# Assignment_4

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```
# 'Benchmarking' package is required for running the DEA functions.
#require(Benchmarking)
#install.packages("Benchmarking")
library(Benchmarking)
```

```
## Warning: package 'Benchmarking' was built under R version 4.1.3
```

```
## Loading required package: lpSolveAPI
```

```
## Warning: package 'lpSolveAPI' was built under R version 4.1.3
```

```
## Loading required package: ucminf
```

```
## Warning: package 'ucminf' was built under R version 4.1.3
```

```
## Loading required package: quadprog
```

```
##
## Loading Benchmarking version 0.30h, (Revision 244, 2022/05/05 16:31:31) ...
```

```
## Build 2022/05/05 16:31:40
```

Loading the Data

```
# Create matrix for the two inputs
X <- matrix(c(150, 400, 320, 520, 350, 320, 0.2, 0.7, 1.2, 2.0, 1.2, 0.7), ncol = 2)
# Create matrix for the two outputs
Y <- matrix(c(14000, 14000, 42000, 28000, 19000, 14000, 3500, 21000, 10500, 42000, 25000, 15000), ncol =
# Name the columns of the inputs and outputs
colnames(X) <- c("Staff Hours per Day","Supplies per Day")
colnames(Y) <- c("Reimburse Patient-Days", "Privately Paid Patient-Days")
# Returning  the matrices
print(X)
```

```
##      Staff Hours per Day Supplies per Day
## [1,]                 150              0.2
## [2,]                 400              0.7
## [3,]                 320              1.2
## [4,]                 520              2.0
## [5,]                 350              1.2
## [6,]                 320              0.7
```

```
print(Y)
```

```
##      Reimburse Patient-Days Privately Paid Patient-Days
## [1,]                  14000                         3500
## [2,]                  14000                        21000
## [3,]                  42000                        10500
## [4,]                  28000                        42000
## [5,]                  19000                        25000
## [6,]                  14000                        15000
```

***1. Formulate and perform DEA analysis under all DEA assumptions of FDH, CRS, VRS, IRS, DRS, and FRH. 2. Determine the Peers and Lambdas under each of the above assumptions***

The below code will return the results of DEA using FDH method.

```
# DEA code utilizing the FDH method
FDH <- rep("FDH", times = 6)
Not_Applicable <- rep(NA, times = 6)
DEA_FDH <- dea(X, Y, RTS = "FDH")
DEA_FDH_Peers <- peers(DEA_FDH)
DEA_FDH_Lambda <- lambda(DEA_FDH)
print(DEA_FDH)
```

```
## [1] 1 1 1 1 1 1
```

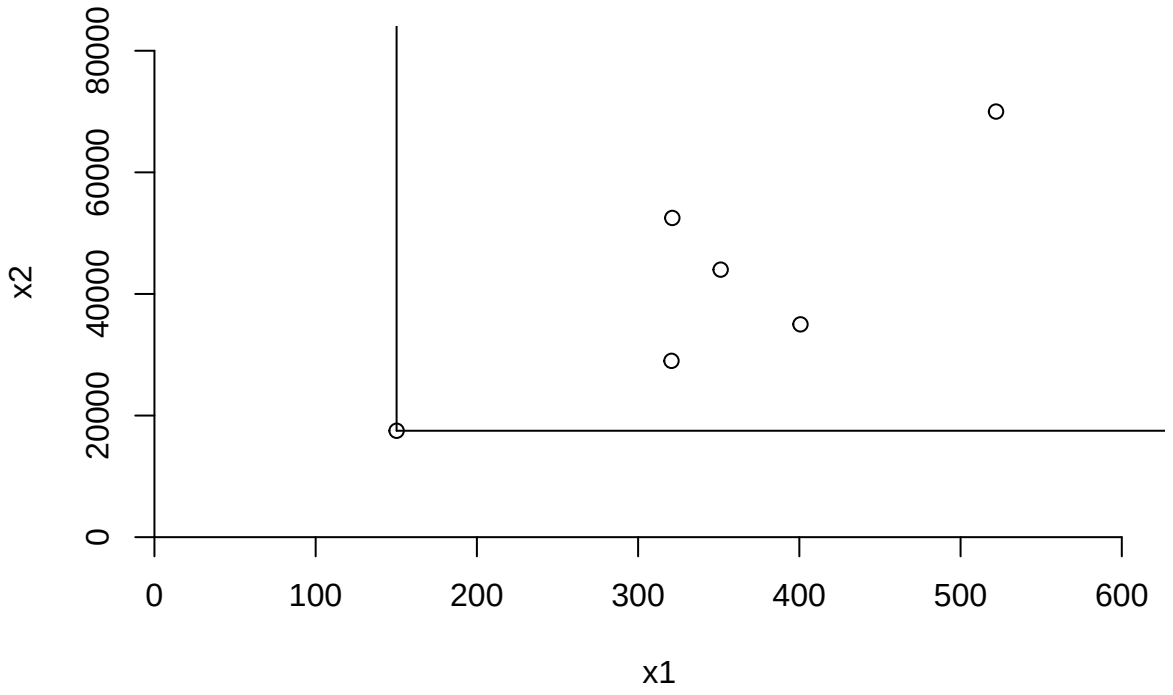
```
print(DEA_FDH_Peers)
```

