Problem Set 1

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March 22, 2017

```r
## Q1

library(foreign)

# Read in data
# taxi <- read.dta("./Spring 2017/Research Methods/02 taxi_phd.dta")
taxi <- read.dta("./02 taxi_phd.dta")
taxi_no_nas <- na.omit(taxi[,-2])

head(taxi)
```

```
##   fips tcrpid taxis   downrt  msa medianinc89 worktransit evercmptr
## 1 1097     NA    25 20.00000 5160       27601         1.2         0
## 2 1097    370    40 19.73684 5160       27601         1.2         0
## 3 2220    170     3  0.00000 9999       49327         1.6         0
## 4 2261    634     3  0.00000 9999       52929         0.7         0
## 5 4013     NA   550  0.00000 6200       36078         2.1         1
## 6 4013    408    15 50.00000 6200       36078         2.1         0
##   logtaxis logtaxisq logdensity northeast midwestdum southdum
## 1 3.218876 10.361162   7.430796         0          0        1
## 2 3.688879 13.607832   7.430796         0          0        1
## 3 1.098612  1.206949   8.000000         0          0        0
## 4 1.098612  1.206949   2.900467         0          0        0
## 5 6.309918 39.815071   7.930913         0          0        0
## 6 2.708050  7.333536   8.061882         0          0        0
```

```r
summary(taxi)
```

```
##       fips           tcrpid          taxis             downrt      
##  Min.   : 1097   Min.   :  2.0   Min.   :   1.00   Min.   :  0.00  
##  1st Qu.:15003   1st Qu.:198.0   1st Qu.:   7.00   1st Qu.:  0.00  
##  Median :29147   Median :358.5   Median :  19.00   Median :  0.00  
##  Mean   :28802   Mean   :342.5   Mean   :  63.98   Mean   : 20.34  
##  3rd Qu.:41007   3rd Qu.:476.8   3rd Qu.:  50.00   3rd Qu.: 29.85  
##  Max.   :56021   Max.   :676.0   Max.   :1484.00   Max.   :100.00  
##  NA's   :1       NA's   :267                                       
##       msa        medianinc89     worktransit       evercmptr     
##  Min.   :   0   Min.   :19527   Min.   : 0.000   Min.   :0.0000  
##  1st Qu.:2160   1st Qu.:32214   1st Qu.: 0.800   1st Qu.:0.0000  
##  Median :5380   Median :36330   Median : 2.200   Median :0.0000  
##  Mean   :5027   Mean   :38252   Mean   : 5.244   Mean   :0.3064  
##  3rd Qu.:7320   3rd Qu.:42634   3rd Qu.: 6.500   3rd Qu.:1.0000  
##  Max.   :9999   Max.   :62749   Max.   :58.400   Max.   :1.0000  
##  NA's   :1      NA's   :5                                        
##     logtaxis       logtaxisq        logdensity       northeast     
##  Min.   :0.000   Min.   : 0.000   Min.   : 2.900   Min.   :0.0000  
```

```
##  1st Qu.:1.946   1st Qu.: 3.787   1st Qu.: 7.591   1st Qu.:0.0000
##  Median :2.944   Median : 8.670   Median : 8.000   Median :0.0000
##  Mean   :3.023   Mean   :11.277   Mean   : 8.013   Mean   :0.2857
##  3rd Qu.:3.912   3rd Qu.:15.304   3rd Qu.: 8.381   3rd Qu.:1.0000
##  Max.   :7.302   Max.   :53.326   Max.   :10.712   Max.   :1.0000
##
##    midwestdum        southdum
##  Min.   :0.0000   Min.   :0.0000
##  1st Qu.:0.0000   1st Qu.:0.0000
##  Median :0.0000   Median :0.0000
##  Mean   :0.2186   Mean   :0.1824
##  3rd Qu.:0.0000   3rd Qu.:0.0000
##  Max.   :1.0000   Max.   :1.0000
##
```

```r
cor(taxi$evercmptr, taxi$logtaxis)
```

```
## [1] 0.5287976
```

```r
cor(taxi$evercmptr, taxi$logtaxisq)
```

```
## [1] 0.5484535
```

```r
cor(taxi_no_nas$evercmptr, taxi_no_nas$msa)
```

```
## [1] -0.07315375
```

```r
cor(taxi_no_nas)
```

```
##                    fips         taxis       downrt         msa medianinc89
## fips         1.00000000 -0.1231353607 -0.033433544 -0.01330391 -0.12142977
## taxis       -0.12313536  1.0000000000  0.144118182 -0.06460424  0.06195537
## downrt      -0.03343354  0.1441181821  1.000000000  0.03493522  0.05192196
## msa         -0.01330391 -0.0646042448  0.034935221  1.00000000 -0.05844503
## medianinc89 -0.12142977  0.0619553694  0.051921962 -0.05844503  1.00000000
## worktransit -0.10156608  0.2445882522  0.185140015 -0.04187248  0.26751690
## evercmptr   -0.07423793  0.4306553816  0.009279573 -0.07315375  0.06615210
## logtaxis    -0.06742299  0.7013789568  0.135538282 -0.12323772  0.16732118
## logtaxisq   -0.10754376  0.8353026288  0.173164138 -0.09765490  0.14065099
## logdensity  -0.03556574  0.2599082773  0.185076927 -0.14703670  0.31980268
## northeast    0.11338316 -0.0890843309 -0.060683507 -0.10701046  0.42203041
## midwestdum   0.15059653 -0.0006121092 -0.062162470 -0.07448855 -0.19832548
## southdum    -0.03267988  0.0289440993  0.008585447  0.05130345 -0.21253221
##             worktransit    evercmptr    logtaxis   logtaxisq  logdensity
## fips        -0.10156608 -0.074237928 -0.06742299 -0.10754376 -0.03556574
## taxis        0.24458825  0.430655382  0.70137896  0.83530263  0.25990828
## downrt       0.18514001  0.009279573  0.13553828  0.17316414  0.18507693
## msa         -0.04187248 -0.073153753 -0.12323772 -0.09765490 -0.14703670
## medianinc89  0.26751690  0.066152099  0.16732118  0.14065099  0.31980268
## worktransit  1.00000000  0.181845756  0.30404935  0.31707935  0.51463528
## evercmptr    0.18184576  1.000000000  0.52915519  0.55050439  0.20726383
```

