QF600 Asset Pricing Homework 3

Linear Factor Model

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Contents

Part 1: Computation

Question 1: Using excess returns for the ten industry portfolios, calculate the following performance metrics

Sharpe Ratio

The Sharpe Ratio formula is below:

$$S_i = \frac{E(R_i - R_f)}{\sqrt{Var(R_i - R_f)}}$$

Therefore, we need to compute the excess return for each industry portfolios. Furthermore, we need to compute the expectation of excess return and standard deviation for each industry portfolios to calculate the Sharpe ratio respectively.

Table 1: The Sharpe ratio for Ten Industry Portfolios

	Sharpe Ratio
NoDur	0.2310988
Durbl	0.0723556
Manuf	0.1666165
Enrgy	0.1817085
HiTec	0.1185525
Telcm	0.1690644
Shops	0.1917534
Hlth	0.1725295
Utils	0.2109477
Other	0.0646929

Table 1 shows the Sharpe ratio for each industry portfolio respectively.

Sortino Ratio (Using Risk-Free Rate as Target)

The Sortino ratio formula is below:

$$S_{t_i} = \frac{E(R_i - R_t)}{\sqrt{SV(R_i; R_t)}}$$

Thus, we need to compute the target return for each industry portfolios and we use the risk-free rate as target return. Furthermore, we need to compute the expectation of excess return and the below-target semi-deviation for each industry portfolios to compute Sortino ratio respectively.

On the other hands, the estimated sample semi-variance formula is:

$$\frac{1}{T} \sum_{t=1}^{T} \min(R_{it} - R_{ft}, 0)^2$$

We could use the square root of below-target semi-variance as denominator for the Sortino ratio.

Table 2: The Sortino Ratio for Ten Industry Portfolios

	Sortino Ratio
NoDur	0.3508041
Durbl	0.1119666
Manuf	0.2412597
Enrgy	0.2736116
HiTec	0.1706204
Telcm	0.2449400
Shops	0.2930315
Hlth	0.2702939
Utils	0.2900436
Other	0.0873509

Table 2 shows the Sortino ratio for ten industry portfolios respectively.

Treynor Ratio (Using CAPM β)

The Treynor ratio formula is below:

$$T_i = \frac{E(R_i - R_f)}{\beta_i}$$

Therefore, we need to compute the expectation of excess return of industry portfolios and the slope β of capital asset pricing model of industry portfolios to calculate the Treynor ratio for each industry portfolios respectively.

Table 3: The Treynor Ratio for Ten Industry Portfolios

	Treynor Ratio
NoDur	1.1863722
Durbl	0.3674626
Manuf	0.7582512
Enrgy	1.1433304
HiTec	0.5642947
Telcm	0.8363634
Shops	0.9512583
Hlth	0.9714347
Utils	1.4523337
Other	0.2997810

Table 3 shows the Treynor ratio for ten industry portfolios respectively.

Jensen's α

The Jensen'a α is the intercept coefficient of market model, and the formula for Jensen's α is that:

$$\alpha_i = E(R_i - R_f) - \beta_i E(R_m - R_f)$$

Therefore, we need to fit the specific industry portfolio excess return with the market excess

return and extract the intercept coefficient for the market model of each industry portfolio respectively.

Table 4: Jensen's Alpha for Ten Industry Portfolios

	Jensen's Alpha
NoDur	0.3697175
Durbl	-0.4179031
Manuf	0.1604943
Enrgy	0.5044852
HiTec	-0.0640236
Telcm	0.1943480
Shops	0.2740926
Hlth	0.2369681
Utils	0.4465234
Other	-0.3875078

Table 4 shows the Jensen's α for ten industry portfolios.

Three-Factor α

The three-factor α is the intercept coefficient for Fama-French 3-Factor Model, and the formula for Fama-French 3-Factor Model is below:

$$R_i - R_f = \alpha_i + \beta_i(R_m - R_f) + \gamma_i(R_s - R_b) + \delta_i(R_h - R_l) + \epsilon$$

Therefore, we need to fit the Fama-French 3-Factor model for specific industry portfolios with market risk, size risk and value risk as independent variables. Furthermore, we could extract the intercept coefficient of Fama-French 3-Factor model as three-factor α for each industry portfolios.

Table 5: Three-Factor Alpha for Ten Industry Portfolio

	Three-Factor Alpha
NoDur	0.3867045
Durbl	-0.4743418
Manuf	0.1532846
Enrgy	0.5230070
HiTec	-0.0659794
Telcm	0.2007240
Shops	0.2559411
Hlth	0.2574723
Utils	0.4744106
Other	-0.4044115

Table 5 shows the three-factor α for ten industry portfolios.

Question 2: Create a table showing the performance metrics of the ten industry portfolios.

Table 6: Sharpe Ratio, Sortino Ratio, Treynor Ratio, Jensen's Alpha and Three-Factor Alpha for Ten Industry Portfolios

	Sharpe Ratio	Sortino Ratio	Treynor Ratio	Jensen's Alpha	Three-Factor Alpha
NoDur	0.2311	0.3508	1.1864	0.3697	0.3867
Durbl	0.0724	0.1120	0.3675	-0.4179	-0.4743
Manuf	0.1666	0.2413	0.7583	0.1605	0.1533
Enrgy	0.1817	0.2736	1.1433	0.5045	0.5230
HiTec	0.1186	0.1706	0.5643	-0.0640	-0.0660
Telcm	0.1691	0.2449	0.8364	0.1943	0.2007
Shops	0.1918	0.2930	0.9513	0.2741	0.2559

	Sharpe Ratio	Sortino Ratio	Treynor Ratio	Jensen's Alpha	Three-Factor Alpha
Hlth	0.1725	0.2703	0.9714	0.2370	0.2575
Utils	0.2109	0.2900	1.4523	0.4465	0.4744
Other	0.0647	0.0874	0.2998	-0.3875	-0.4044

Table 6 show the Sharpe ratio, Sortino ratio, Treynor ratio, Jensen's Alpha and three-factor Alpha for ten industry portfolios respectively.