```
##      peer1
## [1,]     1
## [2,]     2
## [3,]     3
## [4,]     4
## [5,]     5
## [6,]     6
```

```
print(DEA_FDH_Lambda)
```

```
##      L1 L2 L3 L4 L5 L6
## [1,]  1  0  0  0  0  0
## [2,]  0  1  0  0  0  0
## [3,]  0  0  1  0  0  0
## [4,]  0  0  0  1  0  0
## [5,]  0  0  0  0  1  0
## [6,]  0  0  0  0  0  1
```

```
dea.plot.isoquant(X, Y, RTS= "FDH")
```




```
# Summarize the results for addition to a summary table
DEA_FDH_Peers <- cbind(DEA_FDH_Peers, Not_Applicable, Not_Applicable)
FDH_Summary <- cbind(FDH, DEA_FDH$eff, DEA_FDH_Peers, DEA_FDH_Lambda)
colnames(FDH_Summary) <- c("Method","Eff", "P1", "P2", "P3", "L1", "L2", "L3", "L4", "L5", "L6")
print(FDH_Summary)
```

```
##      Method Eff P1  P2 P3 L1  L2  L3  L4  L5  L6
## [1,] "FDH"  "1" "1" NA NA "1" "0" "0" "0" "0" "0"
## [2,] "FDH"  "1" "2" NA NA "0" "1" "0" "0" "0" "0"
## [3,] "FDH"  "1" "3" NA NA "0" "0" "1" "0" "0" "0"
## [4,] "FDH"  "1" "4" NA NA "0" "0" "0" "1" "0" "0"
## [5,] "FDH"  "1" "5" NA NA "0" "0" "0" "0" "1" "0"
## [6,] "FDH"  "1" "6" NA NA "0" "0" "0" "0" "0" "1"
```

The below code will return the results of DEA using CRS method.

```
# DEA code utilizing the CRS method
CRS <- rep("CRS", times = 6)
DEA_CRS <- dea(X, Y, RTS = "CRS")
DEA_CRS_Peers <- peers(DEA_CRS)
DEA_CRS_Lambda <- lambda(DEA_CRS)
print(DEA_CRS)
```

```
## [1] 1.0000 1.0000 1.0000 1.0000 0.9775 0.8675
```

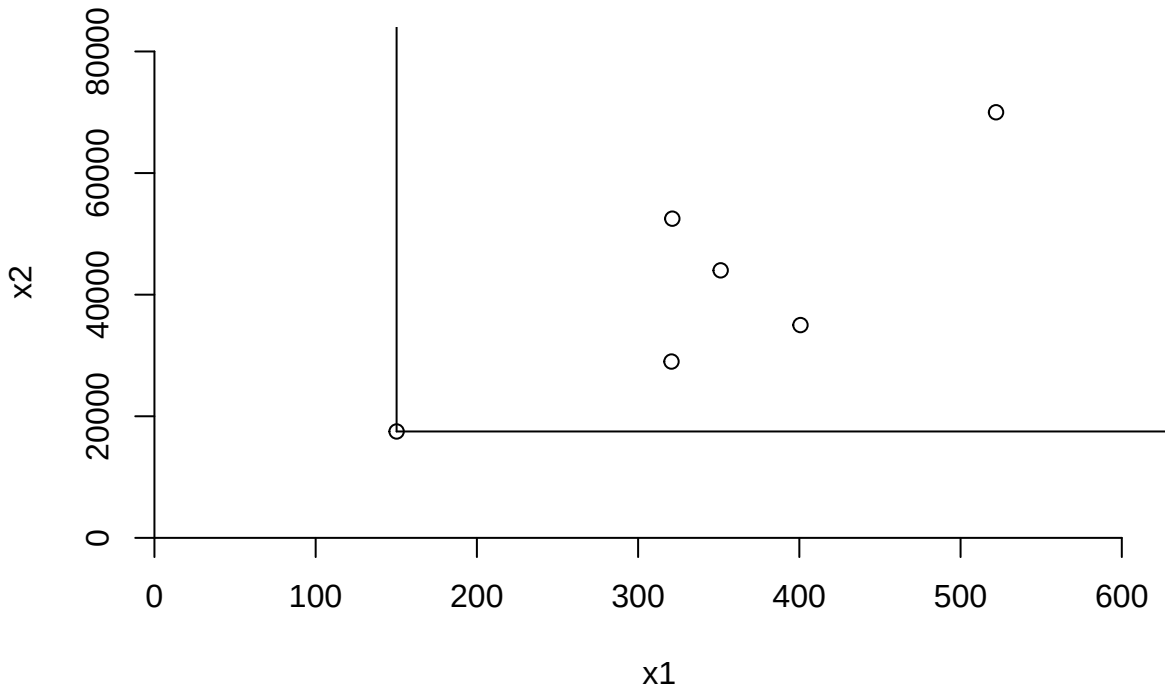
```
print(DEA_CRS_Peers)
```

