HWDiamond Price

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Table of contents

Kaggle URL: https://www.kaggle.com/datasets/enashed/diamond-prices/discussion/547512

```
library(readr)
library(psych)
library(Hmisc)
library(DataExplorer)
library(ggplot2)
library(MASS)
library(car)
library(stargazer)
data <- data.table::fread("Diamonds Prices2022.csv")[,-1]
```

0. 資料簡介

Dimension of the Data : ***53943 samples x 10 columns***

Variables	Explanation	remark
carat	克拉 (重量)	連續變數 (公克)
cut	切工	類別變數, Fair,Good,Ideal,Premium,Very Good
color	顏色	類別變數, D,E,F,G,H,I,J 無色(D~F),近乎無色(G~J)
clarity	淨度	類別變數, IF: 內部無暇,VVS1: 極輕微瑕,VS1: 輕微內含物 1,VS2: 輕微內含物 2,SI1: 微內含物 1,SI2: 微內含物 2,I1: 內含物
depth	深度	連續變數 (mm)
table	檯面尺寸	連續變數
price	價格	連續變數
x	鑽石的長	連續變數 (mm)
y	鑽石的寬	連續變數 (mm)

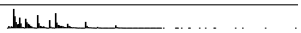
Variables	Explanation	remark
z	鑽石的高	連續變數 (mm)

1.Data Preprocessing

```
latex(describe(data, title="Diamond Price Dataset"), title="", file="")
```

data
10 Variables 53943 Observations

carat



n	missing	distinct	Info	Mean	Gmd	.05	.10	.25	.50	.75	.90	.95
53943	0	273	0.999	0.7979	0.5122	0.30	0.31	0.40	0.70	1.04	1.51	1.70

lowest : 0.2 0.21 0.22 0.23 0.24, highest: 4 4.01 4.13 4.5 5.01

cut

n	missing	distinct
53943	0	5

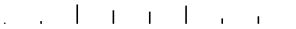
Value	Fair	Good	Ideal	Premium	Very Good
Frequency	1610	4906	21551	13793	12083
Proportion	0.030	0.091	0.400	0.256	0.224

color

n	missing	distinct
53943	0	7

Value	D	E	F	G	H	I	J
Frequency	6775	9799	9543	11292	8304	5422	2808
Proportion	0.126	0.182	0.177	0.209	0.154	0.101	0.052

clarity



n	missing	distinct
53943	0	8

Value	I1	IF	SI1	SI2	VS1	VS2	VVS1	VVS2
Frequency	741	1790	13067	9194	8171	12259	3655	5066
Proportion	0.014	0.033	0.242	0.170	0.151	0.227	0.068	0.094

depth

n	missing	distinct	Info	Mean	Gmd	.05	.10	.25	.50	.75	.90	.95
53943	0	184	0.999	61.75	1.515	59.3	60.0	61.0	61.8	62.5	63.3	63.8

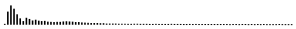
lowest : 43 44 50.8 51 52.2, highest: 72.2 72.9 73.6 78.2 79

table

n	missing	distinct	Info	Mean	Gmd	.05	.10	.25	.50	.75	.90	.95
53943	0	127	0.98	57.46	2.448	54	55	56	57	59	60	61

lowest : 43 44 49 50 50.1, highest: 71 73 76 79 95

price



n	missing	distinct	Info	Mean	Gmd	.05	.10	.25	.50	.75	.90	.95
53943	0	11602	1	3933	4012	544	646	950	2401	5324	9821	13107

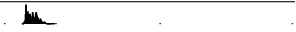
lowest : 326 327 334 335 336, highest: 18803 18804 18806 18818 18823

x

n	missing	distinct	Info	Mean	Gmd	.05	.10	.25	.50	.75	.90	.95
53943	0	554	1	5.731	1.276	4.29	4.36	4.71	5.70	6.54	7.31	7.66

lowest : 0 3.73 3.74 3.76 3.77 , highest: 10.01 10.02 10.14 10.23 10.74

y



n	missing	distinct	Info	Mean	Gmd	.05	.10	.25	.50	.75	.90	.95
53943	0	552	1	5.735	1.269	4.30	4.36	4.72	5.71	6.54	7.30	7.65