The Sharpe ratio for industry NoDur is 0.2311, the Sharpe ratio for industry Durbl is 0.0724, the Sharpe ratio for industry Manuf is 0.1666, the Sharpe ratio for industry Enrgy is 0.1817, the Sharpe ratio for industry HiTec is 0.1186, the Sharpe ratio for industry Telem is 0.1691, the Sharpe ratio for industry Shops is 0.1918, the Sharpe ratio for industry Hlth is 0.1725, the Sharpe ratio for industry Utils is 0.2109, the Sharpe ratio for other industry is 0.0647.

The Sortino ratio for industry NoDur is 0.3508, the Sortino ratio for industry Durbl is 0.112, the Sortino ratio for industry Manuf is 0.2413, the Sortino ratio for industry Enrgy is 0.2736, the Sortino ratio for industry HiTec is 0.1706, the Sortino ratio for industry Telcm is 0.2449, the Sortino ratio for industry Shops is 0.293, the Sortino ratio for industry Hlth is 0.2703, the Sortino ratio for industry Utils is 0.29, the Sortino ratio for other industry is 0.0874.

The Treynor ratio for NoDur industry is 1.1864, the Treynor ratio for Durbl industry is 0.3675, the Treynor ratio for Manuf industry is 0.7583, the Treynor ratio for Enrgy industry is 1.1433, the Treynor ratio for HiTec industry is 0.5643, the Treynor ratio for Telcm industry is 0.8364, the Treynor ratio for Shops industry is 0.9513, the Treynor ratio for Hlth industry is 0.9714, the Treynor ratio for Utils industry is 1.4523, the Treynor ratio for other industry is 0.2998.

The Jensen's α for NoDur industry is 0.3697, the Jensen's α for Durbl industry is -0.4179, the Jensen's α for Manuf industry is 0.1605, the Jensen's α for Enrgy industry is 0.5045, the Jensen's α for HiTec industry is -0.064, the Jensen's α for Telcm industry is 0.1943, the Jensen's α for Shops industry is 0.2741, the Jensen's α for Hlth industry is 0.237, the Jensen's α for Utils industry is 0.4465 and the Jensen's α for the other industry is -0.3875

The three-factor α for NoDur industry is 0.3867, the three-factor α for Durbl industry is -0.4743, the three-factor α for Manuf industry is 0.1533, the three-factor α for Enrgy industry is 0.523, the three-factor α for HiTec industry is -0.066, the three-factor α for Telcm industry is 0.2007, the three-factor α for Shops industry is 0.2559, the three-factor α for Hlth industry is 0.2575, the three-factor α for Utils industry is 0.4744 and the three-factor α for the other industry is -0.4044.

Part 2: Visualization of Performance Metrics

Question 3: Plot your Results as a Bar Chart for each Performance Metric
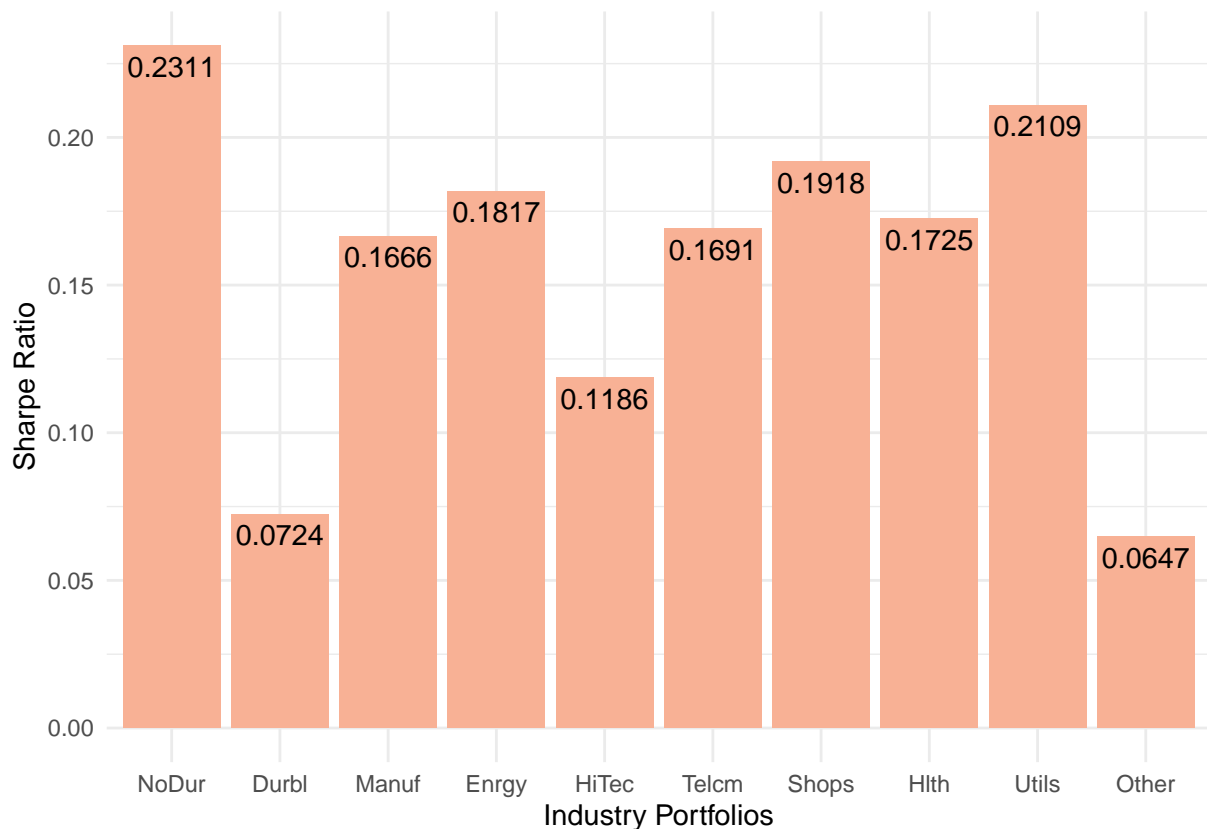
Sharpe Ratio

