%
22	Country Port	Italy	-2.93%	-8.35%	-11.36%	-8.29%	-18.51%	2.66%	60.15%	56.49%	54.07%	55.43%	45.51%	39.13%	48.79%	30.55%	100.00%	22.77%	55.39%	61.56%	-0.46%
23	Country Port	Japan	-18.33%	11.57%	-7.60%	-3.68%	-12.44%	1.91%	39.85%	34.26%	33.05%	45.03%	32.54%	25.49%	57.00%	46.54%	22.77%	100.00%	40.89%	47.16%	-12.20%
24	Country Port	Norway	-14.86%	-11.19%	-18.31%	-26.65%	-23.19%	-8.56%	57.88%	65.24%	65.25%	50.42%	61.04%	50.74%	65.18%	48.70%	55.39%	40.89%	100.00%	62.71%	-13.87%
25	Country Port	US	-10.46%	-7.15%	-4.85%	-10.50%	-6.46%	4.10%	63.14%	58.28%	75.55%	64.23%	56.57%	53.05%	46.59%	47.93%	36.72%	48.83%	77.87%	-0.40%	0.00%
26	US Riskfree	US Riskfree	-5.39%	-3.10%	9.31%	7.22%	9.51%	-18.39%	-5.50%	-5.88%	3.34%	5.59%	7.63%	-16.46%	-6.59%	-0.46%	-12.20%	-13.87%	-0.06%	100.00%	
27	Mean	0.70%	1.17%	1.26%	2.44%	2.08%	1.56%	0.71%	1.39%	1.54%	0.72%	1.01%	0.99%	1.15%	0.79%	1.36%	0.42%	1.40%	0.82%	0.29550%	
28	Standard Deviation	0.103131	0.1	0.039	0.137372	0.090854	0.103368	0.0803251	0.052199839	0.050267604	0.04627249	0.0436489	0.04391344	0.0504263	0.078340471	0.063317699	0.059087913	0.06777404	0.0460107	0.00146045	
29	Variance	0.010636	0.01	0.008817	0.018871	0.008254	0.010685	0.006452122	0.002724823	0.002526832	0.002338023	0.0019052	0.00192639	0.00250426	0.006137229	0.004090131	0.00459332	0.002117	2.1329E-06		

Question 2 ii

a

For Country Portfolio - Australia, the equation of the efficient frontier is

$$Var(R_p) = \frac{C \cdot \{E(R_p)\}^2 - 2B \cdot E(R_p) + A}{D}$$

where

$$\begin{aligned} A &= E(\mathbf{R})'V^{-1}E(\mathbf{R}), \\ B &= E(\mathbf{R})'V^{-1}\mathbf{1} = \mathbf{1}'V^{-1}E(\mathbf{R}), \\ C &= \mathbf{1}'V^{-1}\mathbf{1}, \\ D &= \begin{vmatrix} A & B \\ B & C \end{vmatrix} = AC - B^2, \\ E(R_p) &\neq E(\mathbf{R})^* \end{aligned}$$

$E(R_p)$ is the expected return on efficient portfolio p and $E(\mathbf{R}) = \begin{bmatrix} E(R_1) \\ E(R_2) \\ E(R_3) \\ E(R_4) \\ E(R_5) \\ E(R_6) \end{bmatrix} = \begin{bmatrix} 0.0115 \\ 0.0079 \\ 0.0136 \\ 0.0042 \\ 0.014 \\ 0.0082 \end{bmatrix}$.

$$V = \begin{bmatrix} Cov(R_1, R_1) & Cov(R_1, R_2) & Cov(R_1, R_3) & Cov(R_1, R_4) & Cov(R_1, R_5) & Cov(R_1, R_6) \\ \vdots & & & & & \\ Cov(R_6, R_1) & Cov(R_6, R_2) & Cov(R_6, R_3) & Cov(R_6, R_4) & Cov(R_6, R_5) & Cov(R_6, R_6) \end{bmatrix}, K = \begin{bmatrix} A & B \\ B & C \end{bmatrix}$$

Since a covariance of one value is equivalent to a variance itself, $Cov(R_1, R_1) = \sigma_{R_1}^2 = 0.05004263^2 = 0.00250426$ and so on.