lowest : 0 3.68 3.71 3.72 3.73 , highest: 10.1 10.16 10.54 31.8 58.9

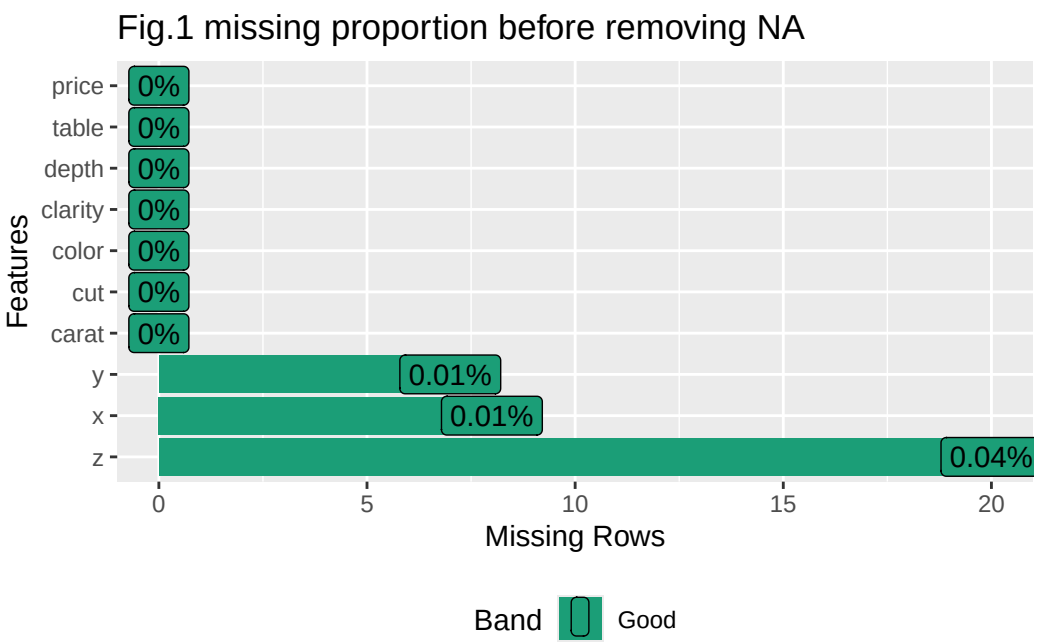
```
z
       n  missing distinct     Info     Mean      Gmd      .05      .10      .25      .50      .75      .90      .95
   53943        0      375        1    3.539   0.7901     2.65     2.69     2.91     3.53     4.04     4.52     4.73

lowest : 0    1.07 1.41 1.53 2.06, highest: 6.43 6.72 6.98 8.06 31.8
```

由 describe 可以發現 x,y,z(長、寬、高) 當中出現 0，這是不合理的量測數值，因此將其作為遺失值處理。

經檢查，此資料有 20 筆資料的長或寬或高為 0，與五萬多的樣本數相比算小，因此刪除。

此外還發現反應變數”價格”有離群值，在後續使用模型建立預測模式時需多加考量。

```
data$x[data$x==0] <- NA
data$y[data$y==0] <- NA
data$z[data$z==0] <- NA
DataExplorer::plot_missing(
  data,
  title = "Fig.1 missing proportion before removing NA")
```




```
data <- data[!(is.na(data$x) | is.na(data$y) | is.na(data$z)),]
```

我們認為僅僅觀察單一的長、寬、高並不具有任何意義，因此建立新變數密度 $= x \times y \times z$。

此外，一些類別型變數以 ordinal 的方式處理，賦予其從 1 開始的整數。(這裡幫我補說明)