```
##      peer1 peer2 peer3
## [1,]     1    NA    NA
## [2,]     2    NA    NA
## [3,]     3    NA    NA
## [4,]     4    NA    NA
## [5,]     1     2     4
## [6,]     1     2     4
```

```
print(DEA_CRS_Lambda)
```

```
##             L1         L2 L3        L4
## [1,] 1.0000000 0.00000000  0 0.0000000
## [2,] 0.0000000 1.00000000  0 0.0000000
## [3,] 0.0000000 0.00000000  1 0.0000000
## [4,] 0.0000000 0.00000000  0 1.0000000
## [5,] 0.2000000 0.08048142  0 0.5383307
## [6,] 0.3428571 0.39499264  0 0.1310751
```

```
dea.plot.isoquant(X, Y, RTS= "CRS")
```



```
# Summarize the results for addition to a summary table
DEA_CRS_Lambda <- cbind(DEA_CRS_Lambda, Not_Applicable, Not_Applicable)
CRS_Summary <- cbind(CRS, DEA_CRS$eff, DEA_CRS_Peers, DEA_CRS_Lambda)
colnames(CRS_Summary) <- c("Method","Eff", "P1", "P2", "P3", "L1", "L2", "L3", "L4", "L5", "L6")
CRS_Summary <- as.data.frame(CRS_Summary)
CRS_Summary
```

```
##   Method               Eff P1   P2   P3                L1                  L2 L3
## 1    CRS                 1  1 <NA> <NA>                 1                   0  0
## 2    CRS                 1  2 <NA> <NA>                 0                   1  0
## 3    CRS                 1  3 <NA> <NA>                 0                   0  1
## 4    CRS                 1  4 <NA> <NA>                 0                   0  0
## 5    CRS 0.977498691784406  1    2    4               0.2 0.0804814233385661  0
## 6    CRS 0.867452135493373  1    2    4 0.342857142857143   0.39499263622975  0
##                   L4   L5   L6
## 1                  0 <NA> <NA>
## 2                  0 <NA> <NA>
## 3                  0 <NA> <NA>
## 4                  1 <NA> <NA>
## 5 0.538330716902146 <NA> <NA>
## 6 0.131075110456554 <NA> <NA>
```

The below code will return the results of DEA using VRS method.

```
# DEA code utilizing the VRS method
VRS <- rep("VRS", times = 6)
DEA_VRS <- dea(X, Y, RTS = "VRS")
DEA_VRS_Peers <- peers(DEA_VRS)
DEA_VRS_Lambda <- lambda(DEA_VRS)
print(DEA_VRS)
```