The other covariances like $Cov(R_1, R_2)$ and $Cov(R_1, R_3)$ are calculated on the Excel spreadsheet using the function COVARIANCE.S using each of the column of monthly returns, then the correlations are derived using the relationship $\rho_{R_1, R_2} = \frac{Cov(R_1, R_2)}{\sigma_{R_1} \sigma_{R_2}}$ and are combined on a 19 X 19 plane.

$$\therefore V = \begin{bmatrix} 0.002504264 & 0.002390442 & 0.001546055 & 0.001685552 & 0.002210671 & 0.0015686 \\ 0.002390442 & 0.006137229 & 0.001515461 & 0.002154257 & 0.002585894 & 0.002156413 \\ 0.001546055 & 0.001515461 & 0.004009131 & 0.000851911 & 0.002376791 & 0.001793284 \\ 0.001685552 & 0.002154257 & 0.000851911 & 0.003491381 & 0.001637559 & 0.001282067 \\ 0.002210671 & 0.002585894 & 0.002376791 & 0.001637559 & 0.004593321 & 0.001955539 \\ 0.0015686 & 0.002156413 & 0.001793284 & 0.001282067 & 0.001955539 & 0.002116982 \end{bmatrix}$$

$$V^{-1} = \begin{bmatrix} 1081.705507 & -144.3777141 & -72.11590133 & -219.0229114 & -210.612872 & -266.1512403 \\ -144.3777141 & 301.6613409 & 55.25862767 & -45.06811878 & -31.7798752 & -190.4611488 \\ -72.11590133 & 55.25862767 & 455.2117242 & 61.51499813 & -119.7185491 & -315.125691 \\ -219.0229114 & -45.06811878 & 61.51499813 & 450.3450969 & -19.67645873 & -98.47205015 \\ -210.612872 & -31.7798752 & -119.7185491 & -19.67645873 & 457.2963775 & -120.6656782 \\ -266.1512403 & -190.4611488 & -315.125691 & -98.47205015 & -120.6656782 & 1301.627469 \end{bmatrix}$$

Now for A, B, C, and D (skipping details where necessary),

$$A = E(\mathbf{R})' V^{-1} E(\mathbf{R})$$

$$= E(\mathbf{R})' \begin{bmatrix} 1081.705507 & -144.3777141 & -72.11590133 & -219.0229114 & -210.612872 & -266.1512403 \\ -144.3777141 & 301.6613409 & 55.25862767 & -45.06811878 & -31.7798752 & -190.4611488 \\ -72.11590133 & 55.25862767 & 455.2117242 & 61.51499813 & -119.7185491 & -315.125691 \\ -219.0229114 & -45.06811878 & 61.51499813 & 450.3450969 & -19.67645873 & -98.47205015 \\ -210.612872 & -31.7798752 & -119.7185491 & -19.67645873 & 457.2963775 & -120.6656782 \\ -266.1512403 & -190.4611488 & -315.125691 & -98.47205015 & -120.6656782 & 1301.627469 \end{bmatrix} \begin{bmatrix} 0.0115 \\ 0.0079 \\ 0.0136 \\ 0.0042 \\ 0.014 \\ 0.0082 \end{bmatrix}$$

⋮

$$= 0.07479308$$

Similarly,

$$B = E(\mathbf{R})' V^{-1} \mathbf{1} = \mathbf{1}' V^{-1} E(\mathbf{R}) = 4.85386548$$

$$C = \mathbf{1}' V^{-1} \mathbf{1} = 574.898349$$

$$D = AC - B^2 = 19.438409$$

$$\begin{aligned} Var(R_p) &= \frac{C \cdot \{E(R_p)\}^2 - 2B \cdot E(R_p) + A}{D} \\ &= \frac{574.898349 \cdot \{E(R_p)\}^2 - 2 \cdot 4.85386548 \cdot E(R_p) + 0.07479308}{19.438409}. \end{aligned}$$

