ECON293_Final_Project

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Role of Default in Probability of Tipping: An ML Approach

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Introduction

Our study examines the default effects by looking at the setting of tipping taxi drivers in New York City. Specifically, we seek to understand whether a higher default tip suggestion would change customer's probability of tipping. This setting offers two unique benefits. First, it provides a setting where consumers are facing the choice sets regularly. Second, the high-frequency nature of tipping results in a large dataset, which enables researchers to apply machine learning methods.

Data Cleaning

```
# Step 1: Cleaning -----
## Read in the stata version of the data
tips2009_vendor_1218 <- read_dta(paste0(Raw_Data,"tips2009_clean.dta"))

## Subset the data according to the following rules:
## 1. Rides from the vendors only
## 2. Fare between 12 to 18 dollars
tips2009_vendor_1218 <- tips2009_vendor_1218 %>% filter(vendor == 1 & fare >= 12 & fare <= 18)

# Step 2: Create additional categorical variables for the covariates  -----
classify_cov <- function(data){
  ## Categorize day of week
  data2 <- data %>%
    mutate(weekend = ifelse(pkp_dow >= 1 & pkp_dow <= 5, 0, 1))
  ## Categorize time of the day
  data3 <- data2 %>%
    mutate(pickup_time_group = ifelse(pkp_hour >= 6 & pkp_hour <= 12, 1,
                                      ifelse(pkp_hour >= 13 & pkp_hour <= 16, 2,
                                             ifelse(pkp_hour >= 17 & pkp_hour <= 20, 3, 0))))
  ## Convert the pick up locations to numeric, because the causal forest package does not support
  ## non-numeric values
  data4 <- data3 %>%
    mutate(Manhattan_pkp = ifelse(pkp_boro == "Manhattan", 1,0),
           Brooklyn_pkp = ifelse(pkp_boro == "Brooklyn", 1,0),
           Queens_pkp = ifelse(pkp_boro == "Queens", 1,0),
           Bronx_pkp = ifelse(pkp_boro == "The Bronx", 1,0),
           Staten_pkp = ifelse(pkp_boro == "Staten Island", 1,0),
           Other_pkp = ifelse(pkp_boro == "", 1,0))
```

```r
  ## Convert the drop off locations to numeric
  data5 <- data4 %>%
    mutate(Manhattan_drf = ifelse(drf_boro == "Manhattan", 1,0),
           Brooklyn_drf = ifelse(drf_boro == "Brooklyn", 1,0),