```
## [1] 1.0000 1.0000 1.0000 1.0000 1.0000 0.8963
```

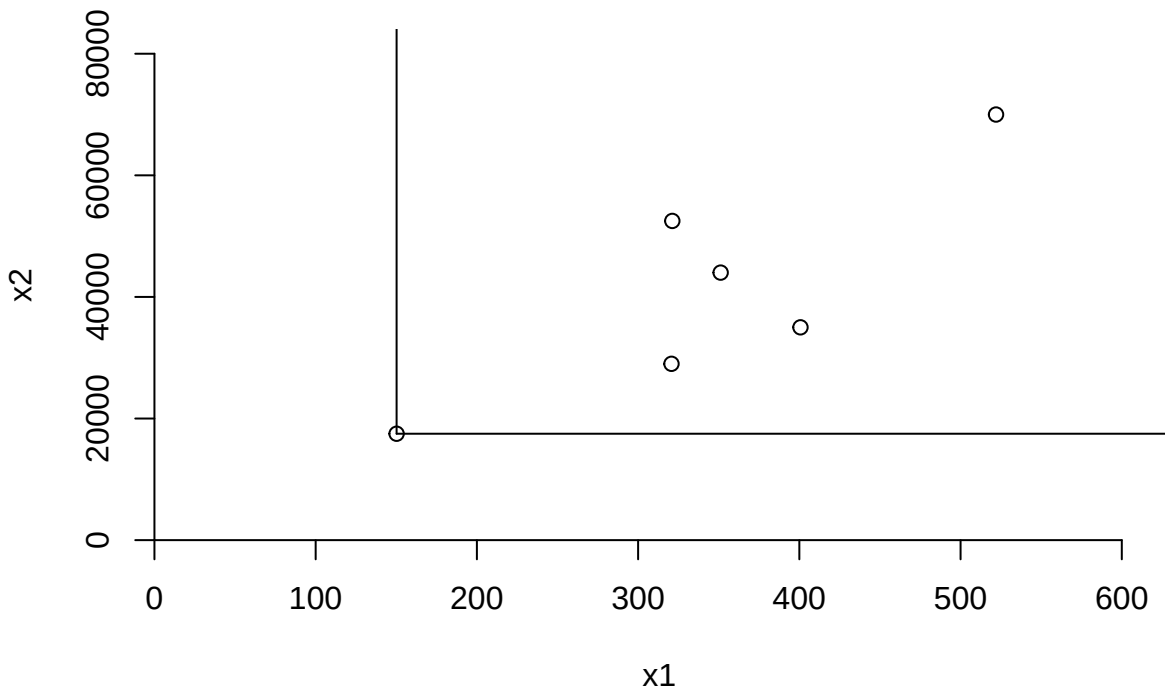
```
print(DEA_VRS_Peers)
```

```
##      peer1 peer2 peer3
## [1,]     1    NA    NA
## [2,]     2    NA    NA
## [3,]     3    NA    NA
## [4,]     4    NA    NA
## [5,]     5    NA    NA
## [6,]     1     2     5
```

```
print(DEA_VRS_Lambda)
```

```
##             L1        L2 L3 L4        L5
## [1,] 1.0000000 0.0000000  0  0 0.0000000
## [2,] 0.0000000 1.0000000  0  0 0.0000000
## [3,] 0.0000000 0.0000000  1  0 0.0000000
## [4,] 0.0000000 0.0000000  0  1 0.0000000
## [5,] 0.0000000 0.0000000  0  0 1.0000000
## [6,] 0.4014399 0.3422606  0  0 0.2562995
```

```
dea.plot.isoquant(X, Y, RTS= "VRS")
```




```
# Summarize the results for addition to a summary table
DEA_VRS_Lambda <- cbind(DEA_VRS_Lambda, Not_Applicable)
VRS_Summary <- cbind(VRS, DEA_VRS$eff, DEA_VRS_Peers, DEA_VRS_Lambda)
colnames(VRS_Summary) <- c("Method","Eff", "P1", "P2", "P3", "L1", "L2", "L3", "L4", "L5", "L6")
VRS_Summary <- as.data.frame(VRS_Summary)
VRS_Summary
```

```
##   Method               Eff P1   P2   P3               L1                L2 L3
## 1    VRS                 1  1 <NA> <NA>                1                 0  0
## 2    VRS                 1  2 <NA> <NA>                0                 1  0
## 3    VRS                 1  3 <NA> <NA>                0                 0  1
## 4    VRS                 1  4 <NA> <NA>                0                 0  0
## 5    VRS                 1  5 <NA> <NA>                0                 0  0
## 6    VRS 0.896328293736501  1    2    5 0.401439884809215 0.342260619150468  0
##   L4                L5   L6
## 1  0                 0 <NA>
## 2  0                 0 <NA>
## 3  0                 0 <NA>
## 4  1                 0 <NA>
## 5  0                 1 <NA>
## 6  0 0.256299496040317 <NA>
```

The below code will return the results of DEA using IRS method.

