Practical assignment cost-effectiveness acceptability frontier - Solution

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Assignment and solutions

```
rm(list  = ls()) # clear environment
options(scipen = 999) # Disable scientific notations
library(tidyverse)
```

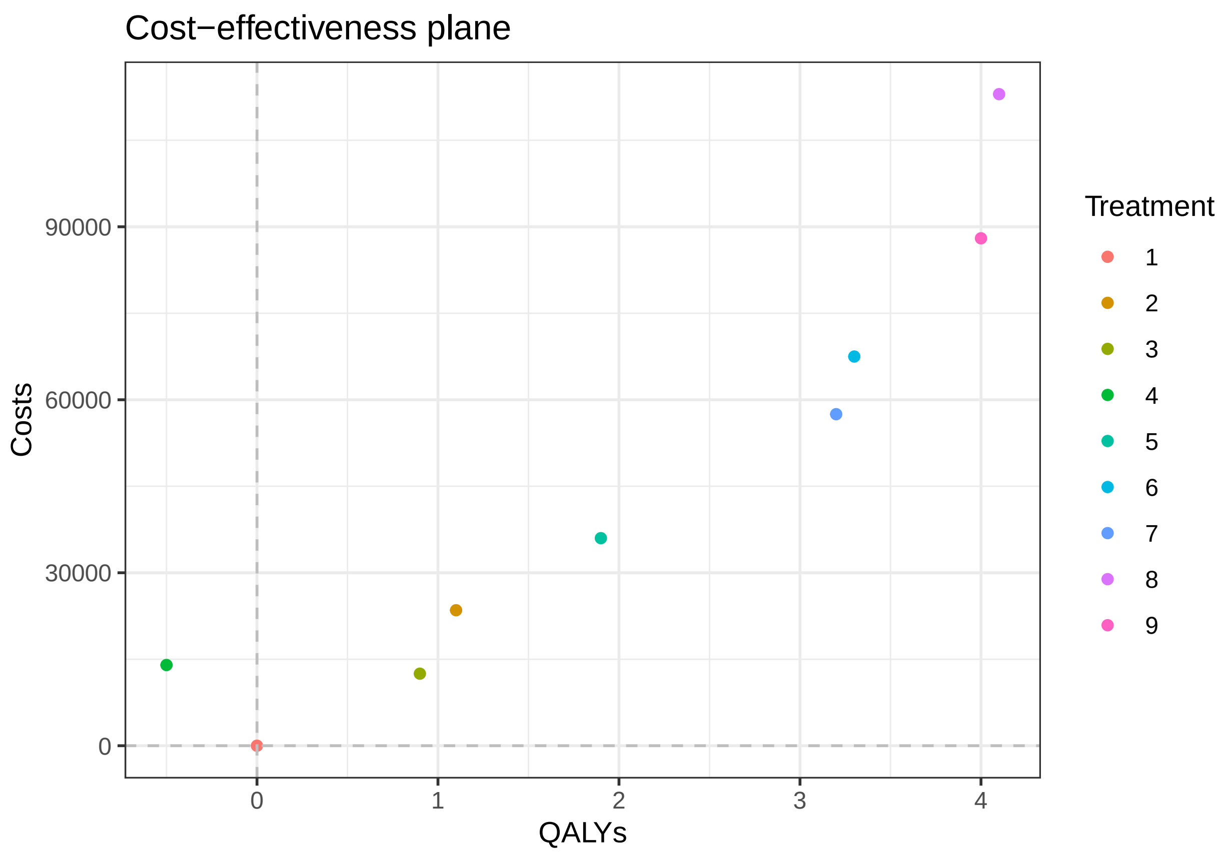
```
## -- Attaching packages --------------------------------------- tidyverse 1.3.0 --

## v ggplot2 3.3.3     v purrr   0.3.4
## v tibble  3.0.5     v dplyr   1.0.3
## v tidyr   1.1.2     v stringr 1.4.0
## v readr   1.4.0     v forcats 0.5.1

## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