The portfolio return that minimizes $Var(R_p)$ is the $E(R_p)$ that finds $\frac{d Var(R_p)}{d E(R_p)} = 0$. The efficient frontier only considers $E(R_p) > E(R_p^G)$ where

$$\Rightarrow \frac{d \operatorname{Var}(R_p)}{d E(R_p)} = \frac{574.898349 \cdot 2}{19.438409} \cdot E(R_p^G) - \frac{2 \cdot 4.85386548}{19.438409} = 0$$

$$E(R_p^G) = \frac{2 \cdot 4.85386548}{19.438409} \cdot \frac{19.438409}{574.898349 \cdot 2} = 0.008443$$

$$\sigma_{R_p^G} = \sqrt{\frac{574.898349 \cdot 0.008443^2 - 2 \cdot 4.85386548 \cdot 0.008443 + 0.07479308}{19.438409}} = 0.041707$$

Confirming the minimum variance at $E(R_p^G)$:

$$\frac{d^2 \operatorname{Var}(R_p)}{d E(R_p)^2} = \frac{2C}{D} = 59.15076 > 0$$

Question 2 ii b

Please refer to the Excel screenshot. It contains the graph in (a) as well as the minimum variance portfolio $E(R_p) - \sigma_{R_p}$ pair, which is highlighted on the graph in (a) as a label. The variance is also included in the screenshot.

A	0.07479308
B	4.85386548
C	574.898349
D	19.438409

Equation:

$$Var(R_p) = \frac{C \cdot \{E(R_p)\}^2 - 2B \cdot E(R_p) + A}{D}$$

$$= \frac{574.898349 \cdot \{E(R_p)\}^2 - 2 \cdot 4.85386548 \cdot E(R_p) + 0.07479308}{19.438409}$$

Solving for $E(R_p)$:

$$E(R_p) = \frac{B}{C} \pm \sqrt{\frac{D \cdot Var(R_p) + \frac{B^2}{C} - A}{C}}$$

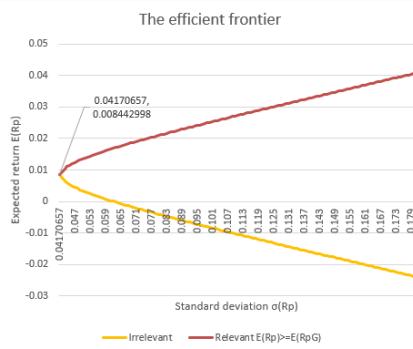
$E(R_p)$ - just refers to

$$E(R_p) = \frac{B}{C} - \sqrt{\frac{D \cdot Var(R_p) + \frac{B^2}{C} - A}{C}}$$

and $E(R_p)+$:

$$E(R_p) = \frac{B}{C} + \sqrt{\frac{D \cdot Var(R_p) + \frac{B^2}{C} - A}{C}}$$

$E(R_p)$	$E(R_p) +$	$Var(R_p)^{0.5}$
0.008443	0.008443	0.041707 GMVP
0.007532	0.00935431	0.042
0.006518	0.01036771	0.043
0.005865	0.01102101	0.044
0.005336	0.01155031	0.045
0.004875	0.01201123	0.046
0.004458	0.01242757	0.047
0.004074	0.01281208	0.048
0.003713	0.01317255	0.049
0.003372	0.0135141	0.05
0.003046	0.01384032	0.051
0.002732	0.01415384	0.052
0.002429	0.01445664	0.053
0.002136	0.01475028	0.054
0.001851	0.01503597	0.055
0.001571	0.01531471	0.056
0.001299	0.01558731	0.057
0.001032	0.01585444	0.058
0.000769	0.01611669	0.059



Since the graph has the standard deviation as the x-axis, the label on the graph to the left is in the order of $(\sigma(R_p), E(R_p))$. In this way, I hope the label on the graph that says $(0.04170657, 0.008442998)$ suffices for the prompt in ii b) to show the global minimum variance portfolio expected return and standard deviation on the graph in (a). Just to make sure, the variance is 0.041707^2 , which is equal to 0.001739.

Question 2 iii a

Revisiting Question 1, the Capital Market Line for the market portfolio is given by

$$E(R_p) = E(R_p^Z) + \frac{D\sigma_{R_{pM}}}{C E(R_{pM}) - B} \times \sigma_{R_p}$$

where $E(R_p^Z) = 0.004$ (given) and R_{p^*} refers to the tangency portfolio $\begin{bmatrix} \sigma_{R_p} \\ E(R_p) \end{bmatrix}$.