Figure 1: Sharpe Ratio for Ten Industry Portfolios

Figure 1 is the bar plot which shows the Sharpe ratio for each industry portfolio respectively. We could see that the industry of NoDur has the largest Sharpe ratio in this case. That means the industry of NoDur has the largest risk premium per unit of total risk. On the other hand, the other industry has the smallest Sharpe ratio in this case, that means the other industry has the smallest risk premium per unit of total risk.
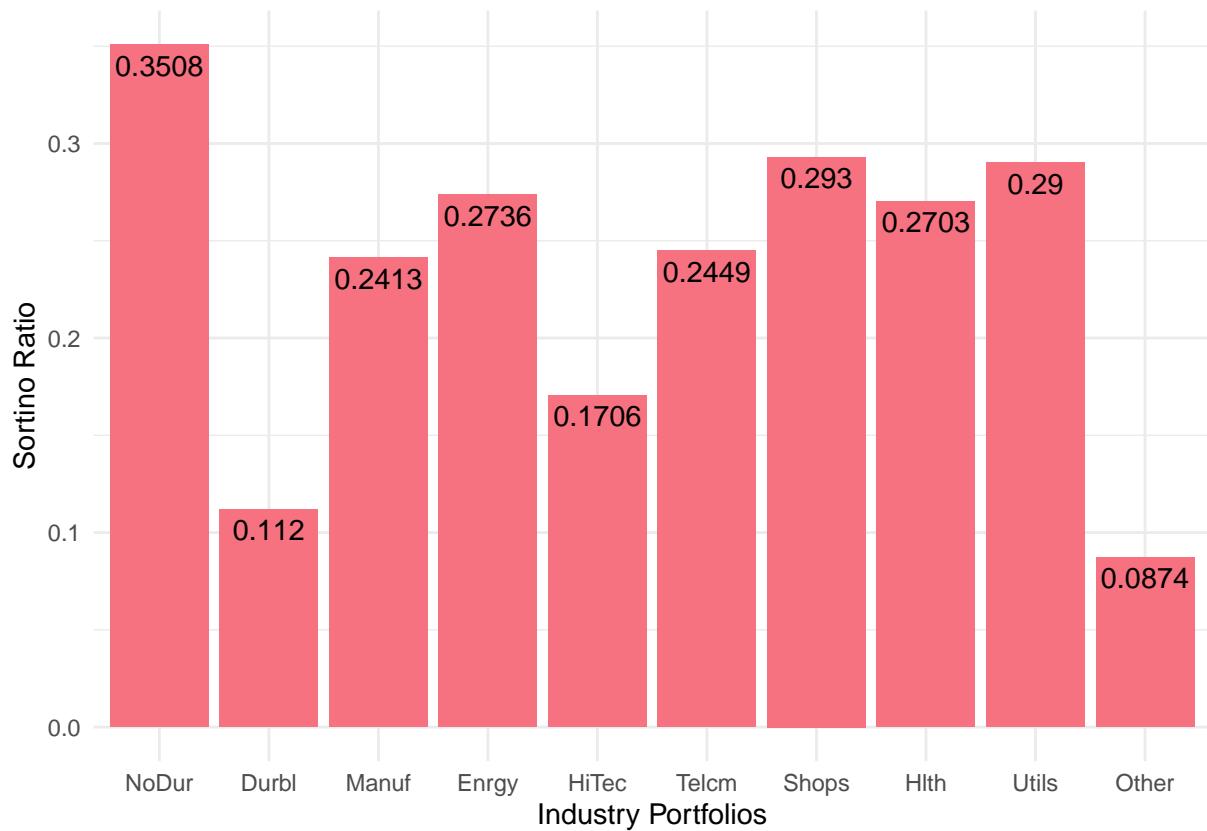
Sortino Ratio (Using Risk-Free Rate as Target)

