Assignment4

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Question 1 - Hope Valley Health Care Association

Problem Description – The Hope Valley Health Care Association owns and operates six nursing homes in adjoining states. An evaluation of their efficiency has been undertaken using two inputs and two outputs. The inputs are staffing labor (measured in average hours per day) and the cost of supplies (in thousands of dollars per day). The outputs are the number of patient-days reimbursed by third-party sources and the number of patient-days reimbursed privately. A summary of performance data is shown in the table below.

```
#loading package
require(Benchmarking)
```

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

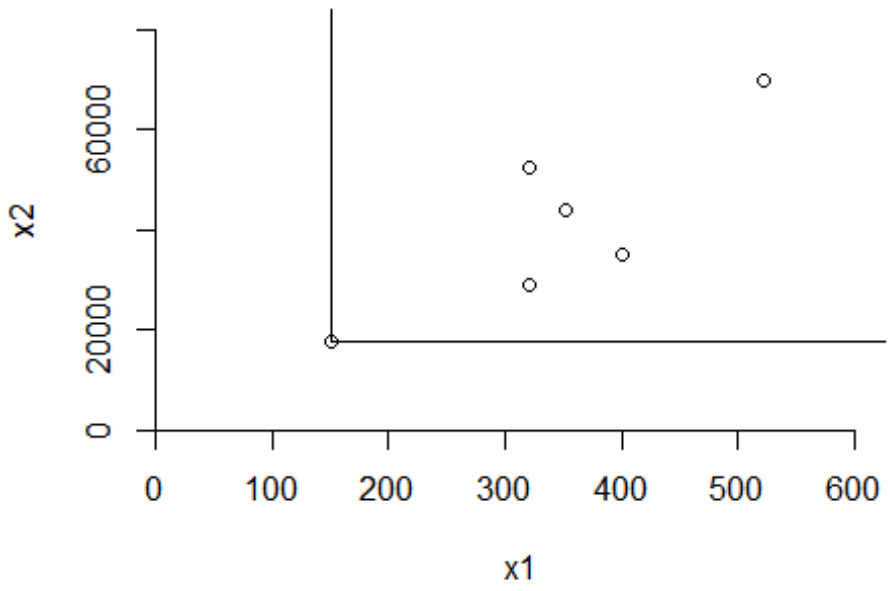
```
##
## Loading Benchmarking version 0.30h, (Revision 244, 2022/05/05 16:31:31)
...
```

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

```
#  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)
#  matrix for the two outputs
Y <- matrix(c(14000, 14000, 42000, 28000, 19000, 14000, 3500, 21000, 10500,
42000, 25000, 15000), ncol = 2)
colnames(X) <- c("Staff Hours per Day","Supplies per Day")
colnames(Y) <- c("Reimburse Patient-Days", "Privately Paid Patient-Days")
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

# 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")
```




```
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"
```

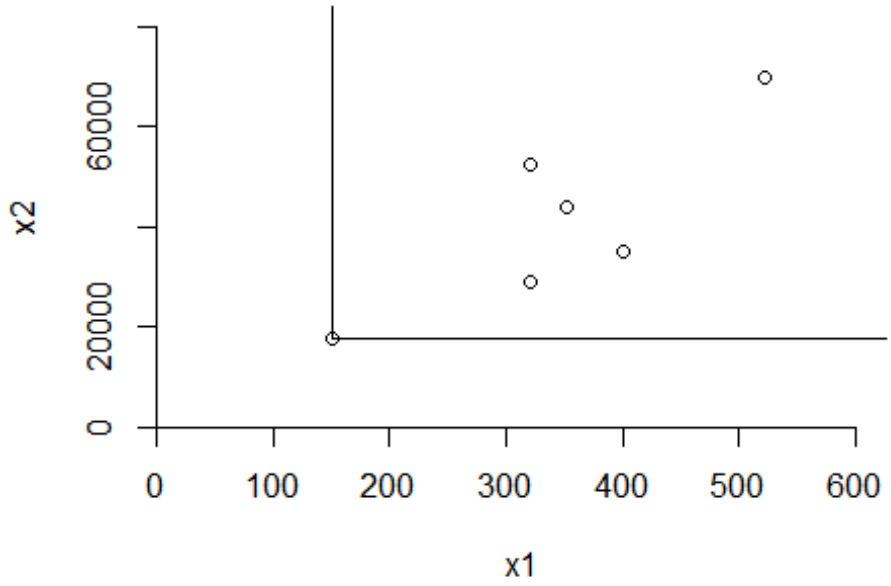
```
# DEA code utilizing the CRS method
CRS <- rep("CRS", times = 6)
DEA_CRS <- dea(X, Y, RTS = "CRS")
DEA_CRS_Peers <- peers(DEA_CRS)
DEA_CRS_Lambda <- lambda(DEA_CRS)
print(DEA_CRS)
```