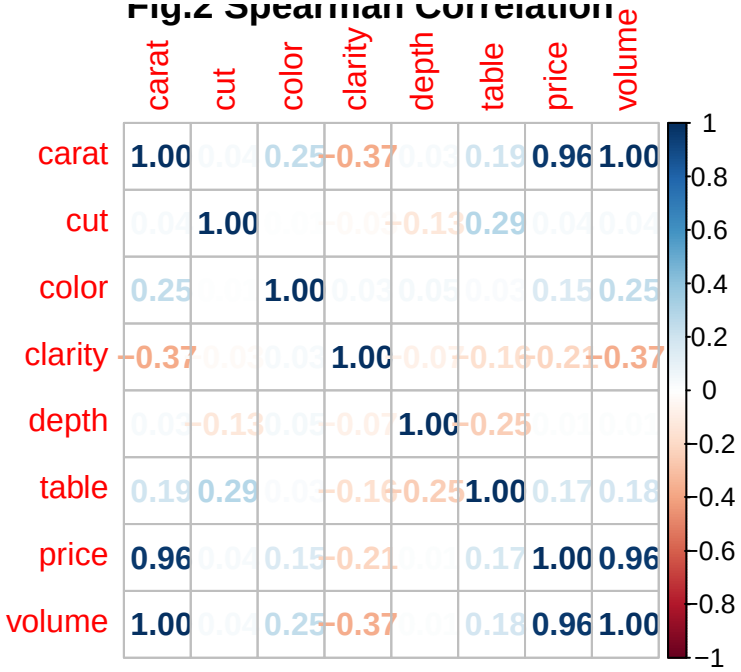
```
# 定義體積 = x * y * z
data$volume <- data$x * data$y * data$z
data$x <- NULL
data$y <- NULL
data$z <- NULL

# 定義類別順序
levelcut <- c("Fair", "Good", "Ideal", "Premium", "Very Good")
levelcolor <- c("D","E","F","G","H","I","J")
levelclarity <- c("I1","SI2","SI1","VS2","VS1","VVS2","VVS1","IF")

# 使用 match 進行編碼
data$cut <- match(data$cut,levelcut)
```

```
data$color <- match(data$color,levelcolor)
data$clarity <- match(data$clarity,levelclarity)
```

2.Data visualization for exploratory data analysis

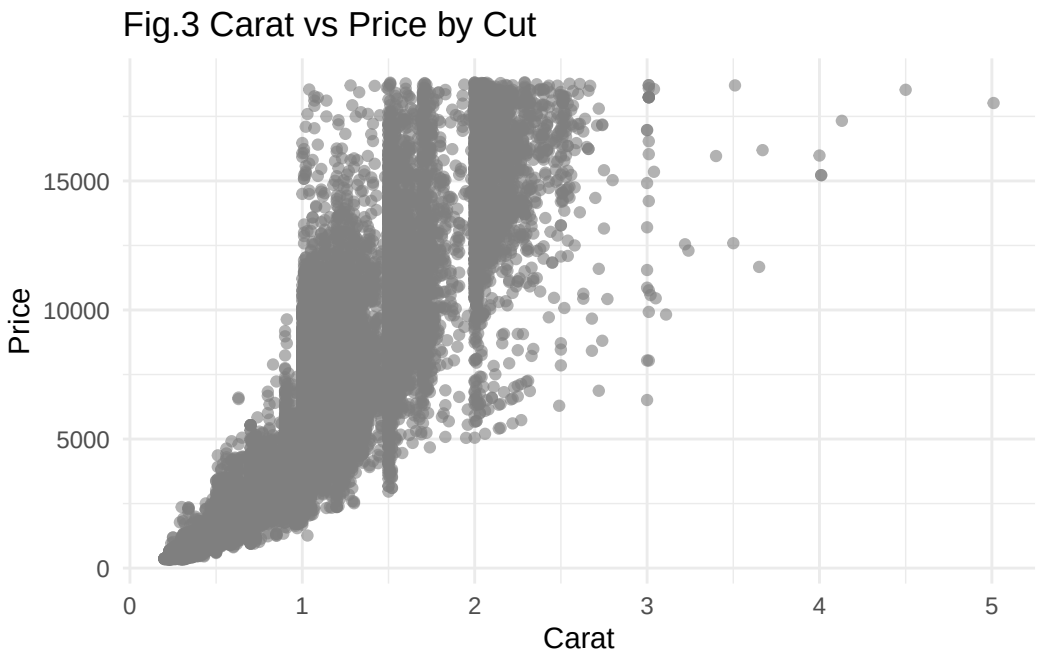
從圖 2 的 Spearman 相關係數可以發現，鑽石的克拉數與體積幾乎與價格是正比，在後續分析的時候可以稍微注意，此外並無其他變數有特別的相關性。

```
corrplot::corrplot(cor(data, method = 'spearman'),
                   method = 'number',
                   title = "Fig.2 Spearman Correlation")
```