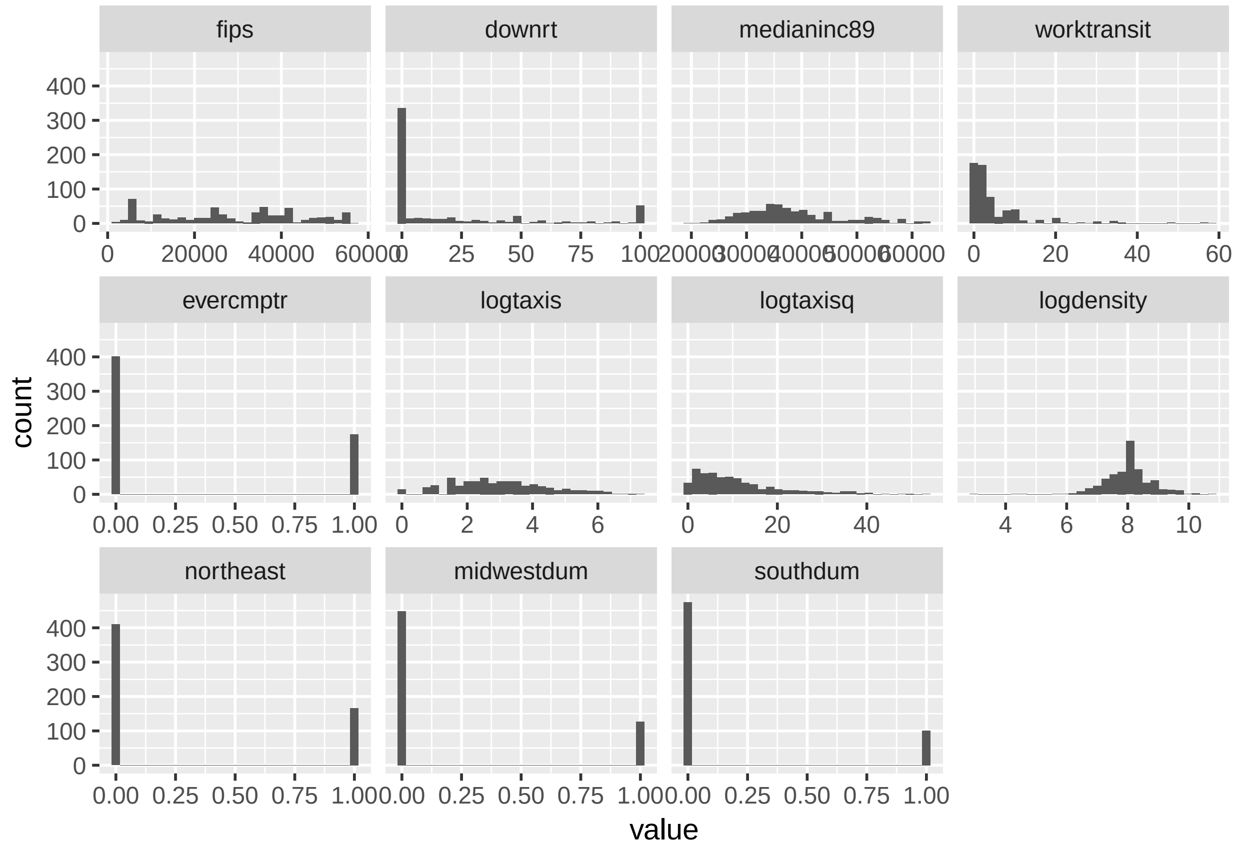
```
## logtaxis     0.30404935  0.529155186  1.00000000  0.96127516  0.37520013
## logtaxisq    0.31707935  0.550504388  0.96127516  1.00000000  0.36977535
## logdensity   0.51463528  0.207263832  0.37520013  0.36977535  1.00000000
## northeast    0.31596320 -0.136971218 -0.01567326 -0.05481631  0.25556704
## midwestdum  -0.12807643  0.012883723 -0.07286115 -0.06178894 -0.01930884
## southdum    -0.16655781  0.003119463  0.09425321  0.08121722 -0.23731592
##               northeast    midwestdum     southdum
## fips         0.11338316  0.1505965326 -0.032679884
## taxis       -0.08908433 -0.0006121092  0.028944099
## downrt      -0.06068351 -0.0621624700  0.008585447
## msa         -0.10701046 -0.0744885540  0.051303450
## medianinc89  0.42203041 -0.1983254788 -0.212532209
## worktransit  0.31596320 -0.1280764312 -0.166557808
## evercmptr   -0.13697122  0.0128837226  0.003119463
## logtaxis    -0.01567326 -0.0728611471  0.094253205
## logtaxisq   -0.05481631 -0.0617889429  0.081217223
## logdensity   0.25556704 -0.0193088375 -0.237315925
## northeast    1.00000000 -0.3384081437 -0.293410734
## midwestdum  -0.33840814  1.0000000000 -0.245240714
## southdum    -0.29341073 -0.2452407141  1.000000000
```

```r
library(reshape2)
library(ggplot2)
d <- melt(taxi_no_nas[,c(1,3,5,6,7,8,9,10,11,12,13)])
```

```
## No id variables; using all as measure variables
```

```r
ggplot(d,aes(x = value)) +
    facet_wrap(~variable,scales = "free_x") +
    geom_histogram()
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```



Q1) The correlations between evercmptr and logtaxis and logtaxisq are 0.529 and 0.551 respectively, suggesting that computer adoption and firm size are postively correlated. The correlation between evercmptr logdensity is 0.207, suggesting that computer adoption and population density are postively correlated. The correlation between evercmptr and northeast, midwest, south dummy variables are -0.137, 0.013 and 0.003 respectively.