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

```
print(DEA_CRS_Peers)
```

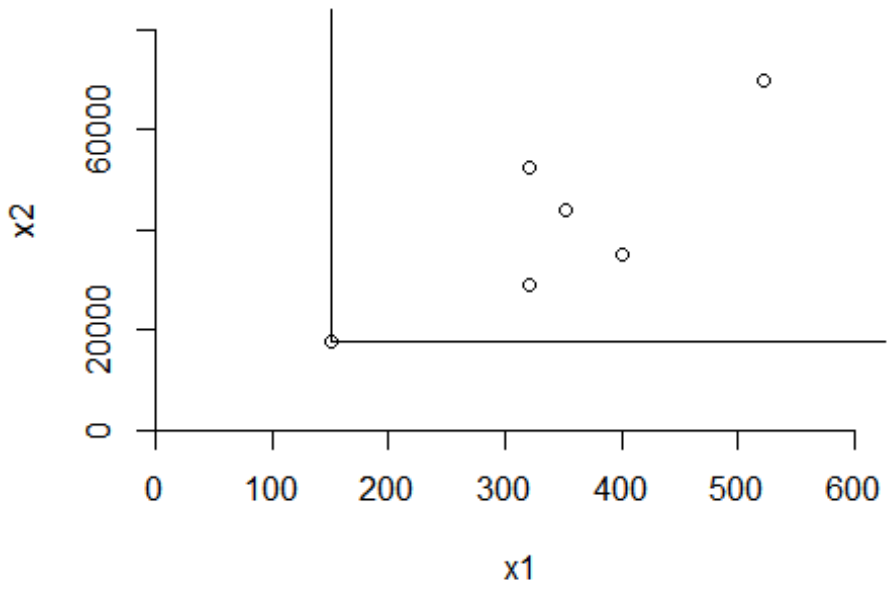
```
##      peer1 peer2 peer3
## [1,]     1    NA    NA
## [2,]     2    NA    NA
```

```
## [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")
```




```
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
```