```
library(knitr)

path_file <- "C:/Users/PouwelsXGLV/Documents/Onderwijs/Teaching/Basics/"
df_thx <- readRDS(paste0(path_file,"data_CEAF.rds")) # Load data

kable(df_thx) # Show data frame
```

Treatment	Name	Costs	QALYs
1	No screening (REF)	0	0.0
2	Screening once, at age 40	23500	1.1
3	Screening once, at age 60	12500	0.9
4	Screening once, at age 80	14000	-0.5
5	Screening twice, at age 40 and 60	36000	1.9
6	Screening every 10 years from age 40 to 80	67500	3.3
7	Screening every 10 years from age 50 to 80	57500	3.2
8	Screening every 5 years from age 40 to 80	113000	4.1
9	Screening every 5 years from age 50 to 80	88000	4.0

1. Create a cost-effectiveness plane for the outcomes of interventions 1-9

```
ggplot(data = df_thx, aes(x = QALYs, Costs, colour = Treatment)) +
  geom_point() +
  geom_hline(yintercept = 0, linetype = "dashed", color = "grey") +
  geom_vline(xintercept = 0, linetype = "dashed", color = "grey") +
  ggtitle("Cost-effectiveness plane") +
  theme_bw()
```



1.a. Question: based on this graph, can you already tell which intervention is (extendedly) dominated?
1.a. **Answer:** On this graph, you can see that 4 is dominated by 1, and that 2 and 5 are probably extendedly dominated by 7, and 6 extendedly dominated by 9.
2. Calculate the fully incremental ICERs of these screening strategies against each other
2.a. *To do so, use the method described in the paper from Paulden (literature list). Using for loops may be required. You can also perform this exercise using a pen and a paper.*
3. Which interventions are dominated?

```
# Order by increasing number of QALYs
df_thx <- df_thx[order(df_thx$QALYs),]

# Identify dominated strategies
df_thx$Dominated <- NA # create new column to identify dominated strategies

for (i in 1:(nrow(df_thx)-1)) {
  df_thx[i, "Dominated"] <- ifelse(df_thx[i + 1, "Costs"] < df_thx[i, "Costs"], 1, 0)
}
```

```
df_thx[nrow(df_thx), "Dominated"] <- 0 # strategies with highest health benefits cannot be dominated

kable(df_thx)
```

	Treatment	Name	Costs	QALYs	Dominated
4	4	Screening once, at age 80	14000	-0.5	1
1	1	No screening (REF)	0	0.0	0
3	3	Screening once, at age 60	12500	0.9	0
2	2	Screening once, at age 40	23500	1.1	0
5	5	Screening twice, at age 40 and 60	36000	1.9	0
7	7	Screening every 10 years from age 50 to 80	57500	3.2	0
6	6	Screening every 10 years from age 40 to 80	67500	3.3	0
9	9	Screening every 5 years from age 50 to 80	88000	4.0	0
8	8	Screening every 5 years from age 40 to 80	113000	4.1	0

3. **Answer:** As you can see in the Table, intervention 4 is dominated, because its health benefits are lower than intervention 1, but its costs are higher.

4. Which interventions are extendedly dominated?

```
# Calculate ICERs for non-dominated strategies.
df_thx$Ext_dominated <- NA # create new column to identify extendedly dominated strategies
df_thx$ICER <- NA # create new column to calculate ICERs identify extendedly dominated strategies

v_nondom <- which(df_thx$Dominated == 0) # vector of non-dominated strategies
df_thx[min(v_nondom), "Ext_dominated"] <- 0 # identify the first intervention in the comparison
df_thx[which(df_thx$Dominated == 1), "ICER"] <- "-"
df_thx[which(df_thx$Dominated == 1), "Ext_dominated"] <- "-"
df_thx[which(df_thx$Ext_dominated == 0), "ICER"] <- "-"