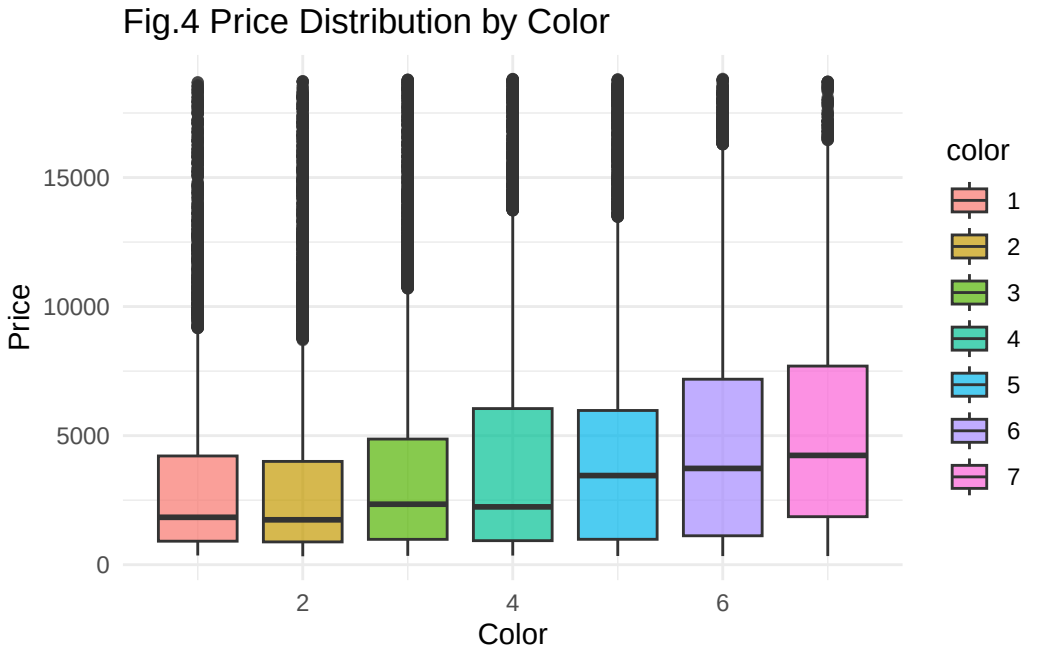

```
# 克拉對價格（加切工）
ggplot(data, aes(x = carat, y = price, color = factor(cut))) +
  geom_point(alpha = 0.6) +
  labs(title = "Fig.3 Carat vs Price by Cut",
       x = "Carat",
       y = "Price",
       color = "Cut") +
  scale_color_manual(values = c( "Fair" = "red", "Good" = "blue", "Ideal" = "green", "Premium" = "purple
  theme_minimal()
```

```
Warning: No shared levels found between `names(values)` of the manual scale and the
data's colour values.
No shared levels found between `names(values)` of the manual scale and the
data's colour values.
```