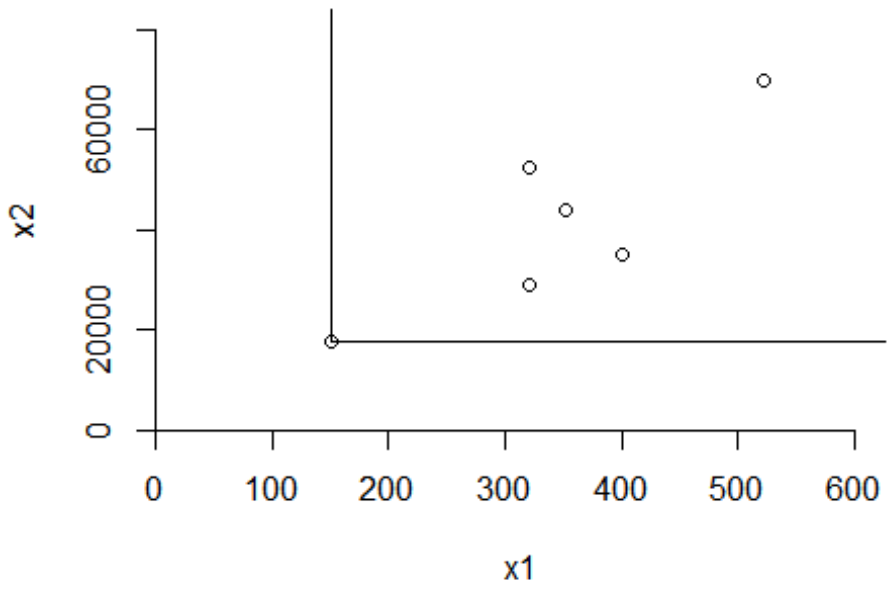
```
## 2    CRS                 1  2 <NA> <NA>                 0
1  0
## 3    CRS                 1  3 <NA> <NA>                 0
0  1
## 4    CRS                 1  4 <NA> <NA>                 0
0  0
## 5    CRS 0.977498691784406  1    2    4               0.2
0.0804814233385661  0
## 6    CRS 0.867452135493373  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>

# 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")
```




```
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>
```

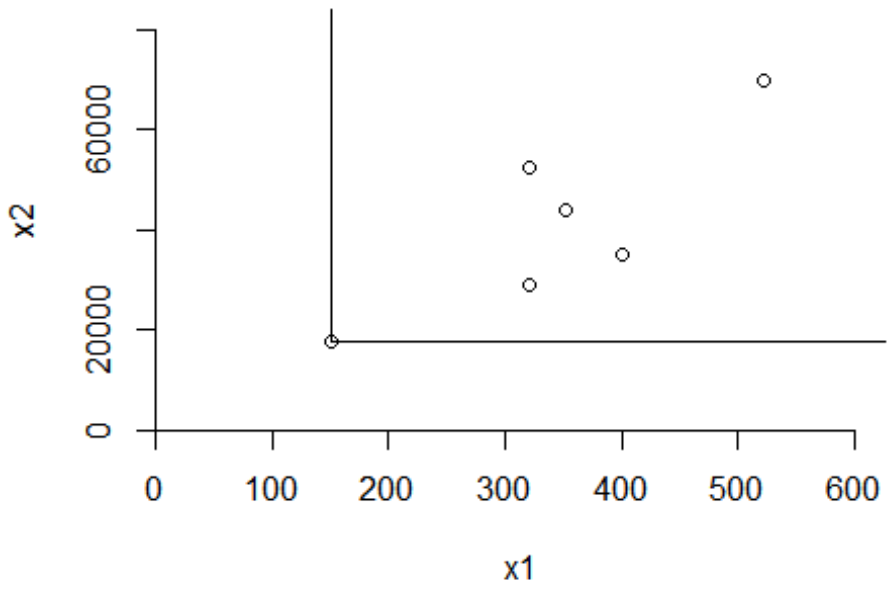
```
## 5  0                 1 <NA>
## 6  0 0.256299496040317 <NA>

# 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

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

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

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




```
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>

# 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

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

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

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




```
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>

# 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

print(DEA_ADD_Peers)

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

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

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

# 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)
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
```

The summary table reveals that the FRH and FDH techniques both return efficiency of 1.0 for all six DMUs, as well as the same peer and lambda values. DMU[1:4] was discovered by the CRS approach to be effective at 1.0. DMU[1:5] was discovered by the VRS approach to be effective at 1.0. DRS and IRS both found DMU[1:5] to be efficient at 1.0, as did the DMU[1:4] technique. The Peer[1] and Peer[2] values for all of the less effective DMUs were 1 and 2, respectively, although the Peer[3] value varied between 4 and 5. Additionally, for the identical DMU across all approaches, the relative weights (lambdas) were rather close.