```
## Q2

logit <- lm(evercmptr ~ .-evercmptr -taxis, data = taxi_no_nas, family = "binomial")
```

```
## Warning: In lm.fit(x, y, offset = offset, singular.ok = singular.ok, ...) :
##  extra argument 'family' will be disregarded
```

```
summary(logit)
```

```
##
## Call:
## lm(formula = evercmptr ~ . - evercmptr - taxis, data = taxi_no_nas,
##     family = "binomial")
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -0.8553 -0.2395 -0.1020  0.1461  1.0671
##
## Coefficients:
##                Estimate Std. Error t value Pr(>|t|)
```

```
## (Intercept) -9.271e-03  2.127e-01  -0.044 0.965245
## fips         3.875e-07  1.083e-06   0.358 0.720653
## downrt      -1.538e-03  5.068e-04  -3.034 0.002522 **
## msa         -4.306e-06  5.272e-06  -0.817 0.414352
## medianinc89  1.680e-06  2.124e-06   0.791 0.429242
## worktransit  3.404e-03  2.429e-03   1.401 0.161730
## logtaxis     8.305e-03  4.088e-02   0.203 0.839095
## logtaxisq    2.358e-02  6.043e-03   3.902 0.000107 ***
## logdensity   8.145e-03  2.617e-02   0.311 0.755720
## northeast   -1.952e-01  4.676e-02  -4.175 3.46e-05 ***
## midwestdum  -3.981e-02  4.566e-02  -0.872 0.383599
## southdum    -1.004e-01  4.876e-02  -2.059 0.039937 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3789 on 564 degrees of freedom
## Multiple R-squared:  0.3353, Adjusted R-squared:  0.3223
## F-statistic: 25.86 on 11 and 564 DF,  p-value: < 2.2e-16
```

Q2) From the regression model, we can see that downrt, northeast, and south have significant coefficients. The coeffciencts suggest that the log odds ratio of adopting computer technology associated with a 1% increase in driver ownership is about -1.54e-03, that the log odds ratio of adopting computer technology associated with being in northeast is about -1.95e-01, and that the log odds ratio of adopting computer technology associated with being in south is about -1.04e-01.