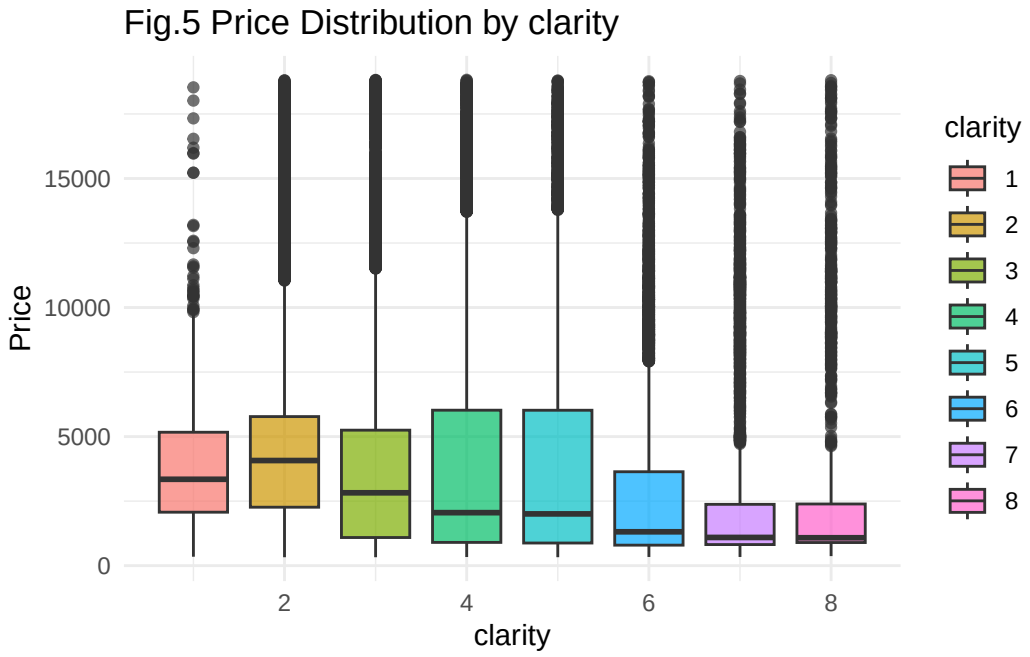
從圖 3 可發現大致上越重的鑽石價格越高。

```
# 顏色對價格圖
ggplot(data, aes(x = color, y = price, fill = factor(color))) +
    geom_boxplot(alpha = 0.7) +
    labs(title = "Fig.4 Price Distribution by Color",
         x = "Color",
         y = "Price",
         fill = "color") +
    theme_minimal()
```



從圖 4 可發現當分類越靠近接近無色時價格越高。

```
# 淨度對價格
ggplot(data, aes(x = clarity, y = price, fill = factor(clarity))) +
  geom_boxplot(alpha = 0.7) +
  labs(title = "Fig.5 Price Distribution by clarity",
       x = "clarity",
       y = "Price",
       fill = "clarity") +
  theme_minimal()
```