Figure 2: Sortino Ratio for Ten Industry Portfolios

Figure 2 is the bar plot which shows the Sortino ratio for industry portfolios respectively. We could see that the industry of NoDur has the largest Sortino ratio in this case, that means the industry portfolio of NoDur has the largest expected deviation from risk-free rate, per unit of below-target semi-deviation. On the other hands, the other industry portfolio has the smallest Sortino ratio in this case, that means the other industry portfolio has the smallest expected deviation from risk-free rate, per unit of below-target semi-deviation.
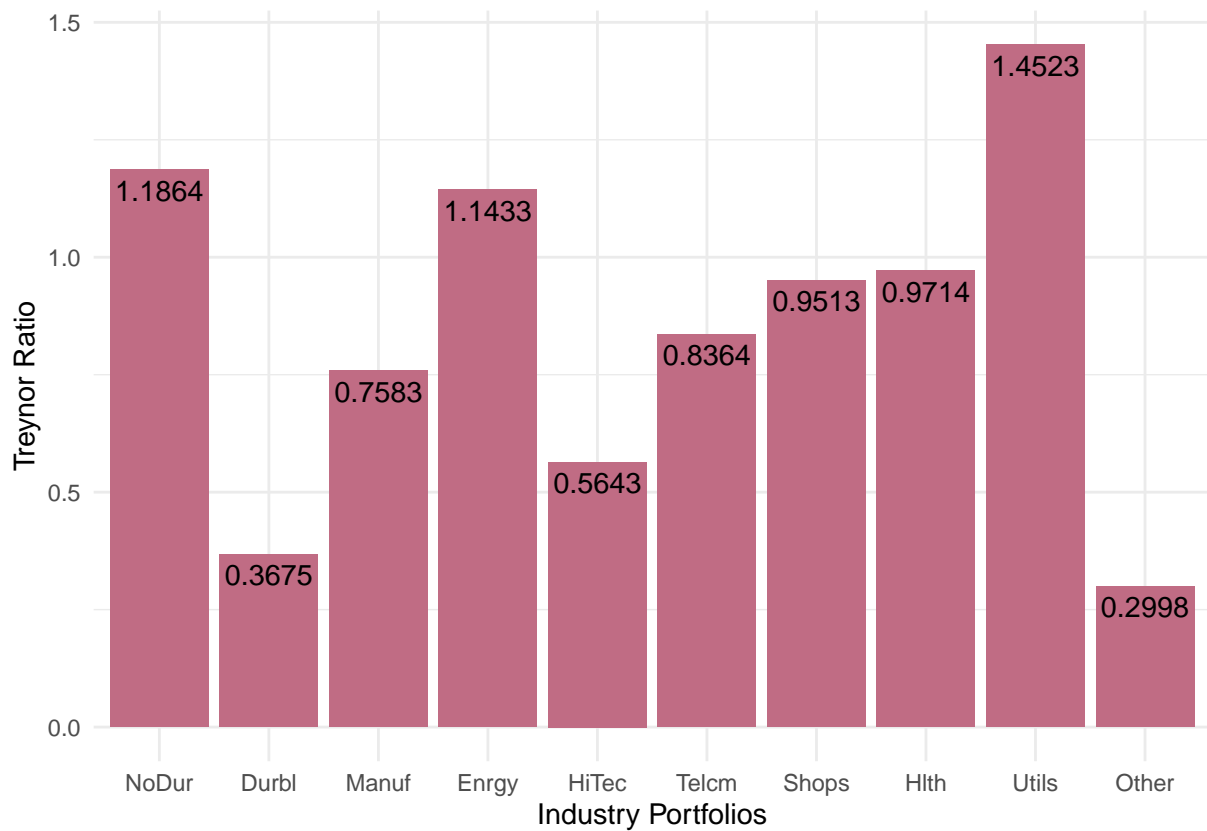
Treynor Ratio (Using CAPM β)

Figure 3: Treynor Ratio for Ten Industry Ratio

Figure 3 is the bar plot which shows the Treynor ratio for industry portfolios respectively. We could see that the industry of Utils has the largest Treynor ratio in this case, which means the industry portfolio of Utils has the largest risk premium per unit of systemic risk. On the other hands, the other industry portfolio has the smallest Treynor ratio in this case, that represents the other industry portfolio has the smallest risk premium per unit of systemic risk.
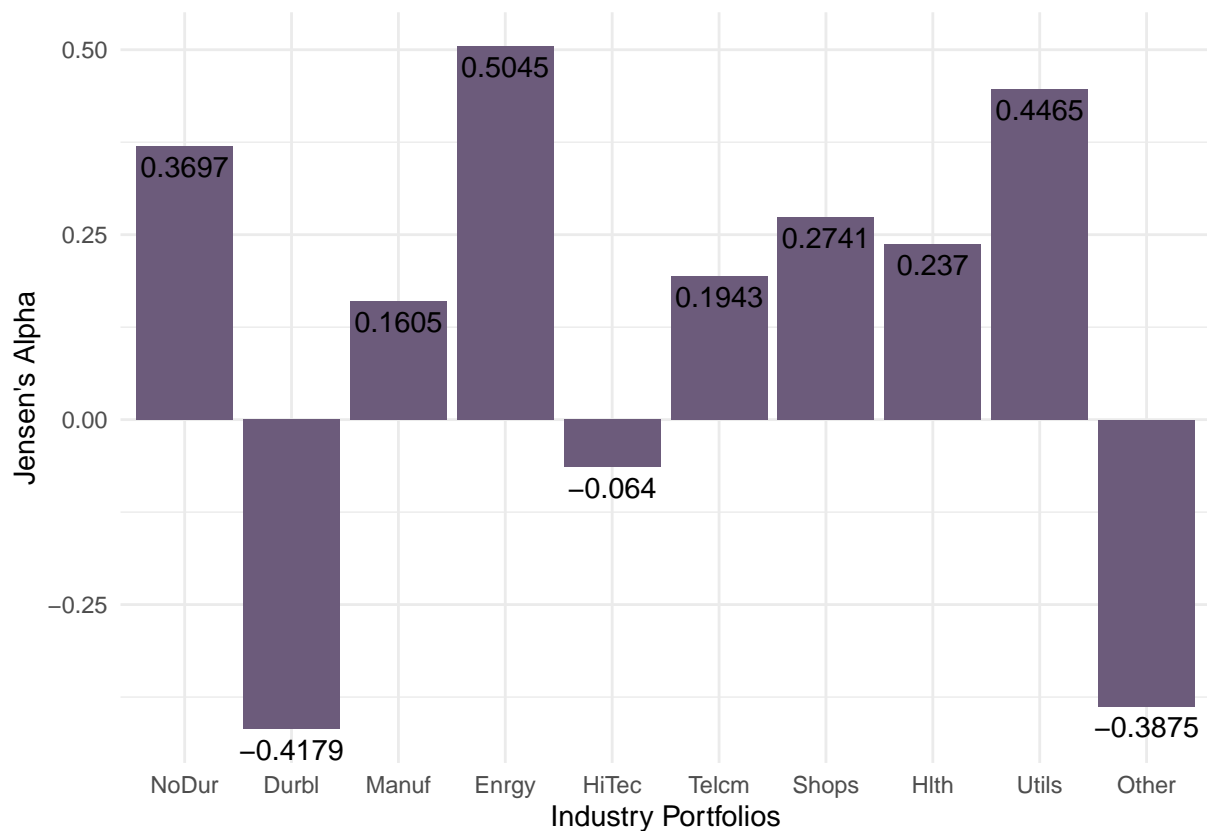
Jensen's α