The part ii) covers the 6 countries portfolio combined, so the values of A, B, C and D below are equal to those in part ii. $E(R_p^Z)$ is found to be 0.003 from the Excel data. Solving for the tangency portfolio,

$$E(R_p^Z) = \frac{B E(R_{pM}) - A}{C E(R_{pM}) - B}$$

$$0.002955 = \frac{4.85386548 \cdot E(R_{pM}) - 0.07479308}{574.898349 \cdot E(R_{pM}) - 4.85386548}$$

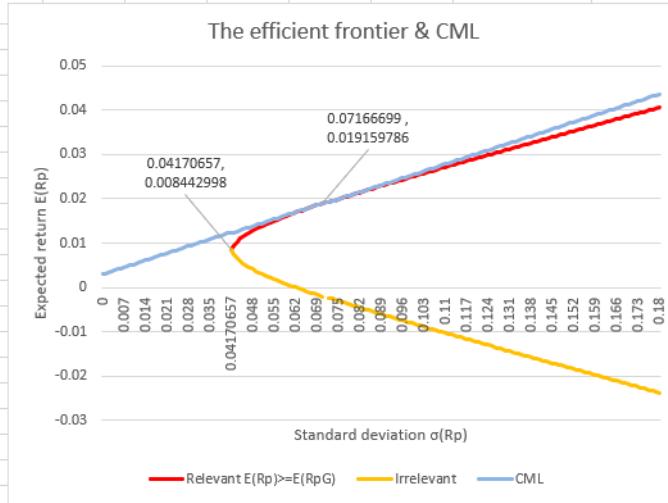
$$E(R_{pM}) = 0.019159786$$

$$\sigma_{R_{pM}} = \sqrt{\frac{574.898349 \cdot \{E(R_{pM})\}^2 - 2 \cdot 4.85386548 \cdot E(R_{pM}) + 0.07479308}{19.438409}} = 0.07166699$$

The Capital Allocation Line is now

$$E(R_p) = 0.002955 + \frac{19.438409 \cdot 0.07166699}{574.898349 \cdot 0.019159786 - 4.85386548} \times \sigma_{R_p} = 0.002955 + 0.226112281 \cdot \sigma_{R_p}$$

1	Tangency portfolio equation:	Capital Market Line
2		
3	$E(R_p^Z) = \frac{B}{C} \frac{E(R_{pM}) - A}{E(R_{pM}) - B}$	$E(R_p) = E(R_p^Z) + \frac{D\sigma_{R_{pM}}}{C(E(R_{pM}) - B)} \times \sigma_{R_p}$
4		
5		
6		
7		
8	Solving for $E(R_{pM})$:	risk-free rate: 0.002955
9		
10	$E(R_{pM}) = \frac{E(R_p^Z) \cdot B - A}{E(R_p^Z) \cdot C - B}$	
11		
12		
13	A 0.074793082	$E(R_{pM})$: 0.019159786
14	B 4.853865484	SD(R_{pM}): 0.07166699
15	C 574.8983488	Slope: 0.226112281
16	D 19.43840905	
17		
18		
19	$E(R_p) -$	$E(R_p) +$
20	0	Var(R_p)^0 CML 0.002955
21	0.001	0.003181112
22	0.002	0.003407225
23	0.003	0.003633337
24	0.004	0.003859449
25	0.005	0.004085561
26	0.006	0.004311674
27	0.007	0.004537786
28	0.008	0.004763898
29	0.009	0.004990011
30	0.01	0.005216123
31	0.011	0.005442235
32	0.012	0.005668347
33	0.013	0.00589446
34	0.014	0.006120572
35	0.015	0.006346684
36	0.016	0.006572796
37	0.017	0.006798909
38	0.018	0.007025021
39	0.019	0.007251133
40	0.02	0.007477246