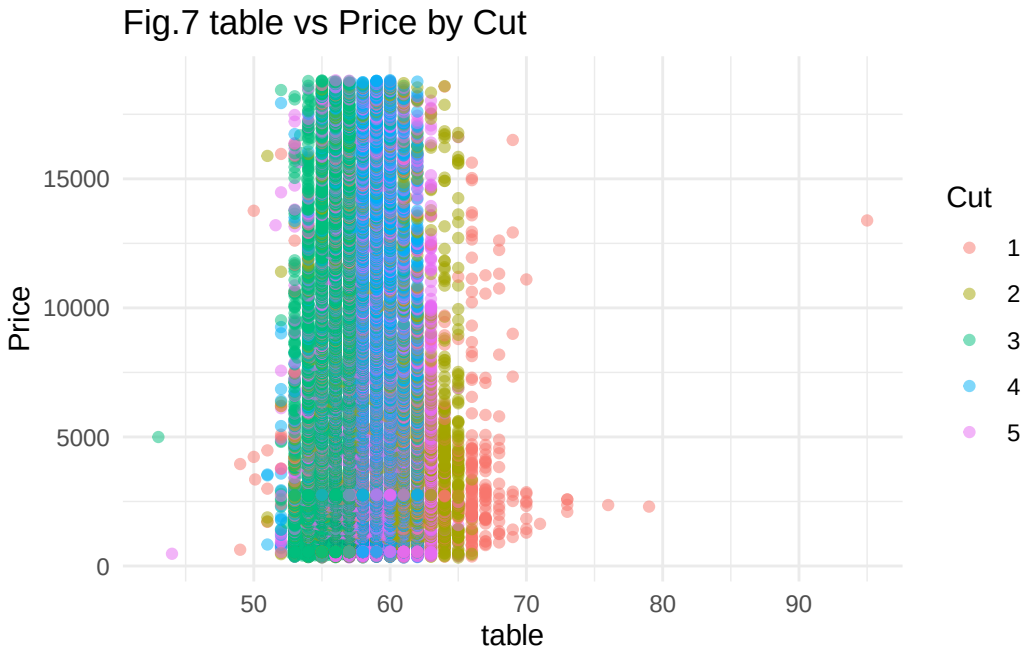


從圖 5 可發現單一淨度指標對價格並沒有直接關連, 高淨度的鑽石未必會有高價格。

```
# 深度對價格
ggplot(data, aes(x = depth, y = price, color =factor(cut))) +
  geom_point(alpha = 0.5) +
  labs(title = "Fig.6 Depth vs Price by Cut",
       x = "Depth",
       y = "Price",
       color = "Cut") +
  theme_minimal()
```

從圖 6 可發現深度和價格沒有相關, 且深度大多集中於 60 附近, 推測是因為深度比例在此區間能切割出最明亮的鑽石。

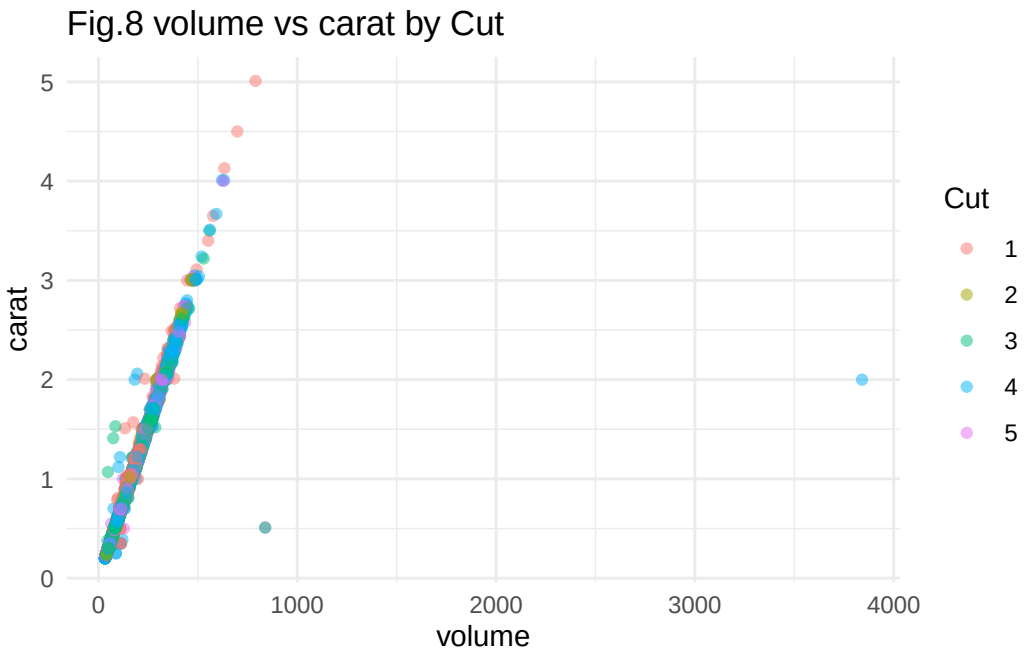
```
# 檯面尺寸對價格
ggplot(data, aes(x = table, y = price, color =factor(cut))) +
  geom_point(alpha = 0.5) +
  labs(title = "Fig.7 table vs Price by Cut",
       x = "table",
       y = "Price",
       color = "Cut") +
  theme_minimal()
```



從圖 7 可發現檯面尺寸對價格沒有相關, 且檯面尺寸約集中在 56~62 之間, 推測也是在這個區間中能切割出最好

的鑽石

```
# 體積對重量
ggplot(data, aes(x = volume, y = carat, color =factor(cut))) +
  geom_point(alpha = 0.5) +
  labs(title = "Fig.8 volume vs carat by Cut",
       x = "volume",
       y = "carat",
       color = "Cut") +
  theme_minimal()
```