Figure 4: Jensen's Alpha for Ten Industry Portfolios

Figure 4 is the bar plot which shows the Jensen's α for ten industry portfolios respectively. We could see there are three industry portfolios have the negative Jensen's α in this case, which are Durbl, HiTec and other industry portfolios. If the industry portfolios are active portfolio, that represents these three industry portfolios underperforms the market and the portfolio of Durbl has the most largest negative difference that means the portfolio of Durbl underperforms the worst in this case. On the other hands, the other industry portfolios have the positive Jensen's α that means the other indsutry portfolio outperform the marekt. Furthermore, the industry portfolio of Enrgy has the largest Jensen's α that means that industry portfolio outperform the best relative to the market.
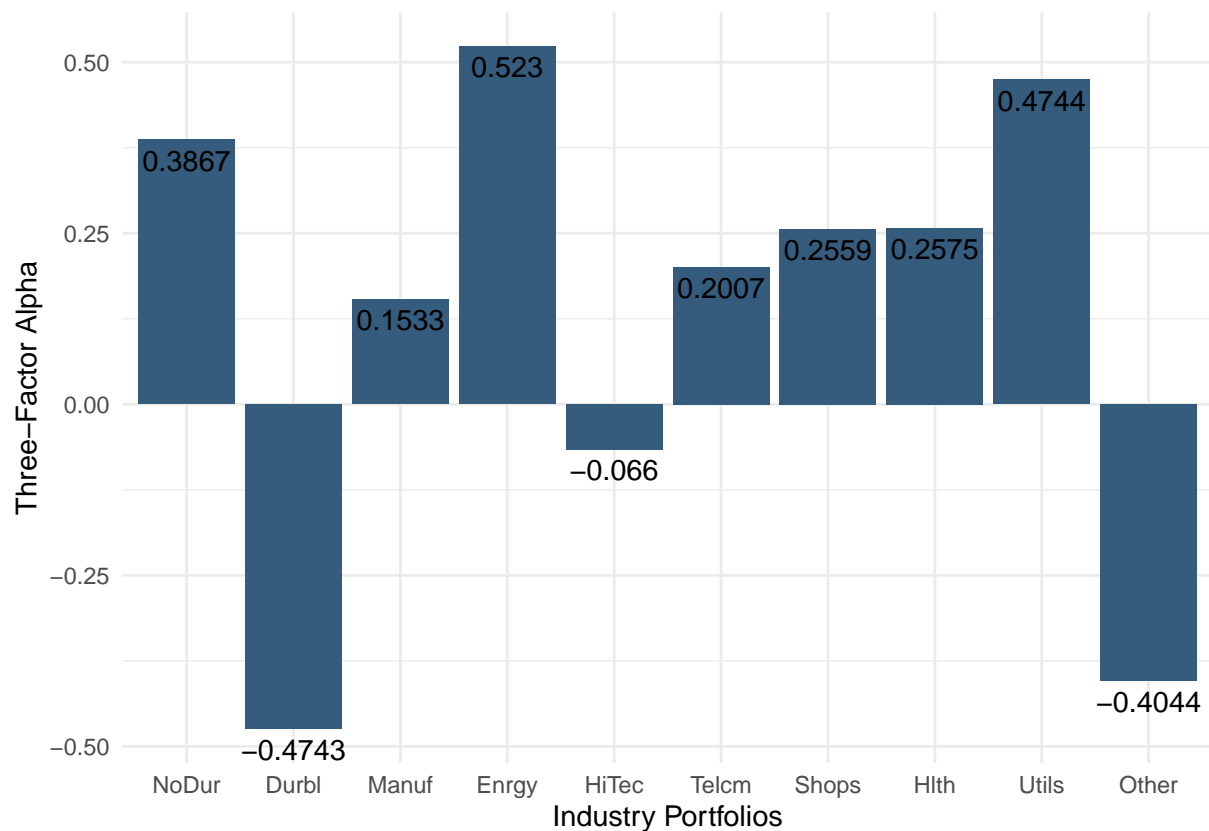
Three-Factor α

Figure 5: Three-Factor Alpha for Ten Industry Portfolios

Figure 5 shows the three-factor α for ten industry portfolios respectively. We could see that there are three industry portfolios have the negative three-factor α which are Durbl, HiTec and other industry portfolios, That represents the these industry portfolio underperform the market after consider size risk and value risk. Meanwhile, the industry portfolio of Durbl has the most negative three-factor α that represents it has the worst performance on beating the market with 3 risk factors. On the other hands, the rest of industry portfolios have the positive three-factor α, that means they outperform the market after consider the size risk and value risk. Furthermore, the industry portfolio of Enrgy has the largest three-factor α, which means the it has the best performance on beating the market.

Part 3: Briefly Explain the Economic Signficance of Performance Ratios

Sharpe Ratio

The Sharpe ratio formula is below:

$$S_i = \frac{E(R_i - R_f)}{\sqrt{\text{Var}(R_i - R_f)}}$$

The Sharpe ratio measure the risk premium per unit of total risk. Base on the formula, $E(R_i - R_f)$ on the numerator represent the expectation of excess return for each portfolio relative to risk-free rate. As the investor would like to compare the excess return for portfolio and seek for the highest one for portfolio selection.

However, the total risk for each asset or portfolio is different and the investor could not compare the excess return without considering about the total risk. Thus, the investor would like to check the excess return of same unit of total risk. Therefore, $\sqrt{\text{Var}(R_i - R_f)}$ on the denominator measure the total risk of excess return. Then, we could use the Sharpe ratio to figure out

As the Sharpe ratio could measure the excess return of portfolio per unit of total risk, then the investor could measure the risk premium per unit of total risk. Moreover, the asset or portfolio have the highest Sharpe ratio, that means the asset or portfolio have the highest risk premium per unit of total risk and the investor would like to select that one.