# Calculate ICERs
for (i in 2:length(v_nondom)) {
  df_thx[v_nondom[i], "ICER"] <- round((df_thx[v_nondom[i], "Costs"] -  df_thx[v_nondom[i-1], "Costs"])
}

df_thx$ICER <- as.numeric(as.character(df_thx$ICER))
```

```
## Warning: NAs introduced by coercion
```

```
# Determine extended dominance
for (i in 2:length(v_nondom)) {
    df_thx[v_nondom[i], "Ext_dominated"] <- ifelse(df_thx[v_nondom[i], "ICER"] == "-", 0,
                                       ifelse(df_thx[v_nondom[i], "ICER"] > df_thx[v_nondom[i + 1], "IC
                                       )
    )
    }

df_thx[nrow(df_thx), "Ext_dominated"] <- 0 # strategies with highest health benefits cannot be extended
v_ext_dom <- df_thx[which(df_thx$Ext_dominated == 1), "Treatment"] # vector of extendedly dominated str

kable(df_thx, row.names = F)
```

Treatment	Name	Costs	QALYs	Dominated	Ext_dominated	ICER
4	Screening once, at age 80	14000	-0.5	1	-	NA
1	No screening (REF)	0	0.0	0	0	NA
3	Screening once, at age 60	12500	0.9	0	0	13889
2	Screening once, at age 40	23500	1.1	0	1	55000
5	Screening twice, at age 40 and 60	36000	1.9	0	0	15625
7	Screening every 10 years from age 50 to 80	57500	3.2	0	0	16538
6	Screening every 10 years from age 40 to 80	67500	3.3	0	1	100000
9	Screening every 5 years from age 50 to 80	88000	4.0	0	0	29286
8	Screening every 5 years from age 40 to 80	113000	4.1	0	0	250000

The extendedly dominated strategies are: 2, 6. Calculating the ICERs has to be reiterated without these strategies.

```
# Calculate ICERs for non-dominated strategies - second round
df_thx$ICER <- NA # clear ICER column

v_nondom <- which(df_thx$Dominated == 0 &
                    df_thx$Ext_dominated == 0) # vector of non-(extendedly) dominated strategies
df_thx[min(v_nondom), "Ext_dominated"] <- 0 # identify the first intervention in the comparison
df_thx[min(v_nondom), "ICER"] <- "-" # identify the first intervention in the comparison

df_thx[which(df_thx$Dominated == 1 |
               df_thx$Ext_dominated == 1), "ICER"] <- "-"

# Calculate ICERs
for (i in 2:length(v_nondom)) {
  df_thx[v_nondom[i], "ICER"] <- round((df_thx[v_nondom[i], "Costs"] -  df_thx[v_nondom[i-1], "Costs"])
}

df_thx$ICER <- as.numeric(as.character(df_thx$ICER))
```

```
## Warning: NAs introduced by coercion
```

```
# Determine extended dominance
for (i in 2:length(v_nondom)) {
    df_thx[v_nondom[i], "Ext_dominated"] <- ifelse(df_thx[v_nondom[i], "ICER"] == "-", 0,
                                           ifelse(df_thx[v_nondom[i], "ICER"] > df_thx[v_nondom[i+1], "ICER
                                           )
    )
    }
df_thx[nrow(df_thx), "Ext_dominated"] <- 0 # strategies with highest health benefits cannot be extended

v_ext_dom_2 <- df_thx[which(df_thx$Ext_dominated == 1), "Treatment"] # vector of extendedly dominated s

kable(df_thx, row.names = F)
```

Treatment	Name	Costs	QALYs	Dominated	Ext_dominated	ICER
4	Screening once, at age 80	14000	-0.5	1	-	NA
1	No screening (REF)	0	0.0	0	0	NA
3	Screening once, at age 60	12500	0.9	0	0	13889

Treatment	Name	Costs	QALYs	Dominated	Ext_dominated	ICER
2	Screening once, at age 40	23500	1.1	0	1	NA
5	Screening twice, at age 40 and 60	36000	1.9	0	1	23500
7	Screening every 10 years from age 50 to 80	57500	3.2	0	0	16538
6	Screening every 10 years from age 40 to 80	67500	3.3	0	1	NA
9	Screening every 5 years from age 50 to 80	88000	4.0	0	0	38125
8	Screening every 5 years from age 40 to 80	113000	4.1	0	0	250000

The extendedly dominated strategies are now: 2, 5, 6. Calculating the ICERs has to be reiterated without these strategies.

