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

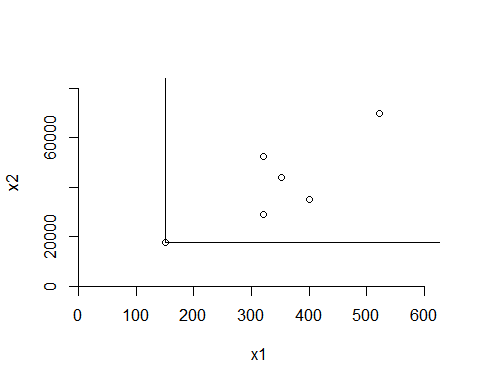
print(DEA\_FDH\_Peers)

## 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

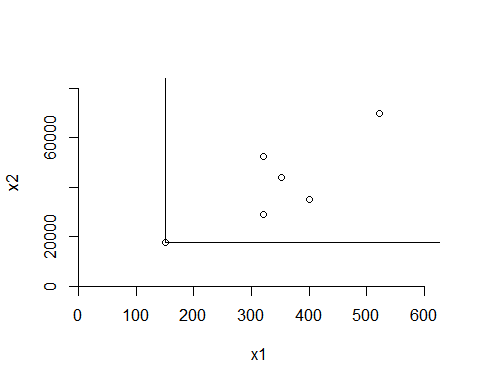
print(DEA\_CRS\_Peers)

## 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

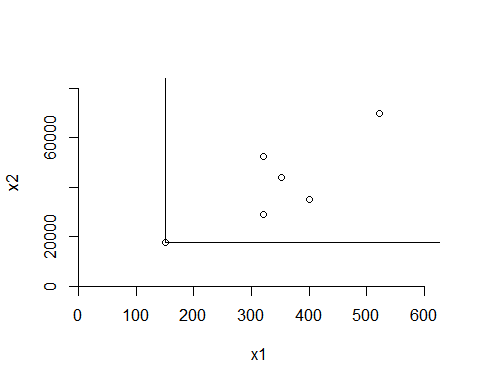
print(DEA\_VRS\_Peers)

## 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

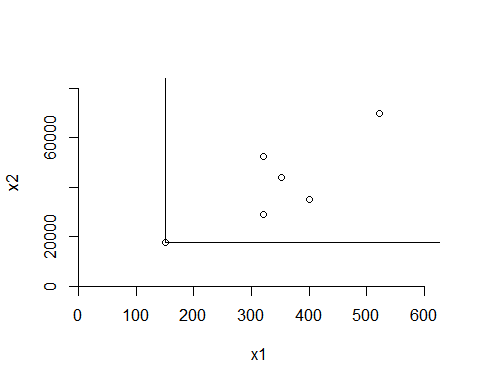
print(DEA\_IRS\_Peers)

## 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

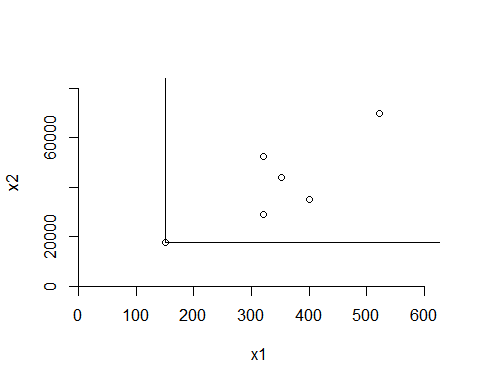
print(DEA\_DRS\_Peers)

## 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.