Sortino Ratio

The Sortino ratio formula is below:

$$S_{t_i} = \frac{E(R_i - R_t)}{\sqrt{\text{SV}(R_i; R_t)}}$$

$$SV(R_i; R_t) = \frac{1}{T} \sum_{t=1}^{T} \min(R_{it} - R_{ft}, 0)^2$$

Sortino ratio measured the expected deviation from target return per unit of below-target semi-deviation. As well, the below-target semi-deviation considered as the downside risk and that means the risk of return of portfolio fall below target return and the return for the investment have losses relative to risk-free rate.

Base on the formula, $E(R_i - R_f)$ on numerator, which is same with Sharpe ratio numerator, also represent the expectation of excess return for asset or portfolio. As the investor would like to measure the excess return per unit of risk of the return lower than the target return for the investors.

Thus, the below-target semi-variance would measure the risk of asset return lower than the target, also considered as downside risk. It would only take the part of asset return lower than the target return, by $\min(R_{it} - R_{ft})$.

Overall, the Sortino ratio measure the risk premium per unit of risk of losses relative to target return. If the asset or portfolio have the higher Sortino ratio that means the asset or portfolio would have higher risk premium for per unit of risk of losses. On the other hands, if the asset or portfolio have the lower Sortino ratio that means the asset or portfolio would have lower risk premium for per unit of risk of losses. The investors would like to select the asset or portfolio with higher Sortino ratio to have more risk premium with given unit risk of losses relative to target return.

Treynor Ratio

The Treynor ratio formula is below:

$$T_i = \frac{E(R_i - R_f)}{\beta_i}$$

The Treynor ratio measures the risk premium for asset or portfolio per unit of market risk. Based on the formula, $E(R_i - R_f)$ on numerator is same with other two ratios, that means the expectation of excess return for the asset or portfolio. However, the β represents the market risk for the asset or portfolio and that could not be reduced by diversification. As the investor would like to measure the excess return on the unit of market risk for diversified portfolio. Thus, we could use the Treynor ratio measures the risk premium for asset or portfolio per unit of market risk.

If the asset or portfolio have the higher Treynor risk, that demonstrates the asset or portfolio would have higher risk premium for each unit of market risk. On the other hands, if the asset or portfolio have the lower Treynor risk, that demonstrates the asset or portfolio would have lower risk premium for each unit of market risk. Thus, the investors would like to select the portfolio with higher Treynor ratio to have higher risk premiun with given unit market risk.

Appendix

Part 1 - Sharpe Ratio

```r
# import the data frame of risk factors for fama-french model
factor_df = read_excel("Risk_Factors.xlsx") %>%
  # drop the column of data
  select(!Date)
# import the data frame of industry portfolios
industry_df = read_excel("Industry_Portfolios.xlsx")
# drop the column of data frame
industry_df = industry_df %>%
  select(!Date)
```

```r
# compute the excess return of industry portfolios
excess_industry_df = industry_df - factor_df$Rf
# compute the mean of excess return of industry portfolios
excess_return = colMeans(excess_industry_df)
# compute the variance of excess return of industry portfolios
var_return = diag(cov(excess_industry_df))
```

```r
# compute the Sharpe ratio
sharpe = excess_return / sqrt(var_return)
# create a table to show the sharpe ratio
kable(sharpe,
      col.names = "Sharpe Ratio",
      caption = "The Sharpe ratio for Ten Industry Portfolios")
```

Part 1 - Sortino Ratio

```r
# compute the below-target semi-variance
semivar_df = data.frame()
for (i in seq(nrow(excess_industry_df))){
  for (j in seq(ncol(excess_industry_df))){
    if(excess_industry_df[i, j] < 0){
      semivar_df[i, j] = excess_industry_df[i, j] ^ 2
    } else{
      semivar_df[i, j] = 0
```

```r
    }
  }
}
# reset the column name for semi-variance dataframe
colnames(semivar_df) = c("NoDur", "Durbl", "Manuf", "Enrgy", "HiTec", "Telcm",
↪ "Shops", "Hlth", "Utils", "Other")
# compute the below-target semi-variance
semidev_target = colMeans(semivar_df)
```

```r
# compute the sortino ratio for industry portfolios
sortino = excess_return / sqrt(semidev_target)
# create a table to show the sortiono ratio for industry portfolios
kable(sortino,
      col.names = "Sortino Ratio",
      caption = "The Sortino Ratio for Ten Industry Portfolios")
```