```r
# DEA code utilizing the IRS method
IRS <- rep("IRS", times = 6)
DEA_IRS <- dea(X, Y, RTS = "IRS")
DEA_IRS_Peers <- peers(DEA_IRS)
DEA_IRS_Lambda <- lambda(DEA_IRS)
print(DEA_IRS)
```

```
## [1] 1.0000 1.0000 1.0000 1.0000 1.0000 0.8963
```

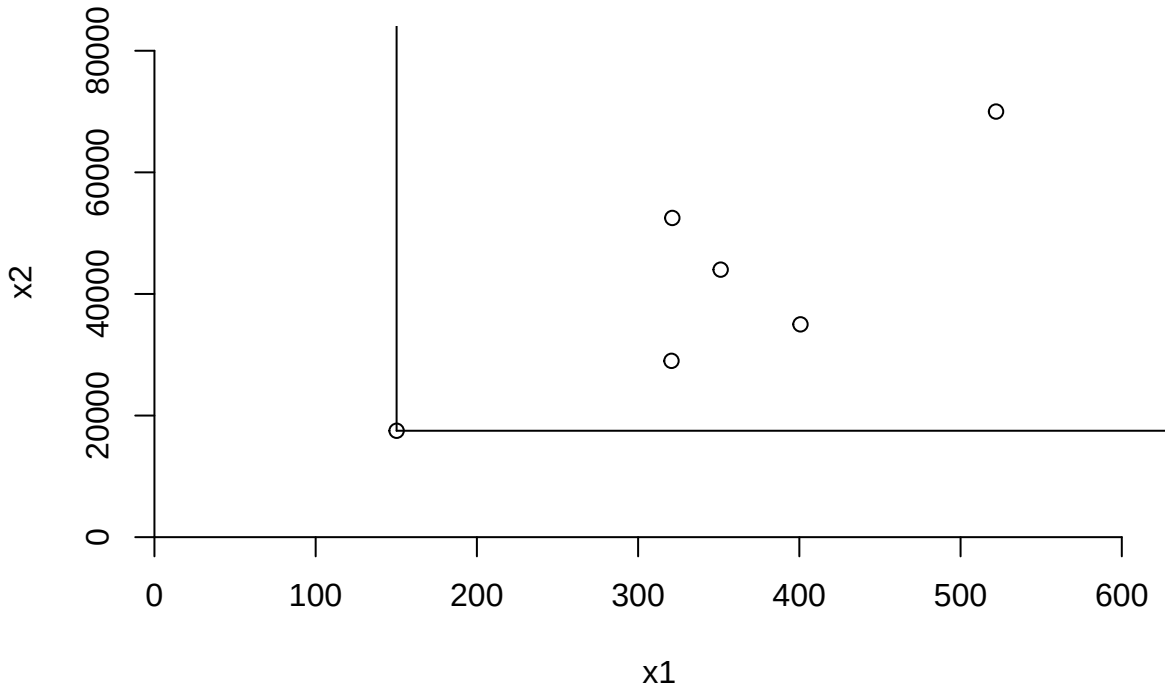
```r
print(DEA_IRS_Peers)
```

```
##      peer1 peer2 peer3
## [1,]     1    NA    NA
## [2,]     2    NA    NA
## [3,]     3    NA    NA
## [4,]     4    NA    NA
## [5,]     5    NA    NA
## [6,]     1     2     5
```

```r
print(DEA_IRS_Lambda)
```

```
##             L1        L2 L3 L4        L5
## [1,] 1.0000000 0.0000000  0  0 0.0000000
## [2,] 0.0000000 1.0000000  0  0 0.0000000
## [3,] 0.0000000 0.0000000  1  0 0.0000000
## [4,] 0.0000000 0.0000000  0  1 0.0000000
## [5,] 0.0000000 0.0000000  0  0 1.0000000
## [6,] 0.4014399 0.3422606  0  0 0.2562995
```

```r
dea.plot.isoquant(X, Y, RTS= "IRS")
```




```
# Summarize the results for addition to a summary table
DEA_IRS_Lambda <- cbind(DEA_IRS_Lambda, Not_Applicable)
IRS_Summary <- cbind(IRS, DEA_IRS$eff, DEA_IRS_Peers, DEA_IRS_Lambda)
colnames(IRS_Summary) <- c("Method","Eff", "P1", "P2", "P3", "L1", "L2", "L3", "L4", "L5", "L6")
IRS_Summary <- as.data.frame(IRS_Summary)
IRS_Summary
```