```
# Calculate ICERs for non-dominated strategies - second round
df_thx$ICER <- NA # clear ICER column

v_nondom <- which(df_thx$Dominated == 0 &
                    df_thx$Ext_dominated == 0) # vector of non-(extendedly) dominated strategies
df_thx[min(v_nondom), "Ext_dominated"] <- 0 # identify the first intervention in the comparison
df_thx[min(v_nondom), "ICER"] <- "-" # identify the first intervention in the comparison

df_thx[which(df_thx$Dominated == 1 |
               df_thx$Ext_dominated == 1), "ICER"] <- "-"

# Calculate ICERs
for (i in 2:length(v_nondom)) {
  df_thx[v_nondom[i], "ICER"] <- round((df_thx[v_nondom[i], "Costs"] -  df_thx[v_nondom[i-1], "Costs"])
}

df_thx$ICER <- as.numeric(as.character(df_thx$ICER))
```

```
## Warning: NAs introduced by coercion
```

```
# Determine extended dominance
for (i in 2:length(v_nondom)) {
    df_thx[v_nondom[i], "Ext_dominated"] <- ifelse(df_thx[v_nondom[i], "ICER"] == "-", 0,
                                             ifelse(df_thx[v_nondom[i], "ICER"] > df_thx[v_nondom[i+1], "ICER
                                             )
    )
    }
df_thx[nrow(df_thx), "Ext_dominated"] <- 0 # strategies with highest health benefits cannot be extended

v_ext_dom_3 <- df_thx[which(df_thx$Ext_dominated == 1), "Treatment"] # vector of extendedly dominated s

kable(df_thx, row.names = F)
```

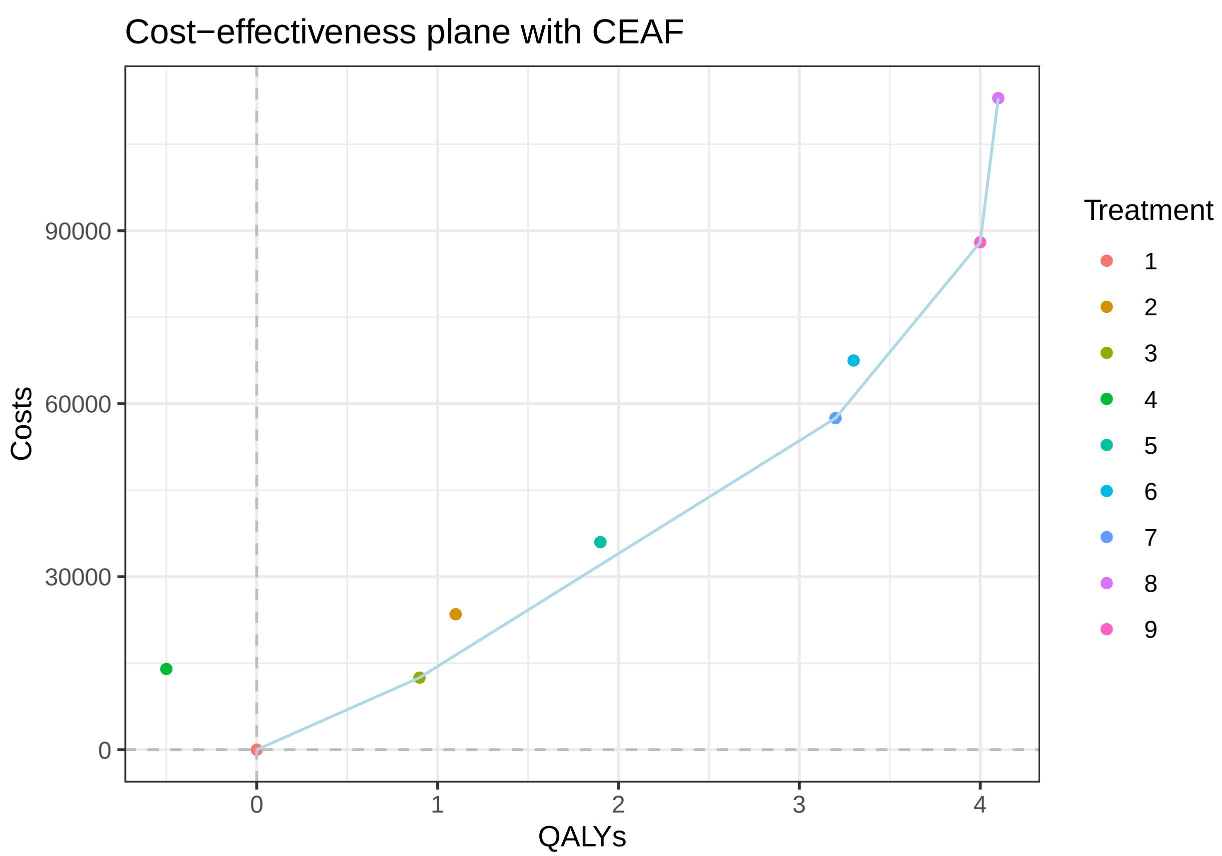
Treatment	Name	Costs	QALYs	Dominated	Ext_dominated	ICER
4	Screening once, at age 80	14000	-0.5	1	-	NA
1	No screening (REF)	0	0.0	0	0	NA
3	Screening once, at age 60	12500	0.9	0	0	13889
2	Screening once, at age 40	23500	1.1	0	1	NA
5	Screening twice, at age 40 and 60	36000	1.9	0	1	NA
7	Screening every 10 years from age 50 to 80	57500	3.2	0	0	19565

Treatment	Name	Costs	QALYs	Dominated	Ext_dominated	ICER
6	Screening every 10 years from age 40 to 80	67500	3.3	0	1	NA
9	Screening every 5 years from age 50 to 80	88000	4.0	0	0	38125
8	Screening every 5 years from age 40 to 80	113000	4.1	0	0	250000

Finally, the extendedly dominated strategies are: 2, 5, 6.

5. Which strategies are on the cost-effectiveness acceptability frontier?
   Answer: The strategies on the CEAF are: 1, 3, 7, 9, 8