Question 2 iii b

The market price of risk is the ratio $(\frac{E[R_{pM} - R_p^Z]}{\sigma_{pM}})$. As the name suggests, it is the measure of the investors' opinion on how much worth there is in taking the risk and investing in the asset. Mathematically speaking, the excess return $E(R_{pM} - R_p^Z)$ divided by σ_{pM} is the excess return you receive 'per risk'. It is also known as the Sharpe ratio.

$$\begin{aligned}\frac{E[R_{pM} - R_p^Z]}{\sigma_{pM}} &= \frac{E(R_{pM}) - E(R_p^Z)}{\sigma_{pM}} \\ &= \frac{0.019159786 - 0.002955}{0.07166699} = 0.226112281\end{aligned}$$

Question 2 iii c

$$\text{From lecture notes, } W = \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ w_4 \\ w_5 \\ w_6 \end{bmatrix} = V^{-1} [E(\mathbf{R}), \mathbf{1}] K^{-1} \begin{bmatrix} E(R_p) \\ 1 \end{bmatrix}.$$

$$V^{-1} = \begin{bmatrix} 1081.705507 & -144.3777141 & -72.11590133 & -219.0229114 & -210.612872 & -266.1512403 \\ -144.3777141 & 301.6613409 & 55.25862767 & -45.06811878 & -31.7798752 & -190.4611488 \\ -72.11590133 & 55.25862767 & 455.2117242 & 61.51499813 & -119.7185491 & -315.125691 \\ -219.0229114 & -45.06811878 & 61.51499813 & 450.3450969 & -19.67645873 & -98.47205015 \\ -210.612872 & -31.7798752 & -119.7185491 & -19.67645873 & 457.2963775 & -120.6656782 \\ -266.1512403 & -190.4611488 & -315.125691 & -98.47205015 & -120.6656782 & 1301.627469 \end{bmatrix}$$

$$[E(\mathbf{R}), \mathbf{1}] = \begin{bmatrix} 0.011499167 & 1 \\ 0.007920833 & 1 \\ 0.01362 & 1 \\ 0.004193333 & 1 \\ 0.013995 & 1 \\ 0.008180833 & 1 \end{bmatrix}$$

$$K^{-1} = \begin{bmatrix} 29.57538075 & -0.249704874 \\ -0.249704874 & 0.003847696 \end{bmatrix}$$

$$\begin{bmatrix} E(R_p) \\ 1 \end{bmatrix} = \begin{bmatrix} 0.0191597864624464 \\ 1 \end{bmatrix}$$

Skipping detailed calculation process (you can see from the Excel screenshot that I used Excel to multiply the matrices. I used MMULT(), MINVERSE(), TRANSPOSE() functions),

$$W = \begin{bmatrix} 1.194580052 \\ -0.173763658 \\ 0.513703915 \\ -0.511328037 \\ 0.367502023 \\ -0.390694295 \end{bmatrix}$$

Equation to find weights:

$$W = V^{-1} [E(\mathbf{R}), \mathbf{1}] \begin{bmatrix} \lambda_1 \\ \lambda_2 \end{bmatrix}$$

$$= V^{-1} [E(\mathbf{R}), \mathbf{1}] \mathbf{K}^{-1} \begin{bmatrix} E(R_p) \\ 1 \end{bmatrix}$$

[E(R),1]	0.011499167	1	V^-1	1081.706	-144.377714	-72.1159	-219.023	-210.613	-266.151
	0.007920833	1		-144.378	301.661341	55.25863	-45.0681	-31.7799	-190.461
	0.01362	1		-72.1159	55.2586277	455.2117	61.515	-119.719	-315.126
	0.004193333	1		-219.023	-45.0681188	61.515	450.3451	-19.6765	-98.4721
	0.013995	1		-210.613	-31.7798752	-119.719	-19.6765	457.2964	-120.666
	0.008180833	1		-266.151	-190.461149	-315.126	-98.4721	-120.666	1301.627
K	0.074793082	4.853865	[E(Rp),1]'	0.01916					
		4.853865484	574.8983				1		
K^-1	29.57538075	-0.2497							
		-0.24970487	0.003848						

Calculation:

1	V^-1[E(Rp),1]'	4.269599364	169.4249						
		-0.7100676	-54.7669						
		1.812906336	65.02521						
		-1.23023211	129.6206						
		1.0260448	-45.1571						
		-0.31438531	310.7517						
2	V^-1[E(Rp),1]'K^-1	83.96881157	-0.41424						
		-7.32496059	-0.03342						
		37.38028361	-0.20249						
		-68.7514676	0.805935						
		41.62160253	-0.42996						
		-86.8942695	1.274181						
3	W	1.194580052							
		-0.17376366							
		0.513703915							
		-0.51132804							
		0.367502023							
		-0.3906943							

Question 2 iii d

1

The mean return rate of the risk-free asset is 0.002955 per month. Therefore, the amount of money expected to remain at the end of the month is $500,000 \times (1 + 0.002955) = 501,477.50$. (\$501,477.50)

2

It is found that $E(R_{p_M}) = 0.019159786$. So the result must be

$$\begin{aligned} & 200,000 \cdot (1 + 0.002955) + 300,000 \cdot (1 + 0.019159786) \\ &= 200,591 + 305,747.90 = 506,338.94 \end{aligned}$$

3

If all of \$500,000 was invested in the market portfolio,

$$500,000 \cdot (1 + 0.019159786) = 509579.89$$

4

The sensible assumption is that $Cov(R_{p_M}, R_p^Z) = 0$, but I wanted to acknowledge the risk-free monthly returns were also a sampled real-life data. It should still be negligibly small, but I did not just let it be zero. I re-mapped the market portfolio by ‘weight-averaging’ the data sample of the 6 countries monthly returns. Then the COVARIANCE.S function was used on the market portfolio versus the risk-free month returns. Please refer to the worksheet ‘iii d 4’. I also outlined the scenario of assuming 0 variance and covariance for the risk-free asset. The difference was, as expected, negligible.

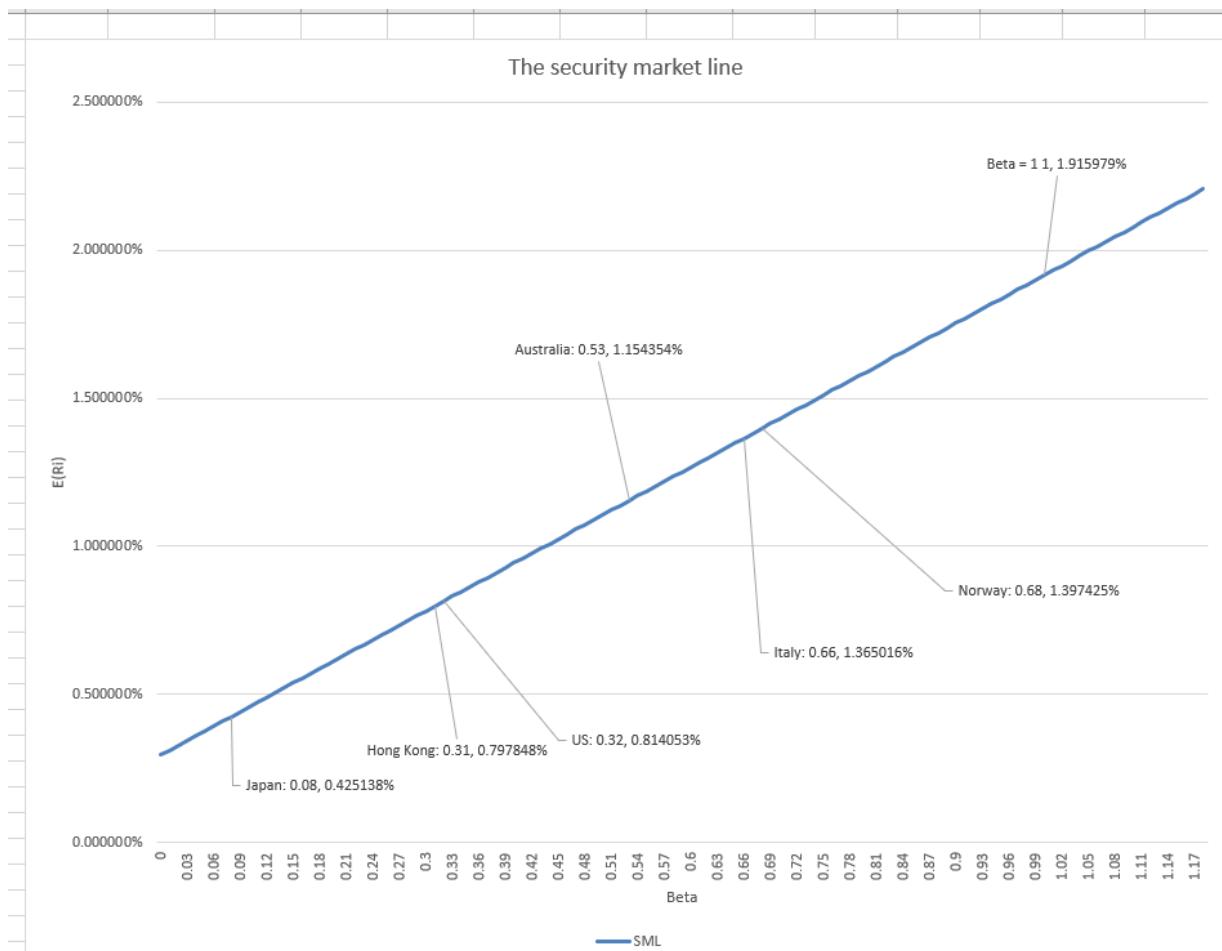
$$\sigma_1 = 0.001460451, \sigma_2 = 0.042931968, \sigma_3 = 0.07166699$$

