Application

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In this document, we reproduce Table 2 and Figure 1 presented in Section 5 of the submitted manuscript. The time required to render this document was less than just two minutes on a Intel(R) Xeon(R) CPU E5-2650 server with 20 cores and 40 threads.

Loading the dataset

```
library(tidyverse)
library(kableExtra)
library(ggplot2)

source("code/sensitivity_analysis_functions.R")
load(file = "data/nhanes.fish.rda")
```

Creating the new treatment variable with three levels

```
nhanes.fish.new <- nhanes.fish %>%
  mutate(fish.level.new = case_when(
    fish == 0 ~ "no",
    fish > 0 & fish <= 1 ~ "low",
    fish > 1 ~ "high"
  )) %>%
  mutate(A = case_when(
    fish == 0 ~ 1,
    fish > 0 & fish <= 1 ~ 2,
    fish > 1 ~ 3
  )) %>%
  mutate(Y = log2(o.LBXTHG))
```

Sensitivity analysis of the pairwise average treatment effects

```
gps.formula <- A~gender + age + income + income.missing + race + education +
  smoking.ever + smoking.now


no_vs_low <- sensitivity_IPW(
  data = nhanes.fish.new, A_name = "A", Y_name = "Y",
  gps.formula = gps.formula, contrast = c(-1, 1, 0),
  lambda = c(0, 0.5, 0.75, 1, 1.5, 2), alpha = 0.1,
  parallel = T, B = 1000
)
```

```r
no_vs_high <- sensitivity_IPW(
  data = nhanes.fish.new, A_name = "A", Y_name = "Y",
  gps.formula = gps.formula, contrast = c(-1, 0, 1),
  lambda = c(0, 0.5, 0.75, 1, 1.5, 2), alpha = 0.1,
  parallel = T, B = 1000
)

low_vs_high <- sensitivity_IPW(
  data = nhanes.fish.new, A_name = "A", Y_name = "Y",
  gps.formula = gps.formula, contrast = c(0, -1, 1),
  lambda = c(0, 0.5, 0.75, 1, 1.5, 2), alpha = 0.1,
  parallel = T, B = 1000
)

result <- as_tibble(rbind(no_vs_low, no_vs_high, low_vs_high))
names(result) <- c("lambda", "lower", "upper", "lower_5", "upper_95")
```

Table 2 (Section 5)

```r
result_table <-
  result %>%
  mutate(
    Lambda = as.factor(round(exp(lambda), 2)),
    midpoint = (lower + upper) / 2,
    estimand = factor(
      rep(1:3, each = 6),
      levels = 1:3,
      labels = c(
        "$\\tau_{1, 2}$",
        "$\\tau_{1, 3}$",
        "$\\tau_{2, 3}$"
      )
    ),
    point_interval = paste0(
      "$", "(", sprintf("%.2f", result$lower), ", ",
      sprintf("%.2f", result$upper), ")", "$"
    ),
    conf_interval = paste0(
      "$", "(", sprintf("%.2f", result$lower_5), ", ",
      sprintf("%.2f", result$upper_95), ")", "$"
    ),
  )

result_table %>%
  select(estimand, Lambda, lambda, point_interval, conf_interval) %>%
  kbl(
    booktabs = T,
    align = "crrrr",
    digits = 2,
    escape = F,
    caption = "Sensitivity analysis results presented in Table 2 (Section 5)",
    col.names = linebreak(c(
```

```
      "Estimand", "$\\Lambda$", "$\\lambda$",
      "Point estimate \n interval",
      "90\\% confidence \n interval"
    ), align = "c")
  ) %>%
  kable_styling(position = "center", latex_options = "hold_position") %>%
  collapse_rows(
    columns = 1,
    valign = "middle",
    latex_hline = "major"
  )
```

Table 1: Sensitivity analysis results presented in Table 2 (Section 5)

Estimand	Λ	λ	Point estimate interval	90% confidence interval
$\tau_{1,2}$	1	0.00	$(0.45, 0.45)$	$(0.31, 0.58)$
	1.65	0.50	$(-0.09, 0.99)$	$(-0.23, 1.13)$
	2.12	0.75	$(-0.36, 1.25)$	$(-0.50, 1.41)$
	2.72	1.00	$(-0.62, 1.51)$	$(-0.76, 1.69)$
	4.48	1.50	$(-1.13, 2.01)$	$(-1.29, 2.22)$
	7.39	2.00	$(-1.62, 2.50)$	$(-1.80, 2.78)$
$\tau_{1,3}$	1	0.00	$(2.08, 2.08)$	$(1.88, 2.25)$
	1.65	0.50	$(1.44, 2.69)$	$(1.25, 2.85)$
	2.12	0.75	$(1.14, 2.98)$	$(0.95, 3.13)$
	2.72	1.00	$(0.84, 3.25)$	$(0.65, 3.41)$
	4.48	1.50	$(0.29, 3.77)$	$(0.08, 3.93)$
	7.39	2.00	$(-0.24, 4.27)$	$(-0.45, 4.47)$
$\tau_{2,3}$	1	0.00	$(1.63, 1.63)$	$(1.43, 1.84)$
	1.65	0.50	$(0.90, 2.34)$	$(0.68, 2.53)$
	2.12	0.75	$(0.55, 2.68)$	$(0.33, 2.85)$
	2.72	1.00	$(0.21, 3.00)$	$(-0.01, 3.17)$
	4.48	1.50	$(-0.42, 3.59)$	$(-0.69, 3.76)$
	7.39	2.00	$(-1.02, 4.17)$	$(-1.35, 4.37)$