典型相關分析 (CCA)

```
# 欲分析幾何特性 vs. 做工及價格之間的關係
# 選擇兩組變數
X <- data[, c("carat", "color", "clarity", "volume")]
Y <- data[, c("price", "cut", "depth", "table")]

cca <- cancor(X,Y)
print(cca)
```

```
$cor
[1] 0.95138646 0.21406636 0.05580885 0.00958912

$xcoef
                  [,1]          [,2]          [,3]          [,4]
carat   -9.782523e-03 -0.0209243423  0.0266436152 -0.0266250552
color    3.575074e-04 -0.0005933112  0.0014501269  0.0021370516
clarity -5.878241e-04  0.0022925087  0.0013710461 -0.0007033020
volume  -9.360728e-07  0.0001401503 -0.0001657836  0.0001531097

$ycoef
                [,1]          [,2]          [,3]          [,4]
price -1.072401e-06  1.692041e-07  9.347422e-08 -9.412873e-09
```

```
cut    9.137155e-05  1.872188e-04 -1.583651e-04  4.286575e-03
depth -9.380682e-05 -2.346677e-03  2.044904e-03  6.890120e-04
table -1.018839e-04 -1.736365e-03 -1.062866e-03 -1.566226e-04

$xcenter
      carat       color     clarity      volume
  0.7976932   3.5939581   4.0514623 129.8966998

$ycenter
      price         cut       depth       table
3930.927879    3.553122   61.749432   57.456902
```

```
cca$cor
```

```
[1] 0.95138646 0.21406636 0.05580885 0.00958912
```

```
cca$xcoef;cca$ycoef
```

```
                 [,1]          [,2]          [,3]          [,4]
carat   -9.782523e-03 -0.0209243423  0.0266436152 -0.0266250552
color    3.575074e-04 -0.0005933112  0.0014501269  0.0021370516
clarity -5.878241e-04  0.0022925087  0.0013710461 -0.0007033020
volume  -9.360728e-07  0.0001401503 -0.0001657836  0.0001531097
```

```
               [,1]          [,2]          [,3]          [,4]
price -1.072401e-06  1.692041e-07  9.347422e-08 -9.412873e-09
cut    9.137155e-05  1.872188e-04 -1.583651e-04  4.286575e-03
depth -9.380682e-05 -2.346677e-03  2.044904e-03  6.890120e-04
table -1.018839e-04 -1.736365e-03 -1.062866e-03 -1.566226e-04
```

欲分析幾何特性 vs. 做工及價格之間的關係

第一典型相關變數: 最大典型相關係數為 0.9513, 第一典型變數主要由 carat 和 table 貢獻組成

第二典型相關變數: 最大典型相關係數為 0.2112(相關性低)

```
X_loadinds <- cor(X,as.matrix(X) %*% cca$xcoef)
Y_loadinds <- cor(Y,as.matrix(Y) %*% cca$ycoef)
X_loadinds;Y_loadinds
```

```
              [,1]        [,2]        [,3]       [,4]
carat   -0.9724303 -0.18934867 -0.03251382  0.1321716
color   -0.1829844 -0.15802158  0.58347916  0.7753051
clarity  0.1642906  0.81271752  0.53429466 -0.1644021
volume  -0.9528425 -0.07286613 -0.15970412  0.2475407
```

```
              [,1]        [,2]        [,3]        [,4]
price -0.998421874  0.05219380  0.00759783 0.019283209
cut   -0.019690093  0.06683905 -0.24962881 0.965831403
depth -0.009170247 -0.52445980  0.84964025 0.054491046
table -0.166668018 -0.64330017 -0.74724181 0.004042751
```