```
ggplot(data = df_thx, aes(x = QALYs, Costs, colour = Treatment)) +
  geom_point() +
  geom_hline(yintercept = 0, linetype = "dashed", color = "grey") +
  geom_vline(xintercept = 0, linetype = "dashed", color = "grey") +
  geom_line(data = df_thx[which(df_thx$Dominated == 0 & df_thx$Ext_dominated == 0),], aes(x = QALYs, Co
  ggtitle("Cost-effectiveness plane with CEAF") +
  theme_bw()
```



6. Which intervention is optimal if the WTP threshold is equal to €20,000/QALY?
   Answer: The optimal intervention if the WTP threshold is €20,000/QALY is 7, because its ICER is 19565

7. Which intervention is optimal if the WTP threshold is equal to €40,000/QALY?
   Answer: The optimal intervention if the WTP threshold is €40,000/QALY is 9, because its ICER is 38125

8. Which intervention is optimal if the WTP threshold is equal to €100,000/QALY?
   Answer: The optimal intervention if the WTP threshold is €100,000/QALY is 9, because its ICER is 38125

9. At which WTP threshold would intervention 5 be the optimal intervention?
   Answer: None because it is extendedly dominated.

10. At which WTP threshold would intervention 8 be the optimal intervention?
    Answer: When the WTP threshold becomes €250,000/QALY or higher.

11. Calculate the Net Monetary Benefit (NMB) for each intervention for a WTP threshold of €20,000/QALY. Which intervention has the highest NMB? Does this correspond with your answer to question 6?

```r
# Calculate NMB
df_thx$NMB <- 20000 * df_thx$QALYs - df_thx$Costs
optim_strat <- df_thx[which(df_thx$NMB == max(df_thx$NMB)), "Treatment"]
```

Answer: The optimal intervention using the NMB and a WTP threshold is €20,000/QALY is 7. This answer is similar as the answer to question 6.