		ORIGINAL							WEIGHTED								
	Returns	Country Port Month	Country Port Australia	Country Port Hong Kong	Country Port Italy	Country Port Japan	Country Port Norway	Country Port US	Country Port Australia	Country Port Hong Kong	Country Port Italy	Country Port Japan	Country Port Norway	Country Port US	PORTFOLIO RETURN	US Riskfree	
31									1.194580052	-0.17376	0.513704	-0.51133	0.367502	-0.39069			
32									4.29%	-1.08%	1.40%	-1.23%	1.98%	-0.42%	4.93%	0.40%	
33									4.04%	-1.05%	2.95%	-0.23%	3.27%	-0.93%	8.05%	0.42%	
34									10.33%	-0.19%	2.19%	-0.99%	3.25%	-1.45%	13.14%	0.41%	
35									-1.83%	-0.14%	0.34%	0.96%	-2.76%	-0.76%	-4.18%	0.41%	
36									2.66%	-0.47%	2.04%	-0.86%	-1.46%	-0.98%	0.94%	0.42%	
37									2.08%	-0.42%	0.53%	0.42%	1.49%	0.07%	4.17%	0.40%	
38									0.85%	-0.13%	-0.10%	0.56%	-1.07%	0.02%	0.13%	0.40%	
39									-6.56%	-1.09%	-1.10%	3.21%	-2.76%	1.21%	-4.91%	0.43%	
40									11.15%	-0.88%	2.13%	-1.41%	3.61%	-0.51%	14.09%	0.36%	
41									0.51%	-0.21%	1.58%	-1.16%	4.33%	-0.75%	4.31%	0.37%	
42									-2.45%	-0.12%	0.78%	0.52%	-0.30%	0.06%	-1.50%	0.34%	
43									8.95%	-1.01%	3.15%	-2.22%	4.44%	-1.57%	11.75%	0.35%	
44									2.95%	-0.21%	2.26%	-4.56%	1.69%	-0.14%	1.99%	0.32%	
45									3.15%	-0.57%	0.96%	-1.86%	-0.01%	-1.58%	0.08%	0.31%	
46									-6.20%	1.20%	-2.29%	0.38%	-2.63%	0.81%	-9.73%	0.27%	
47									6.39%	-0.42%	0.75%	-4.60%	0.66%	-0.41%	2.38%	0.29%	
48									1.13%	0.17%	0.93%	-3.81%	3.08%	0.23%	1.74%	0.30%	
49									2.89%	-1.08%	2.37%	-0.52%	2.39%	-1.69%	4.36%	0.24%	
50									6.28%	-0.64%	0.41%	-0.36%	3.94%	-0.45%	9.18%	0.23%	
51									-0.12%	0.07%	0.92%	0.99%	0.42%	-1.48%	-1.04%	0.24%	
52									-1.72%	-0.65%	-2.51%	1.10%	-1.29%	0.98%	-4.09%	0.21%	
53									-4.62%	0.59%	-0.32%	1.15%	-1.23%	0.66%	-3.78%	0.21%	
54									5.85%	-0.65%	1.50%	-0.83%	4.64%	-0.89%	9.63%	0.16%	
55									0.88%	0.63%	-0.87%	0.85%	-0.78%	1.04%	1.75%	0.16%	
56									5.20%	-0.37%	4.14%	-2.70%	0.07%	-1.38%	4.96%	0.16%	
57									9.95%	-1.69%	4.03%	-2.45%	4.64%	-1.88%	12.60%	0.15%	
58									7.32%	0.11%	3.04%	-1.23%	0.91%	-0.70%	9.46%	0.11%	
59									7.04%	-0.25%	3.06%	1.43%	4.18%	-0.80%	14.65%	0.11%	