           Queens_drf = ifelse(drf_boro == "Queens", 1,0),
           Bronx_drf = ifelse(drf_boro == "The Bronx", 1,0),
           Staten_drf = ifelse(drf_boro == "Staten Island", 1,0),
           Other_drf = ifelse(drf_boro == "", 1,0))

  data_fnl <- data5
  return(data_fnl)
}

tips2009_1218_regroup <- classify_cov(tips2009_vendor_1218)

# Step 3: Save the data -----
write.csv(tips2009_1218_regroup,paste0(In_Data,"fare_1218_recoded_final.csv"))
```

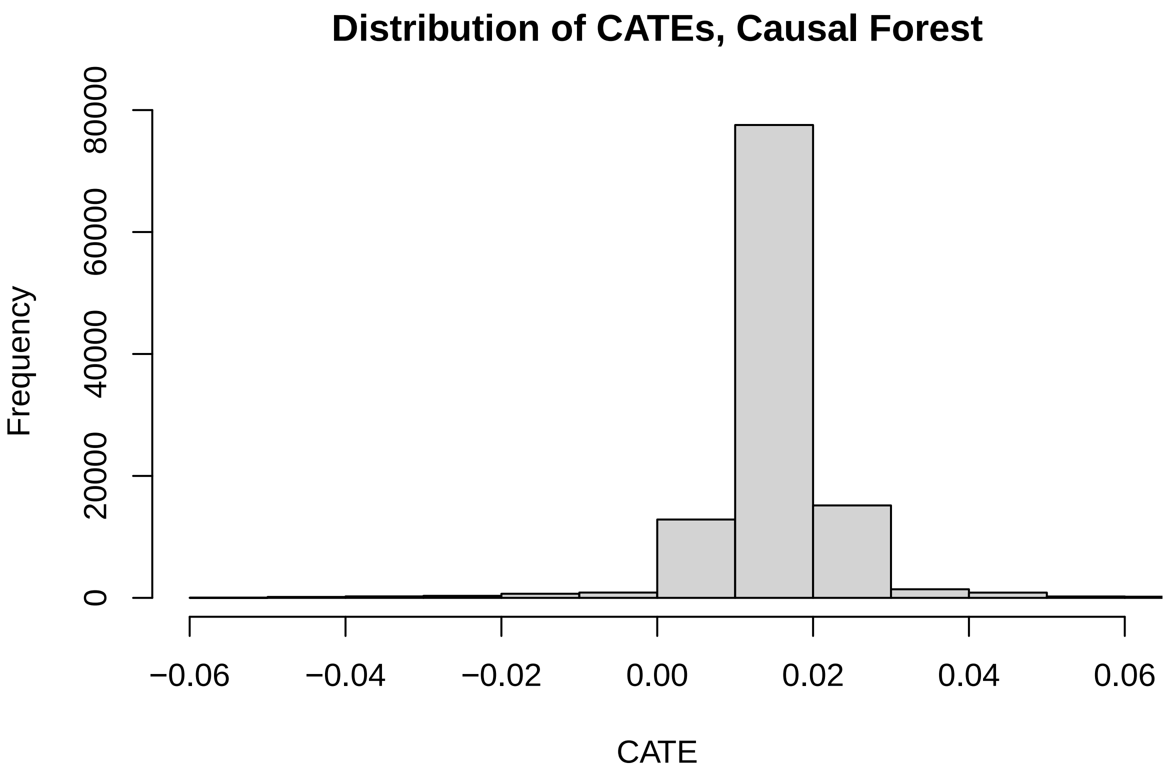
Methods

```r
# Step 1: Import the data -----
tips2009_1218 <- read.csv(paste0(In_Data,"fare_1218_recoded_final.csv"))
# Create subsets
reduced=1
if (reduced == 1){
  data = subset(tips2009_1218, fare>=14 & fare<=16)
  suffix = "r1"
}
if (reduced == 0){
  data = subset(tips2009_1218, fare>=12 & fare<=18)
  suffix = "r0"
}

# Step 2: Set up variables -----
n <- nrow(data)
# Treatment: Whether the fare amount is above or below 15 dollars
treatment <- "dsc_15"
# Outcome: Whether someone tips 0. 1 for yes, 0 for no.
outcome <- "tip_zero"
running = "fare"
# Additional covariates
covariates <- c("weekend", "pickup_time_group", "gr_inc10_All", "Manhattan_pkp", "Brooklyn_pkp", "Queens

# Step 3: Split the data into training and testing -----
split1<- sample(c(rep(0, 0.7 * nrow(data)), rep(1, 0.3 * nrow(data))))
data.train <- data[split1 == 0,]
data.test <- data[split1 == 1,]
# Training code
W_train <- data.train[,treatment]
Y_train <- data.train[,outcome]
X_train <- data.train[,covariates]
Z1_train = (data.train[,running]-15)*W_train
Z0_train = (data.train[,running]-15)*(1-W_train)
```

```r
# Test code
W_test <- data.test[,treatment]
Y_test <- data.test[,outcome]
X_test <- data.test[,covariates]
Z1_test = (data.test[,running]-15)*W_test
Z0_test = (data.test[,running]-15)*(1-W_test)
```

Causal Forest

```r
# Implement causal forest in grf
cf.priority = causal_forest(X_train, Y_train, W_train, num.trees = 100)
priority.cate <- predict(cf.priority, X_test)$predictions

## Estimate the causal forest on the test data
cf.eval <- causal_forest(X_test, Y_test, W_test)

## Estimate the ATE for the whole population
cf.ATE.mean <- mean(priority.cate)
cf.ATE.SD <- sd(priority.cate)
ATE_stats <- c(cf.ATE.mean,cf.ATE.SD)
write.csv(ATE_stats,paste0(Output, "Causal_Forest_sumstats.csv"),row.names=F)