```
##   Method               Eff P1   P2   P3                L1                L2 L3
## 1    IRS                 1  1 <NA> <NA>                 1                 0  0
## 2    IRS                 1  2 <NA> <NA>                 0                 1  0
## 3    IRS                 1  3 <NA> <NA>                 0                 0  1
## 4    IRS                 1  4 <NA> <NA>                 0                 0  0
## 5    IRS                 1  5 <NA> <NA>                 0                 0  0
## 6    IRS 0.896328293736501  1    2    5 0.401439884809215 0.342260619150468  0
##   L4                L5   L6
## 1  0                 0 <NA>
## 2  0                 0 <NA>
## 3  0                 0 <NA>
## 4  1                 0 <NA>
## 5  0                 1 <NA>
## 6  0 0.256299496040317 <NA>
```

The below code will return the results of DEA using DRS method.

```r
# DEA code utilizing the DRS method
DRS <- rep("DRS", times = 6)
DEA_DRS <- dea(X, Y, RTS = "DRS")
DEA_DRS_Peers <- peers(DEA_DRS)
DEA_DRS_Lambda <- lambda(DEA_DRS)
print(DEA_DRS)
```

```
## [1] 1.0000 1.0000 1.0000 1.0000 0.9775 0.8675
```

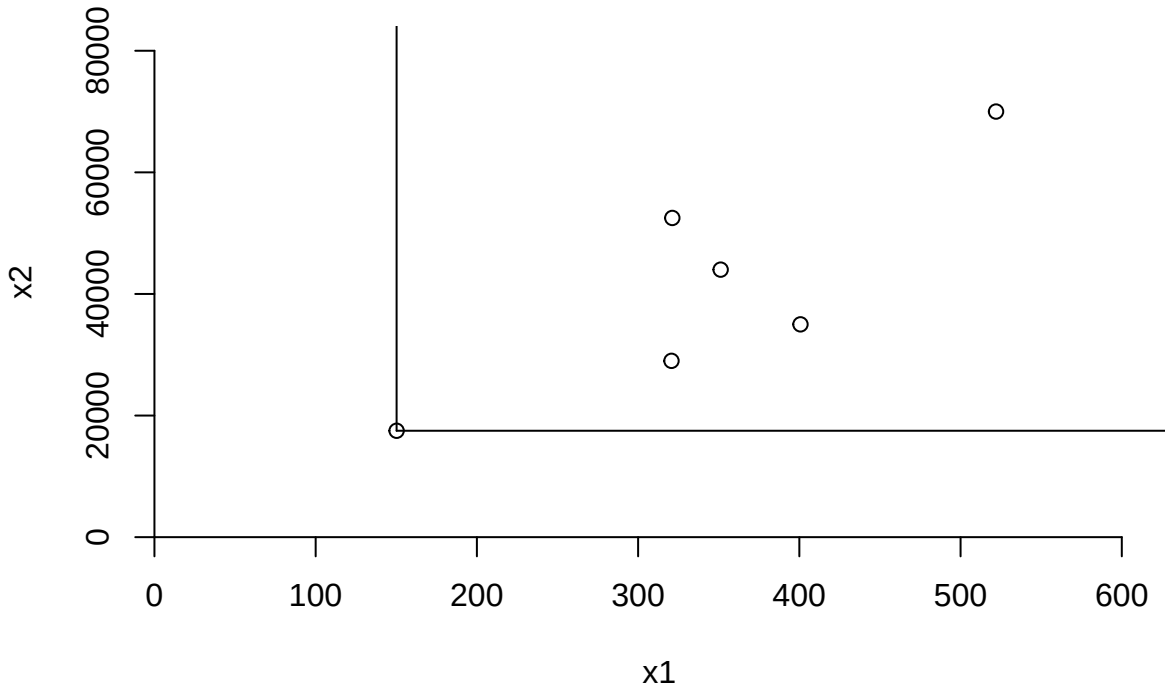
```r
print(DEA_DRS_Peers)
```

```
##      peer1 peer2 peer3
## [1,]     1    NA    NA
## [2,]     2    NA    NA
## [3,]     3    NA    NA
## [4,]     4    NA    NA
## [5,]     1     2     4
## [6,]     1     2     4
```

```r
print(DEA_DRS_Lambda)
```

```
##             L1         L2 L3        L4
## [1,] 1.0000000 0.00000000  0 0.0000000
## [2,] 0.0000000 1.00000000  0 0.0000000
## [3,] 0.0000000 0.00000000  1 0.0000000
## [4,] 0.0000000 0.00000000  0 1.0000000
## [5,] 0.2000000 0.08048142  0 0.5383307
## [6,] 0.3428571 0.39499264  0 0.1310751
```