60									1.43%	-1.10%	-0.28%	-0.34%	1.00%	-0.11%	0.60%	0.11%	
61									0.51%	-0.31%	-1.21%	3.12%	-0.54%	1.47%	3.05%	0.10%	
62									-0.22%	0.05%	1.48%	-2.30%	1.19%	-0.84%	-0.74%	0.08%	
63									1.03%	0.12%	-0.28%	1.48%	1.32%	-0.55%	3.12%	0.06%	
64									-5.87%	0.88%	0.69%	2.54%	-0.96%	0.95%	-1.77%	0.08%	
65									5.09%	-0.55%	0.84%	-0.03%	3.24%	-0.61%	7.98%	0.06%	
66									0.59%	-1.67%	1.04%	-0.86%	0.35%	-0.90%	-1.46%	0.07%	
67									9.45%	-0.39%	2.57%	-3.44%	3.45%	-1.78%	9.86%	0.08%	
68									-0.45%	0.02%	4.15%	1.65%	1.97%	-0.65%	6.70%	0.07%	
69									10.27%	-0.83%	2.61%	-2.13%	4.38%	-2.36%	11.96%	0.07%	
70									3.89%	-1.03%	2.18%	-3.14%	0.07%	0.36%	2.19%	0.08%	
71									3.72%	-1.97%	-1.22%	-5.35%	0.29%	-0.97%	-5.51%	0.07%	
72									0.32%	-1.13%	-0.02%	-2.08%	2.34%	-0.90%	-1.46%	0.07%	
73									4.16%	-0.21%	-1.42%	-4.02%	1.44%	-0.64%	-0.69%	0.10%	
74									5.76%	-1.50%	5.43%	-2.39%	1.82%	-2.48%	6.63%	0.09%	
75									10.12%	0.17%	7.05%	-0.32%	4.73%	-3.23%	18.52%	0.10%	
76									3.56%	0.88%	-2.87%	2.23%	0.20%	-0.40%	3.60%	0.10%	
77									-2.84%	0.18%	1.02%	-0.54%	-2.68%	0.60%	-4.26%	0.09%	

Question 2 iii e

Please refer to the Excel screenshot for the SML line, beta values, etc.

The country portfolio Australia has the beta value 0.52726191. This means for every 1% increase/decrease in the market return, Australia portfolio return should increase/decrease by 0.52726191%, hence less risky than the market portfolio. This is a direct relationship between the country portfolio Australia and the system, which cannot be broken by diversification (systematic risk).



$E(R_i) = E(R_p^Z) + \beta_{iM} [E(R_M) - E(R_p^Z)]$,										
$\beta_{iM} = \frac{\text{Cov}(R_i, R_M)}{\sigma_{RM}^2}, \quad i = 1, 2,$										

Question 2 iii f

Please refer to the Excel screenshot for the calculation background. The function cell is exposed for an inspection and you are able to check that the covariance of 0.0045 was divided by the square of the market return standard deviation.

The expected return for the portfolio is 0.0171527.

$$\beta_{iM} = \frac{Cov(R_i, R_M)}{\sigma_{R_M}^2}, \quad i = 1, 2,$$

*****Please note the answer for iii f is
here!!! :)******