# Show the CATE distribution
hist(priority.cate, main = "Distribution of CATEs, Causal Forest", xlab = "CATE", xlim=c(-0.06,0.06))
```




```r
png(file=paste0(Output, "Causal_Forest_CATE.png"),width=595, height=545)

## Plot QINI curve - using rank_average_treatment_effect
rate <- rank_average_treatment_effect(cf.eval, priority.cate, target = "QINI")
```

```r
png(file=paste0(Output, "Causal_Forest_QINI.png"),width=595, height=545)
plot(rate)
print(rate)
```

```
##       estimate      std.err            target
##  -0.0002170781 0.0003422336 priorities | QINI
```

```r
## Create quartile plots
cf.tau.hat <- priority.cate
strata <- 10
quintiles <- quantile(cf.tau.hat, prob=seq(from=0,to=1,by=1/strata))
cf.tau.hat.quartiles <- cut(cf.tau.hat, breaks = quintiles, labels = 1:strata, include.lowest = TRUE)
## Combine all the data together
combined_data <- as.data.frame(cbind(data.test,cf.tau.hat,cf.tau.hat.quartiles))
## Store tau estimates by quartiles
CATE_test <- combined_data %>% group_by(cf.tau.hat.quartiles) %>%
  summarise(tau.mean = mean(cf.tau.hat,na.rm = TRUE),
            tau.sd = sd(cf.tau.hat,na.rm = TRUE))
## Estimate ATE for each split
ATE.df <- data.frame(ATE=double(),
                     SE=integer())

## Create the calibration plot
for (i in 1:strata){
  temp_data <- combined_data %>% filter(cf.tau.hat.quartiles == i)
  rd_lm <- temp_data %$%
    lm(tip_zero ~ dsc_15 + I(fare - 15) + dsc_15:I(fare - 15))
  ATE.df[i,"ATE"] <- rd_lm$coefficients["dsc_15"]
  ATE.df[i,"SE"] <- summary(rd_lm)$coefficients[2,2]
}

## CI
ATE.df2 <- ATE.df %>% mutate(CI_max = ATE + 1.96*SE, CI_min = ATE - 1.96*SE)
## Combine the dataset
ATE.df.fnl <- cbind(ATE.df2,CATE_test)


cali_plot <- ggplot(ATE.df.fnl, aes(tau.mean, ATE)) +
  geom_point() +
  geom_errorbar(aes(ymin = CI_max, ymax = CI_min)) +
  theme_light() + labs(x = "Tau hat", y = "ATE", title = "")

ggsave(file=paste0(Output, "Calibration_by_quartile.png"), plot = cali_plot, width=8, height=4.94)

cali_plot
```

X Learner

```r
# Implement the x learner on the testing data
tf0 = regression_forest(X_train[W_train==0,], Y_train[W_train==0], num.trees = 100)
yhat0 = predict(tf0, X_train[W_train==1,])$predictions
xf1 = regression_forest(X_train[W_train==1,], Y_train[W_train==1]-yhat0, num.trees = 100)
xf.preds.1 = predict(xf1, X_test)$predictions