Figure 1 (Section 5)

```
sens_plot <- ggplot(
  data = result_table,
  mapping = aes(x = Lambda, y = midpoint, colour = estimand, shape = estimand)
) +
  geom_errorbar(
    mapping = aes(ymin = lower_5, ymax = upper_95),
    width = 0.5,
    size = 0.5,
    position = position_dodge(width = 0.6),
    linetype = 1,
    show.legend = TRUE
  ) +
  geom_errorbar(
```

```
  mapping = aes(ymin = lower_5, ymax = upper_95),
  width = 0.5,
  position = position_dodge(width = 0.6),
  linetype = 2,
  show.legend = TRUE
) +
geom_point(
  position = position_dodge(width = 0.6),
  size = 2.5,
  show.legend = TRUE
) +
geom_hline(yintercept = 0, size = 0.5, linetype = 1, color = "grey") +
xlab(expression(Sensitivity ~ parameter ~ Lambda)) +
ylab("Average treatment effect (ATE)") +
scale_color_brewer(
  palette = "Set1",
  labels = expression(tau[1 * "," * 2], tau[1 * "," * 3], tau[2 * "," * 3])
) +
scale_shape(
  solid = TRUE,
  labels = expression(tau[1 * "," * 2], tau[1 * "," * 3], tau[2 * "," * 3])
) +
theme_bw() +
theme(
  axis.title = element_text(size = 10),
  legend.position = c(0.01, 0.99),
  legend.title = element_blank(),
  legend.justification = c("left", "top"),
  legend.text = element_text(size = 8),
  legend.background = element_rect(colour = "grey45")
)
```

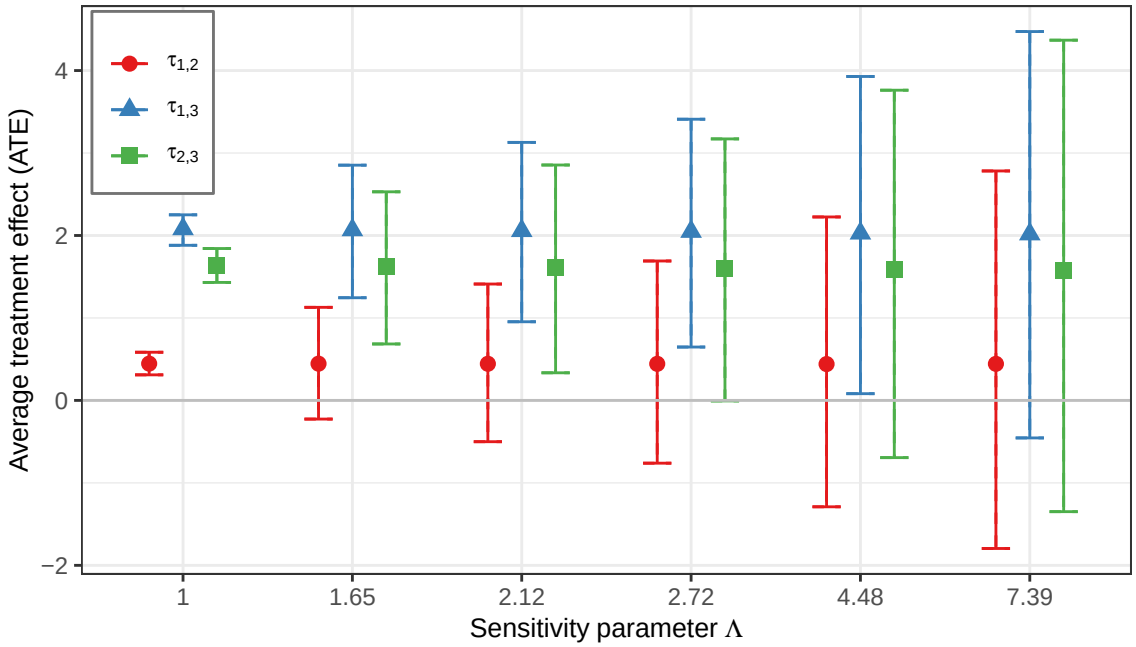

Figure 1: Graphical representation of the sensitivity analysis results presented in Figure 1 (Section 5).