第一典型變數主要受 carat(-),volume(-) 和 price(-) 影響

第二典型變數主要受 clarity(+),depth(-) 和 table(-) 影響

3.Construct a predictive model for price

Linear regression model

我們採用線性回歸模型搭配 AIC 的逐步回歸進行變數選取，

```
model.1 <- lm(price ~ ., data = data)

# 使用 stepAIC 進行變數選擇
step_model <- stepAIC(model.1,
                      direction = "both",
                      trace = 0)
summary(step_model)
```

```

Call:
lm(formula = price ~ carat + cut + color + clarity + depth +
    table + volume, data = data)

Residuals:
     Min       1Q   Median       3Q      Max
-19651.8   -694.7   -170.2    557.4   9326.3

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) 3347.7906   327.2356   10.23  < 2e-16 ***
carat       8597.2447    55.0866  156.07  < 2e-16 ***
cut           86.7397     5.3023   16.36  < 2e-16 ***
color       -317.3952     3.3063  -96.00  < 2e-16 ***
clarity      527.5760     3.5246  149.69  < 2e-16 ***
depth        -68.2104     3.9973  -17.06  < 2e-16 ***
table        -61.3112     2.5849  -23.72  < 2e-16 ***
volume         1.1928     0.3304    3.61 0.000307 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1235 on 53915 degrees of freedom
Multiple R-squared:  0.9041,    Adjusted R-squared:  0.9041
F-statistic: 7.26e+04 on 7 and 53915 DF,  p-value: < 2.2e-16
```

```
vif(step_model)
```

```
    carat       cut     color   clarity     depth     table    volume
24.084069  1.049873  1.118656  1.191418  1.159026  1.179164 23.617923
```

```
model.2 <- lm(price ~.-carat  , data = data)
step_model <- stepAIC(model.2,
                      direction = "both",
                      trace = 0)
summary(step_model)
```

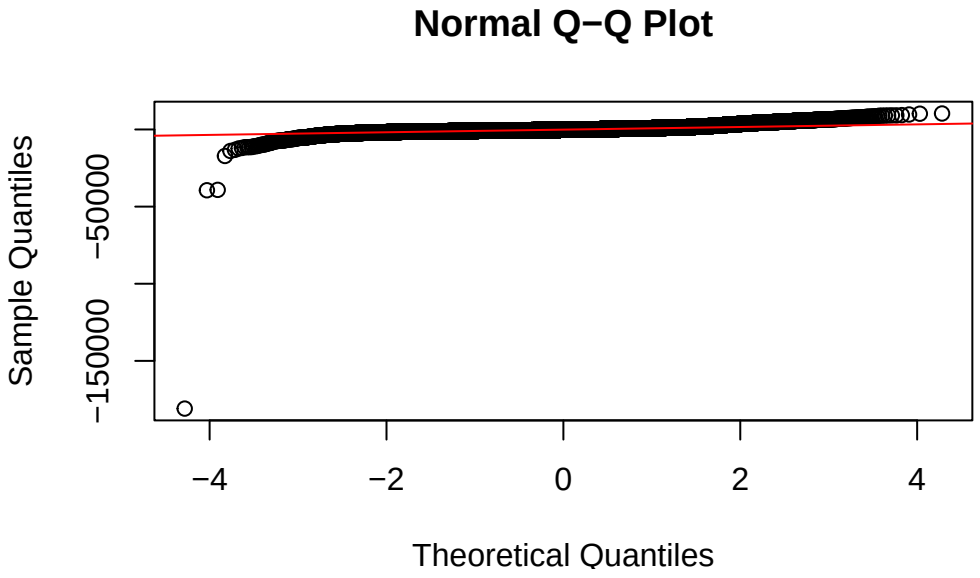
```

Call:
lm(formula = price ~ cut + color + clarity + table + volume,
    data = data)

Residuals:
```

```
    Min      1Q  Median      3Q     Max
-180940    -684    -207     470   10363

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) -2.963e+03  1.707e+02 -17.356  < 2e-16 ***
cut          7.749e+01  6.309e+00  12.282  < 2e-16 ***
color       -2.793e+02  3.966e+00 -70.410  < 2e-16 ***
clarity      4.819e+02  4.205e+00 114.591  < 2e-16 ***
table       -1.742e+01  2.962e+00  -5.883 4.05e-09 ***
volume       5.135e+01  9.241e-02 555.715  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1488 on 53917 degrees of freedom
Multiple R-squared:  0.8607,    Adjusted R-squared:  0.8607
F-statistic: 6.666e+04 on 5 and 53917 DF,  p-value: < 2.2e-16
```

```r
vif(step_model)
```

```
     cut    color  clarity    table   volume
1.023906 1.108936 1.168415 1.066192 1.272455
```

```r
qqnorm(resid(step_model))
qqline(resid(step_model), col = "red")
```



而 model.2 的 R-squared = 0.9041