xf.preds.1[W_test==1] = predict(xf1,X_test[W_test==1,])$predictions
```

```r
tf1 = regression_forest(X_train[W_train==1,], Y_train[W_train==1], num.trees = 100)
yhat1 = predict(tf1, X_train[W_train==0,])$predictions
xf0 = regression_forest(X_train[W_train==0,], yhat1-Y_train[W_train==0], num.trees = 100)
xf.preds.0 = predict(xf0, X_test)$predictions
xf.preds.0[W_test==0] = predict(xf0,X_test[W_test==0,])$predictions
propf = regression_forest(X_test, W_test)
ehat = predict(propf)$predictions
preds.xf = (1 - ehat) * xf.preds.1 + ehat * xf.preds.0

## Estimate the ATE for the whole population
xf.ATE.mean <- mean(preds.xf)
xf.ATE.SD <- sd(preds.xf)
ATE_stats <- c(xf.ATE.mean,xf.ATE.SD)
write.csv(ATE_stats,paste0(Output, "X_learner_sumstats.csv"),row.names=F)

## Plot QINI curve - using rank_average_treatment_effect
rate <- rank_average_treatment_effect(cf.eval, preds.xf, target = "QINI")
png(file=paste0(Output, "X_Learner_QINI.png"),width=595, height=545)
plot(rate)
print(rate)
```

```
##       estimate      std.err            target
##  -0.0001572807 0.0003460642 priorities | QINI
```

```r
dev.off()
```

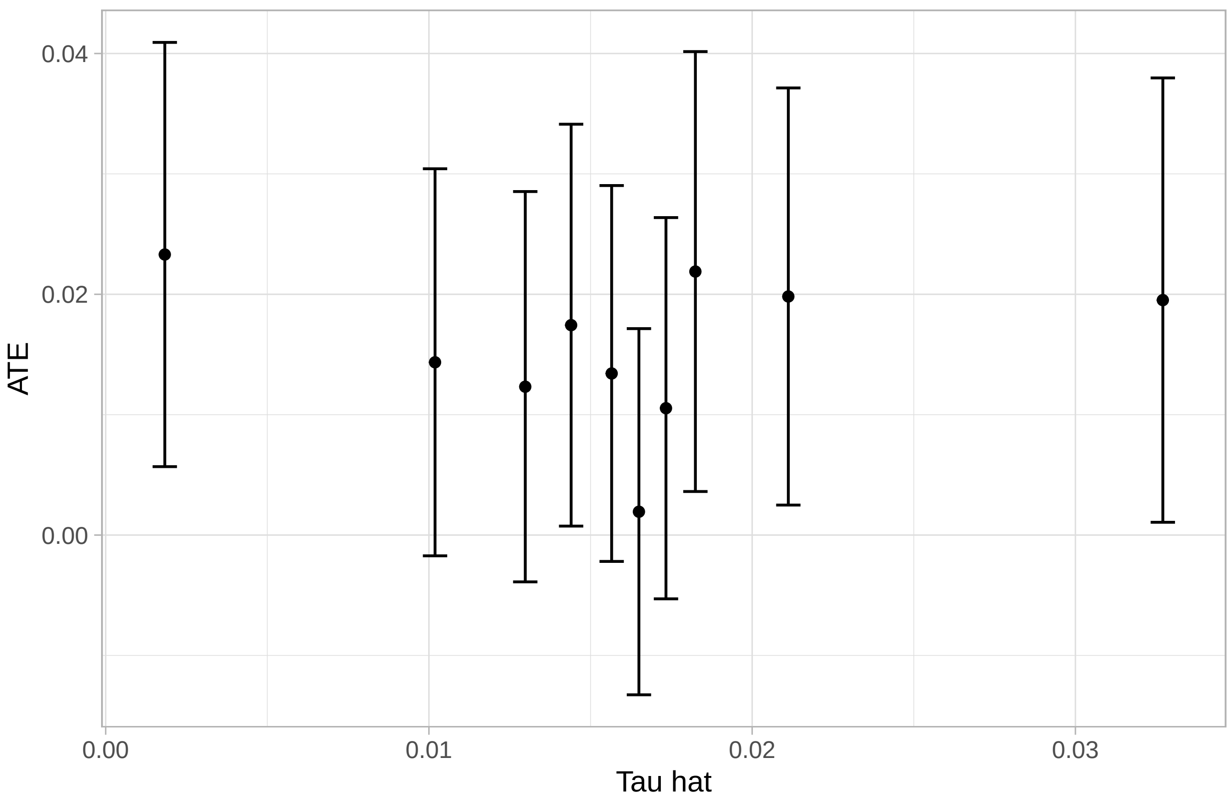
```
## pdf
##   2
```

```r
# Show the CATE distribution
png(file=paste0(Output, "X_Learner_CATE.png"),width=595, height=545)
hist(ehat, main = "", xlab = "CATE")
dev.off()
```

```
## pdf
##   2
```

```r
## Create quartile plots
xf.tau.hat <- preds.xf
strata <- 10
quintiles <- quantile(xf.tau.hat, prob=seq(from=0,to=1,by=1/strata))
xf.tau.hat.quartiles <- cut(xf.tau.hat, breaks = quintiles, labels = 1:strata, include.lowest = TRUE)
## Combine all the data together
combined_data <- as.data.frame(cbind(data.test,xf.tau.hat,xf.tau.hat.quartiles))
## Store tau estimates by quartiles
CATE_test <- combined_data %>% group_by(xf.tau.hat.quartiles) %>%
  summarise(tau.mean = mean(xf.tau.hat,na.rm = TRUE),
            tau.sd = sd(xf.tau.hat,na.rm = TRUE))
## Estimate ATE for each split
ATE.df <- data.frame(ATE=double(),
                  SE=integer())

## Create the calibration plot
for (i in 1:strata){
  temp_data <- combined_data %>% filter(xf.tau.hat.quartiles == i)
  rd_lm <- temp_data %$%
```

```
    lm(tip_zero ~ dsc_15 + I(fare - 15) + dsc_15:I(fare - 15))
  ATE.df[i,"ATE"] <- rd_lm$coefficients["dsc_15"]
  ATE.df[i,"SE"] <- summary(rd_lm)$coefficients[2,2]
}