Part 1 - Treynor Ratio

```r
# create a data frame includes the excess return
return_df = data.frame(excess_industry_df)
# add the market excess return into the data frame
return_df$market_risk = factor_df$`Rm-Rf`
```

```r
# fit the market model for industry NoDur
model1 = lm(NoDur ~ market_risk, data = return_df)
# beta of CAPM for industry NoDur
beta1 = summary(model1)$coefficients[2]
```

```r
# fit the market model for industry Durbl
model2 = lm(Durbl ~ market_risk, data = return_df)
# beta of CAPM for industry Durbl
beta2 = summary(model2)$coefficients[2]
```

```r
# fit the market model for industry Manuf
model3 = lm(Manuf ~ market_risk, data = return_df)
# beta of CAPM for industry Manuf
beta3 = summary(model3)$coefficients[2]
```

```r
# fit the market model for industry Enrgy
model4 = lm(Enrgy ~ market_risk, data = return_df)
# beta of CAPM for industry Enrgy
beta4 = summary(model4)$coefficient[2]
```

```r
# fit the market model for industry HiTec
model5 = lm(HiTec ~ market_risk, data = return_df)
# beta of CAPM for industry HiTec
beta5 = summary(model5)$coefficient[2]
```

```r
# fit the market model for industry Telcm
model6 = lm(Telcm ~ market_risk, data = return_df)
# beta of CAPM for industry Telcm
beta6 = summary(model6)$coefficient[2]
```

```r
# fit the market model for industry Shops
model7 = lm(Shops ~ market_risk, data = return_df)
# beta of CAPM for industry Shops
beta7 = summary(model7)$coefficient[2]
```

```r
# fit the market model for industry Hlth
model8 = lm(Hlth ~ market_risk, data = return_df)
# beta of CAPM for industry Hlth
beta8 = summary(model8)$coefficient[2]
```

```r
# fit the market model for industry Utils
model9 = lm(Utils ~ market_risk, data = return_df)
# beta of CAPM for industry Utils
beta9 = summary(model9)$coefficient[2]
```

```r
# fit the market model for other industry
model10 = lm(Other ~ market_risk, data = return_df)
# beta of CAPM for other industry
beta10 = summary(model10)$coefficient[2]
```

```r
# extract the slope coefficient from each market model
beta_df = data.frame(rbind(beta1, beta2, beta3, beta4, beta5, beta6, beta7, beta8,
↪  beta9, beta10),
                      row.names = c("NoDur", "Durbl", "Manuf", "Enrgy", "HiTec",
                      ↪  "Telcm", "Shops", "Hlth", "Utils", "Other"))

# reset the column name for beta data frame
colnames(beta_df) = "Beta"
```

```r
# compute the Treynor ratio for each industry portfolio
Treynor = excess_return / beta_df
# create a table to show Treynor ratio for industry portfolios
kable(Treynor,
      col.names = "Treynor Ratio",
      caption = "The Treynor Ratio for Ten Industry Portfolios")
```

Part 1 - Jensen's Alpha

```r
# extract the intercept coefficients from the market model for each industry
↪  portfolios
alpha1 = summary(model1)$coefficients[1]
alpha2 = summary(model2)$coefficients[1]
alpha3 = summary(model3)$coefficients[1]
alpha4 = summary(model4)$coefficients[1]
alpha5 = summary(model5)$coefficients[1]
alpha6 = summary(model6)$coefficients[1]
alpha7 = summary(model7)$coefficients[1]
alpha8 = summary(model8)$coefficients[1]
alpha9 = summary(model9)$coefficients[1]
alpha10 = summary(model10)$coefficients[1]
# create a data frame contains the intercept coefficient Jensen's alpha
alpha_df = data.frame(rbind(alpha1, alpha2, alpha3, alpha4, alpha5, alpha6, alpha7,
↪  alpha8, alpha9, alpha10), row.names =  c("NoDur", "Durbl", "Manuf", "Enrgy",
↪  "HiTec", "Telcm", "Shops", "Hlth", "Utils", "Other"))
# reset the column name of the Jensen's alpha data frame
colnames(alpha_df) = "JensenAlpha"
```

```r
# create a table to show the Jensen's Alpha for industry portfolios
kable(alpha_df,
      col.names = "Jensen's Alpha",
      caption = "Jensen's Alpha for Ten Industry Portfolios")
```

Part 1 - Three-Factor Alpha

```r
# add the column of size risk to return data frame
return_df$size_risk = factor_df$SMB
# add the column of value risk to return data frame
return_df$value_risk = factor_df$HML
```

```r
# fit the fama-french 3 factor model for NoDur industry
model11 = lm(NoDur ~ market_risk + size_risk + value_risk, data = return_df)
# intercept coefficient of the model for NoDur
alpha11 = summary(model11)$coefficients[1]
```

```r
# fit the fama-french 3 factor model for Durbl industry
model12 = lm(Durbl ~ market_risk + size_risk + value_risk, data = return_df)
# intercept coefficient of the model for Durbl
alpha12 = summary(model12)$coefficients[1]
```

```r
# fit the fame-french 3 factor model for Manuf industry
model13 = lm(Manuf ~ market_risk + size_risk + value_risk, data = return_df)
# intercpet coefficient of the model for Manuf
alpha13 = summary(model13)$coefficients[1]
```

```r
# fit the fama-french 3 factor model for Enrgy industry
model14 = lm(Enrgy ~ market_risk + size_risk + value_risk, data = return_df)
# intercept coefficient of model for Enrgy
alpha14 = summary(model14)$coefficients[1]
```

```r
# fit the fama-french 3 factor model for HiTec industry
model15 = lm(HiTec ~  market_risk + size_risk + value_risk, data = return_df)
# intercept coefficient of model for HiTec
alpha15 = summary(model15)$coefficients[1]
```

```r
# fit the fama-french 3 factor model for Telcm industry
model16 = lm(Telcm ~ market_risk + size_risk + value_risk, data = return_df)
# intercpet coefficient of model for Telcm
alpha16 = summary(model16)$coefficients[1]
```

```r
# fit the fama-french 3 factor model for Shops industry
model17 = lm(Shops ~ market_risk + size_risk + value_risk, data = return_df)
# intercept coefficien of model for Shops
alpha17 = summary(model17)$coefficients[1]
```

```r
# fit the fama-french 3 factor model for Hlth industry
model18 = lm(Hlth ~ market_risk + size_risk + value_risk, data = return_df)
# intercept coefficient of the model for Hlth
alpha18 = summary(model18)$coefficients[1]
```

```r
# fit the fama-french 3 factor model for Utils industry
model19 = lm(Utils ~ market_risk + size_risk + value_risk, data = return_df)
# intercpet coefficient of the mdoel for Utilis
alpha19 = summary(model19)$coefficients[1]
```

```r
# fit the fama-french 3 factor model for other industry
model20 = lm(Other ~ market_risk + size_risk + value_risk, data = return_df)
# intercept coefficient of the model for the other industry
alpha20 = summary(model20)$coefficients[1]
```

```r
# extract the three factor alpha for the industry portfolios
three_alpha_df = data.frame(rbind(alpha11, alpha12, alpha13, alpha14, alpha15,
↪   alpha16, alpha17, alpha18, alpha19, alpha20),
                            row.names =  c("NoDur", "Durbl", "Manuf", "Enrgy",
                            ↪   "HiTec", "Telcm", "Shops", "Hlth", "Utils", "Other"))
# reset the column name for the three factor alpha data frame
colnames(three_alpha_df) = "ThreeFactorAlpha"
```

```r
# crate a table to show the three-factor alpha for ten industry portfolios
kable(three_alpha_df,
      col.names = "Three-Factor Alpha",
      caption = "Three-Factor Alpha for Ten Industry Portfolio")
```