```r
dea.plot.isoquant(X, Y, RTS= "DRS")
```




```
# Summarize the results for addition to a summary table
DEA_DRS_Lambda <- cbind(DEA_DRS_Lambda, Not_Applicable, Not_Applicable)
DRS_Summary <- cbind(DRS, DEA_DRS$eff, DEA_DRS_Peers, DEA_DRS_Lambda)
colnames(DRS_Summary) <- c("Method","Eff", "P1", "P2", "P3", "L1", "L2", "L3", "L4", "L5", "L6")
DRS_Summary <- as.data.frame(DRS_Summary)
DRS_Summary
```

```
##   Method               Eff P1   P2   P3               L1                 L2 L3
## 1    DRS                 1  1 <NA> <NA>                1                  0  0
## 2    DRS                 1  2 <NA> <NA>                0                  1  0
## 3    DRS                 1  3 <NA> <NA>                0                  0  1
## 4    DRS                 1  4 <NA> <NA>                0                  0  0
## 5    DRS 0.977498691784406  1    2    4              0.2 0.0804814233385655  0
## 6    DRS 0.867452135493373  1    2    4 0.342857142857143  0.394992636229749  0
##                   L4   L5   L6
## 1                  0 <NA> <NA>
## 2                  0 <NA> <NA>
## 3                  0 <NA> <NA>
## 4                  1 <NA> <NA>
## 5 0.538330716902146 <NA> <NA>
## 6 0.131075110456554 <NA> <NA>
```

The below code will return the results of DEA using FRH/ADD method.

```r
# DEA code utilizing the ADD method
ADD <- rep("ADD", times = 6)
DEA_ADD <- dea(X, Y, RTS = "ADD")
DEA_ADD_Peers <- peers(DEA_ADD)
DEA_ADD_Lambda <- lambda(DEA_ADD)
print(DEA_ADD)
```

```
## [1] 1 1 1 1 1 1
```

```r
print(DEA_ADD_Peers)
```

```
##      peer1
## [1,]     1
## [2,]     2
## [3,]     3
## [4,]     4
## [5,]     5
## [6,]     6
```

```r
print(DEA_ADD_Lambda)
```

```
##      L1 L2 L3 L4 L5 L6
## [1,]  1  0  0  0  0  0
## [2,]  0  1  0  0  0  0
## [3,]  0  0  1  0  0  0
## [4,]  0  0  0  1  0  0
## [5,]  0  0  0  0  1  0
## [6,]  0  0  0  0  0  1
```

```r
# Summarize the results for addition to a summary table
DEA_ADD_Peers <- cbind(DEA_ADD_Peers, Not_Applicable, Not_Applicable)
ADD_Summary <- cbind(ADD, DEA_ADD$eff, DEA_ADD_Peers, DEA_ADD_Lambda)
colnames(ADD_Summary) <- c("Method","Eff", "P1", "P2", "P3", "L1", "L2", "L3", "L4", "L5", "L6")
ADD_Summary <- as.data.frame(ADD_Summary)
ADD_Summary
```

```
##   Method Eff P1   P2   P3 L1 L2 L3 L4 L5 L6
## 1    ADD   1  1 <NA> <NA>  1  0  0  0  0  0
## 2    ADD   1  2 <NA> <NA>  0  1  0  0  0  0
## 3    ADD   1  3 <NA> <NA>  0  0  1  0  0  0
## 4    ADD   1  4 <NA> <NA>  0  0  0  1  0  0
## 5    ADD   1  5 <NA> <NA>  0  0  0  0  1  0
## 6    ADD   1  6 <NA> <NA>  0  0  0  0  0  1
```

***3. Summarize your results in a tabular format***

```r
# Combine all of the method summary tables into one large summary table for each method
Summary_Table <- rbind(FDH_Summary, CRS_Summary, VRS_Summary, IRS_Summary, DRS_Summary, ADD_Summary)
# Return the summary table for review
print(Summary_Table)
```