## CI
ATE.df2 <- ATE.df %>% mutate(CI_max = ATE + 1.96*SE, CI_min = ATE - 1.96*SE)
## Combine the dataset
ATE.df.fnl <- cbind(ATE.df2,CATE_test)


cali_plot <- ggplot(ATE.df.fnl, aes(tau.mean, ATE)) +
  geom_point() +
  geom_errorbar(aes(ymin = CI_max, ymax = CI_min)) +
  theme_light() + labs(x = "Tau hat", y = "ATE", title = "")

ggsave(file=paste0(Output, "Calibration_by_quartile.png"), plot = cali_plot, width=8, height=4.94)

cali_plot
```



LM Forest

```
## LM forest
lmf = lm_forest(X_train, Y_train, cbind(W_train, Z0_train, Z1_train), num.tree = 100)
lm.tau.hat <- predict(lmf,X_test)$predictions[, 1, ]

## Estimate the ATE for the whole population
lm.ATE.mean <- mean(lm.tau.hat)
```

```r
lm.ATE.SD <- sd(lm.tau.hat)
ATE_stats <- c(lm.ATE.mean,lm.ATE.SD)
write.csv(ATE_stats,paste0(Output, "LM_forest_sumstats_", suffix,".csv"),row.names=F)

## Plot QINI curve - using rank_average_treatment_effect
rate <- rank_average_treatment_effect(cf.eval, lm.tau.hat, target = "QINI")
png(file=paste0(Output, "LM_forest_QINI_", suffix,".png"),width=595, height=545)
plot(rate)
print(rate)
```

```
##      estimate     std.err           target
##  0.0003823195 0.000368536 priorities | QINI
```

```r
dev.off()
```

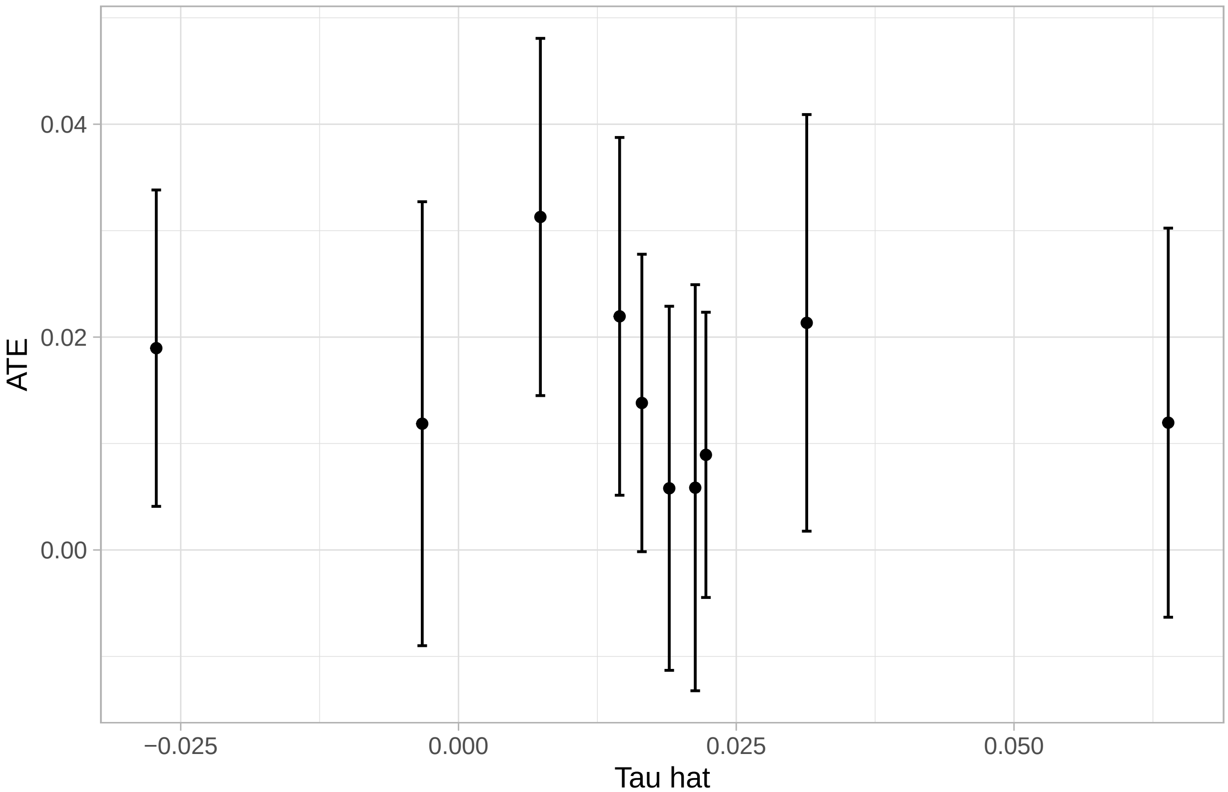
```
## pdf
##   2
```

```r
# Show the CATE distribution
png(file=paste0(Output, "LM_forest_CATE_", suffix,".png"),width=595, height=545)
hist(lm.tau.hat, main = "", xlab = "CATE")
dev.off()
```

```
## pdf
##   2
```

```r
## Create quantile plots ----
strata <- 10
quintiles <- quantile(lm.tau.hat, prob=seq(from=0,to=1,by=1/strata))
lm.tau.hat.quartiles <- cut(lm.tau.hat, breaks = quintiles, labels = 1:strata, include.lowest = TRUE)

## Combine all the data together
combined_data <- as.data.frame(cbind(data.test,lm.tau.hat,lm.tau.hat.quartiles))

## Store tau estimates by quartiles
CATE_test <- combined_data %>% group_by(lm.tau.hat.quartiles) %>%
  summarise(tau.mean = mean(lm.tau.hat,na.rm = TRUE),
            tau.sd = sd(lm.tau.hat,na.rm = TRUE))

## Estimate ATE for each split
ATE.df <- data.frame(ATE=double(),
                     SE=integer())

## Create the calibration plot
for (i in 1:strata){
  temp_data <- combined_data %>% filter(lm.tau.hat.quartiles == i)
  rd_lm <- temp_data %$%
    lm(tip_zero ~ dsc_15 + I(fare - 15) + dsc_15:I(fare - 15))