Part 1 - Question 2

```r
# create a new data frame to include the sharpe ratio, sortino ratio, Treynor ratio,
↪  Jensen's alpha and three-factor alpha
final_df = data.frame(sharpe, sortino, Treynor, alpha_df, three_alpha_df)
colnames(final_df) = c("sharpe", 'sortino', 'treynor', "Jensen's alpha", 'three-factor
↪  alpha')

# create a table to show the performance metrics of ten industry portfolios
kable(final_df,
      col.names = c("Sharpe Ratio", "Sortino Ratio", "Treynor Ratio", "Jensen's
      ↪  Alpha", "Three-Factor Alpha"),
      caption = "Sharpe Ratio, Sortino Ratio, Treynor Ratio, Jensen's Alpha and
      ↪  Three-Factor Alpha for Ten Industry Portfolios", digits = 4)
```

Part 2 - Sharpe Ratio

```r
# Sharpe ratio bar plot
final_df %>%
  # select the categorical of industry portfolio as x-axis
  # select Sharpe ratio as y-axis
  ggplot(aes(x = factor(row.names(final_df), levels = c("NoDur", "Durbl", "Manuf",
  ↪  "Enrgy", "HiTec", "Telcm", "Shops", "Hlth", "Utils", "Other")), y = sharpe)) +
  # plot bar chart and adjust the filling color
  geom_bar(stat = 'identity', fill ='#F8B195') +
  # add the text to show the corresponding Sharpe ratio
  geom_text(aes(label = round(sharpe, 4)), vjust = 1.5)+
  # use the minimalistic theme
  theme_minimal() +
  # add x label
  xlab("Industry Portfolios") +
  # add y label
  ylab("Sharpe Ratio")
```

Part 2 - Sortino Ratio

```r
# Sortino ratio bar chart
final_df %>%
  # select the categorical of industry portfolio as x-axis
  # use Sortino ratio as y-axix
  ggplot(aes(x = factor(row.names(final_df), levels = c("NoDur", "Durbl", "Manuf",
  →   "Enrgy", "HiTec", "Telcm", "Shops", "Hlth", "Utils", "Other")), y = sortino)) +
  # plot bar chart and adjst the fill color
  geom_bar(stat = 'identity', fill ='#F67280') +
  # add text of number of Sortino ratio corresponding to each industry portfolios
  geom_text(aes(label = round(sortino, 4)), vjust = 1.5)+
  # use minimalistic theme
  theme_minimal() +
  # add x label
  xlab("Industry Portfolios") +
  # add y label
  ylab("Sortino Ratio")
```

Part 2 - Treynor Ratio

```r
# Treynor ratio bar chart
final_df %>%
  # select categorical of industry portfolio as x-axis
  # use Treynor ratio corresponding to industry portfolio as x-axis
  ggplot(aes(x = factor(row.names(final_df), levels = c("NoDur", "Durbl", "Manuf",
  →   "Enrgy", "HiTec", "Telcm", "Shops", "Hlth", "Utils", "Other")), y = treynor)) +
  # plot the bar chart and adjust the filling color
  geom_bar(stat = 'identity', fill ='#C06C84') +
  # add text to show Treynor ratio corresponding to each industry portfolios
  geom_text(aes(label = round(treynor, 4)), vjust = 1.5)+
  # use minimalistic theme
  theme_minimal() +
  # add x label
  xlab("Industry Portfolios") +
  # add y label
  ylab("Treynor Ratio")
```

Part 2 - Jensen's alpha

```r
# Jensen's alpha bar chart
final_df %>%
  # select categorical of industry portfolio as x-axis
  # select Jensen's alpha as y-axis
  ggplot(aes(x = factor(row.names(final_df), levels = c("NoDur", "Durbl", "Manuf",
  →   "Enrgy", "HiTec", "Telcm", "Shops", "Hlth", "Utils", "Other")), y = `Jensen's
  →   alpha`)) +
  # plot bar chart and adjust filling color
  geom_bar(stat = 'identity', fill ='#6C5B7B') +
  # add text to show Jensen's alpha corresponding industry portfolio
  geom_text(aes(label = round(`Jensen's alpha`, 4)), vjust = 1.5)+
  # use minimalistic theme
  theme_minimal() +
  # add x label
  xlab("Industry Portfolios") +
  # add y label
  ylab("Jensen's Alpha")
```

Part 2 - Three-Factor alpha

```r
# three-factor alpha bar chart
final_df %>%
  # use categorical of industry portoflios as x-axis
  # use three-factor alpha as y-axis
  ggplot(aes(x = factor(row.names(final_df), levels = c("NoDur", "Durbl", "Manuf",
  →   "Enrgy", "HiTec", "Telcm", "Shops", "Hlth", "Utils", "Other")), y =
  →   `three-factor alpha`)) +
  # plot bar chart and adjst filling color
  geom_bar(stat = 'identity', fill ='#355C7D') +
  # add text to show three-factor alpha corresponding to industry portfolio
  geom_text(aes(label = round(`three-factor alpha`, 4)), vjust = 1.5) +
  # use minimalistic theme
  theme_minimal() +
  # add x label
  xlab("Industry Portfolios") +
  # add y label
  ylab("Three-Factor Alpha")
```