```
##    Method               Eff P1   P2   P3                L1                  L2
## 1     FDH                 1  1 <NA> <NA>                 1                   0
## 2     FDH                 1  2 <NA> <NA>                 0                   1
## 3     FDH                 1  3 <NA> <NA>                 0                   0
## 4     FDH                 1  4 <NA> <NA>                 0                   0
## 5     FDH                 1  5 <NA> <NA>                 0                   0
## 6     FDH                 1  6 <NA> <NA>                 0                   0
## 7     CRS                 1  1 <NA> <NA>                 1                   0
## 8     CRS                 1  2 <NA> <NA>                 0                   1
## 9     CRS                 1  3 <NA> <NA>                 0                   0
## 10    CRS                 1  4 <NA> <NA>                 0                   0
## 11    CRS 0.977498691784406  1    2    4               0.2 0.0804814233385661
## 12    CRS 0.867452135493373  1    2    4 0.342857142857143   0.39499263622975
## 13    VRS                 1  1 <NA> <NA>                 1                   0
## 14    VRS                 1  2 <NA> <NA>                 0                   1
## 15    VRS                 1  3 <NA> <NA>                 0                   0
## 16    VRS                 1  4 <NA> <NA>                 0                   0
## 17    VRS                 1  5 <NA> <NA>                 0                   0
## 18    VRS 0.896328293736501  1    2    5 0.401439884809215  0.342260619150468
## 19    IRS                 1  1 <NA> <NA>                 1                   0
## 20    IRS                 1  2 <NA> <NA>                 0                   1
## 21    IRS                 1  3 <NA> <NA>                 0                   0
## 22    IRS                 1  4 <NA> <NA>                 0                   0
## 23    IRS                 1  5 <NA> <NA>                 0                   0
## 24    IRS 0.896328293736501  1    2    5 0.401439884809215  0.342260619150468
## 25    DRS                 1  1 <NA> <NA>                 1                   0
## 26    DRS                 1  2 <NA> <NA>                 0                   1
## 27    DRS                 1  3 <NA> <NA>                 0                   0
## 28    DRS                 1  4 <NA> <NA>                 0                   0
## 29    DRS 0.977498691784406  1    2    4               0.2 0.0804814233385655
## 30    DRS 0.867452135493373  1    2    4 0.342857142857143  0.394992636229749
## 31    ADD                 1  1 <NA> <NA>                 1                   0
## 32    ADD                 1  2 <NA> <NA>                 0                   1
## 33    ADD                 1  3 <NA> <NA>                 0                   0
## 34    ADD                 1  4 <NA> <NA>                 0                   0
## 35    ADD                 1  5 <NA> <NA>                 0                   0
## 36    ADD                 1  6 <NA> <NA>                 0                   0
##    L3                L4                L5   L6
## 1   0                 0                 0    0
## 2   0                 0                 0    0
## 3   1                 0                 0    0
## 4   0                 1                 0    0
## 5   0                 0                 1    0
## 6   0                 0                 0    1
## 7   0                 0              <NA> <NA>
## 8   0                 0              <NA> <NA>
## 9   1                 0              <NA> <NA>
## 10  0                 1              <NA> <NA>
## 11  0 0.538330716902146              <NA> <NA>
## 12  0 0.131075110456554              <NA> <NA>
## 13  0                 0                 0 <NA>
## 14  0                 0                 0 <NA>
## 15  1                 0                 0 <NA>
## 16  0                 1                 0 <NA>
```

```
## 17  0                 0                 1 <NA>
## 18  0                 0 0.256299496040317 <NA>
## 19  0                 0                 0 <NA>
## 20  0                 0                 0 <NA>
## 21  1                 0                 0 <NA>
## 22  0                 1                 0 <NA>
## 23  0                 0                 1 <NA>
## 24  0                 0 0.256299496040317 <NA>
## 25  0                 0              <NA> <NA>
## 26  0                 0              <NA> <NA>
## 27  1                 0              <NA> <NA>
## 28  0                 1              <NA> <NA>
## 29  0 0.538330716902146              <NA> <NA>
## 30  0 0.131075110456554              <NA> <NA>
## 31  0                 0                 0    0
## 32  0                 0                 0    0
## 33  1                 0                 0    0
## 34  0                 1                 0    0
## 35  0                 0                 1    0
## 36  0                 0                 0    1
```

***4. Compare and contrast the above results***

As shown in the summary table, all six DMU's return FRH and FDH efficiency values of 1.0, along with identical peer and lambda values.

In the CRS method, DMU[1:4] is efficient at 1.0.

In the VRS method DMU[1:5] is efficient at 1.0.

In the IRS method DMU[1:5] is efficient at 1.0, and

In the DRS method DMU[1:4] is efficient at 1.0.

All of these less efficient DMU's had a Peer[1] and Peer [2] value of 1 and 2, respectively;

Depending on the method,However, the Peer[3] value was either 4 or 5.

Furthermore, all methods were relatively close in terms of relative weights (lambdas).