  ATE.df[i,"ATE"] <- rd_lm$coefficients["dsc_15"]
  ATE.df[i,"SE"] <- summary(rd_lm)$coefficients[2,2]
}

## CI
ATE.df2 <- ATE.df %>% mutate(CI_max = ATE + 1.96*SE, CI_min = ATE - 1.96*SE)

## Combine the dataset
```

```r
ATE.df.fnl <- cbind(ATE.df2,CATE_test)

## GGplot
cali_plot <- ggplot(ATE.df.fnl, aes(tau.mean, ATE)) +
  geom_point() +
  geom_errorbar(aes(ymin = CI_max, ymax = CI_min)) +
  theme_light() + labs(x = "Tau hat", y = "ATE", title = "")

ggsave(file=paste0(Output,"Calibration_by_quartile_LM_forest_", suffix,".png"), plot = cali_plot, width=

cali_plot
```



Create HTE plots by categoircal variables

```r
HTE_plot <- function(lm.tau.hat,data.test,factor, factor_label){
  ## Combine all the data together
  combined_data <- as.data.frame(cbind(data.test,lm.tau.hat))
  ## Store tau estimates by drop off borough
  CATE_test <- combined_data %>% group_by(get(factor)) %>%
    summarise(tau.mean = mean(lm.tau.hat,na.rm = TRUE),
              tau.sd = sd(lm.tau.hat,na.rm = TRUE))
  ## ATE storage df
  ATE.df <- data.frame(ATE=double(),
                       SE=integer(),
                       strata = integer(),
                       method = c())
  ## Estimate Causal Forest for each split
```

```r
CausalF.df <- data.frame(ATE=double(),
                         SE=integer(),
                         strata = integer(),
                         method = c())
## LM forest storage df
LMforest.df <- data.frame(ATE=double(),
                          SE=integer(),
                          strata = integer(),
                          method = c())

## Create the calibration plot
column_of_interest <- combined_data[,colnames(combined_data) == factor]
strata <- length(unique(column_of_interest))

## Store tau hats from each method for plotting purposes
for (i in 1:strata){
  temp_data <- combined_data %>% filter(get(factor) == sort(unique(column_of_interest))[i])
  ## RD
  rd_lm <- temp_data %$%
    lm(tip_zero ~ dsc_15 + I(fare - 15) + dsc_15:I(fare - 15))
  ATE.df[i,"ATE"] <- rd_lm$coefficients["dsc_15"]
  ATE.df[i,"SE"] <- coeftest(rd_lm, vcov=vcovHC(rd_lm, "HC2"))[2,2]
  ATE.df[i,"strata"] <- i
  ATE.df[i,"method"] <- "Regression Discontinuity"
  ## Causal Forest
  forest <- causal_forest(X=temp_data[,covariates],W=temp_data[,treatment],Y=temp_data[,outcome],num.
  forest.ate <- average_treatment_effect(forest)
  CausalF.df[i,"ATE"] <- forest.ate[1]
  CausalF.df[i,"SE"] <- forest.ate[2]
  CausalF.df[i,"strata"] <- i
  CausalF.df[i,"method"] <- "Causal Forest"
  ## LM forest
  Wlm = temp_data[,treatment]
  Zlm = temp_data$fare - 15
  Z1lm= Zlm*Wlm
  Z0lm= Zlm*(1-Wlm)
  lmforest = lm_forest(X=temp_data[,covariates], Y=temp_data[,outcome], W=cbind(Wlm, Z0lm, Z1lm), num
  tau.temp <- predict(lmforest)$predictions[, 1, ]
  LMforest.df[i,"ATE"] <-mean(tau.temp)
  LMforest.df[i,"SE"] <- sqrt(var(tau.temp) / length(tau.temp))
  LMforest.df[i,"strata"] <- i
  LMforest.df[i,"method"] <- "LM Forest"
}

## Combine the tau hats from all methods
res <- rbind(ATE.df, CausalF.df, LMforest.df)
#res <- rbind(LMforest.df)

## Recode values in strata
for (i in 1:strata){
  res$strata[res$strata == i] <- factor_label[i]
}
```

```
  calibration_plot <- ggplot(res) +
    aes(x = strata, y = ATE, group=method, color=method) +
    geom_point(position=position_dodge(0.2)) +
    geom_errorbar(aes(ymin=ATE-2*SE , ymax=ATE+2*SE), width=.2, position=position_dodge(0.2)) +
    ylab("") + xlab("") +
    ggtitle("Average CATE within each ranking (as defined by predicted CATE)") +
    theme_light() +
    theme(legend.position="bottom", legend.title = element_blank())

  return(calibration_plot)
}

data.test.drfboro <- data.test %>% filter(drf_boro != "")
lm.tau.hat.drfboro <- lm.tau.hat[data.test$drf_boro != ""]

data.test.noNA <- data.test %>% filter(!is.na(gr_inc10_All))
lm.tau.hat2 <- lm.tau.hat[!is.na(data.test$gr_inc10_All)]

## Generate plots of HTE for known groups

# Weekends vs weekdays
sort(unique(data.test.drfboro$weekend))
```

```
## [1] 0 1
```

```
plot_weekend <- HTE_plot(lm.tau.hat,data.test,factor = "weekend", factor_label = c("Weekday", "Weekend"
ggsave(file=paste0(Output, "HTE_by_weekend_LM_forest_",suffix,".png"), plot = plot_weekend, width=8, he

# Morning vs afternoon
sort(unique(data.test.drfboro$pickup_time_group))
```

```
## [1] 1 2 3
```

```
plot_TimeofDay <- HTE_plot(lm.tau.hat,data.test,factor = "pickup_time_group", factor_label = c('Morning
ggsave(file=paste0(Output, "HTE_by_timeofday_LM_forest_",suffix,".png"), plot = plot_TimeofDay, width=8

# Income deciles
sort(unique(data.test.drfboro$gr_inc10_All))
```

```
##  [1]  1  2  3  4  5  6  7  8  9 10
```

```
plot_Income <- HTE_plot(lm.tau.hat2,data.test.noNA,factor = "gr_inc10_All", factor_label = c("1","2","3
ggsave(file=paste0(Output, "HTE_by_income_LM_forest_",suffix,".png"), plot = plot_Income, width=8, heig

# Borough
sort(unique(data.test.drfboro$drf_boro))
```

```
## [1] "Brooklyn"      "Manhattan"     "Queens"        "Staten Island"
## [5] "The Bronx"
```

```
plot_drfboro <- HTE_plot(lm.tau.hat = lm.tau.hat.drfboro,data.test = data.test.drfboro,factor = "drf_bo
ggsave(file=paste0(Output, "HTE_by_dropoff_LM_forest_",suffix,".png"), plot = plot_drfboro, width=8, he
```