```r
## Q3

# a)
# Add control
treatment <- lm(downrt ~ evercmptr + logtaxis + logtaxisq, data = taxi_no_nas)
summary(treatment)
```

```
##
## Call:
## lm(formula = downrt ~ evercmptr + logtaxis + logtaxisq, data = taxi_no_nas)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -44.902 -18.123 -16.787   5.753  89.595
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  26.7611     5.1325   5.214 2.59e-07 ***
## evercmptr    -8.7761     3.4636  -2.534   0.0115 *
## logtaxis     -9.1227     3.3077  -2.758   0.0060 **
## logtaxisq     2.0860     0.4948   4.216 2.90e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 31.92 on 572 degrees of freedom
## Multiple R-squared:  0.0532, Adjusted R-squared:  0.04824
## F-statistic: 10.71 on 3 and 572 DF,  p-value: 7.359e-07
```

```r
# b)
# Robust SE
library(sandwich)
library(lmtest)
```

```
## Loading required package: zoo

##
## Attaching package: 'zoo'

## The following objects are masked from 'package:base':
##
##     as.Date, as.Date.numeric
```

```r
coeftest(treatment, vcov = vcovHC(treatment, "HC1"))
```

```
##
## t test of coefficients:
##
##             Estimate Std. Error t value  Pr(>|t|)
## (Intercept) 26.76106    6.82296  3.9222 9.839e-05 ***
## evercmptr   -8.77612    3.13380 -2.8005 0.0052752 **
## logtaxis    -9.12273    4.21489 -2.1644 0.0308464 *
## logtaxisq    2.08599    0.58096  3.5906 0.0003583 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# Clustered SE
# compute Stata like df-adjustment
G <- length(unique(taxi_no_nas$fips))
N <- length(taxi_no_nas$fips)
dfa <- (G/(G - 1)) * (N - 1)/treatment$df.residual
# display with cluster VCE and df-adjustment
country_vcov <- dfa * vcovHC(treatment, type = "HC0", cluster = "group", adjust = T)
coeftest(treatment, vcov = country_vcov)
```

```
##
## t test of coefficients:
##
##             Estimate Std. Error t value  Pr(>|t|)
## (Intercept) 26.76106    6.82771  3.9195 9.949e-05 ***
## evercmptr   -8.77612    3.13598 -2.7985 0.0053067 **
## logtaxis    -9.12273    4.21783 -2.1629 0.0309627 *
## logtaxisq    2.08599    0.58136  3.5881 0.0003617 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# c)
# Fixed Effects of MSA
treatment_msa <- lm(downrt ~ factor(msa) + evercmptr + logtaxis + logtaxisq, data = taxi_no_nas)
summary(treatment_msa)
```

```
##
## Call:
## lm(formula = downrt ~ factor(msa) + evercmptr + logtaxis + logtaxisq,
##     data = taxi_no_nas)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -57.774 -12.240  -0.969   3.138  97.626
##
## Coefficients:
##                   Estimate Std. Error t value Pr(>|t|)
## (Intercept)      16.284401   7.970053   2.043 0.041680 *
## factor(msa)80     0.424847  31.317905   0.014 0.989183
## factor(msa)160   19.344142  16.337206   1.184 0.237086
## factor(msa)200    0.126669  31.333625   0.004 0.996776
## factor(msa)220    0.465207  31.272697   0.015 0.988139
## factor(msa)240  -10.079845  31.108108  -0.324 0.746085
## factor(msa)280    2.911408  31.072297   0.094 0.925396
## factor(msa)460    0.464176  22.603687   0.021 0.983626
## factor(msa)520   19.846804  13.101528   1.515 0.130591
## factor(msa)560    4.218403  16.280834   0.259 0.795688
## factor(msa)600   24.096704  22.572924   1.068 0.286380
## factor(msa)640   48.179157  18.985266   2.538 0.011532 *
## factor(msa)720   12.998090  12.928461   1.005 0.315311
## factor(msa)730    0.600180  22.607511   0.027 0.978833
## factor(msa)760    3.196467  31.257115   0.102 0.918598
## factor(msa)870   -9.518157  31.082845  -0.306 0.759595
## factor(msa)875   -8.511729  16.296823  -0.522 0.601751
## factor(msa)1010 -11.126842  31.138026  -0.357 0.721024
## factor(msa)1120  -3.715275   8.901891  -0.417 0.676638
## factor(msa)1260  21.878263  31.144842   0.702 0.482791
## factor(msa)1280   9.283253  16.342610   0.568 0.570323
## factor(msa)1305 -10.236697  31.113179  -0.329 0.742315
## factor(msa)1400 -10.195163  31.085042  -0.328 0.743099
## factor(msa)1440  14.917001  31.256088   0.477 0.633441
## factor(msa)1480 -10.884517  31.131660  -0.350 0.726799
## factor(msa)1520   6.568331  18.565092   0.354 0.723673
## factor(msa)1540  31.133557  22.457098   1.386 0.166401
## factor(msa)1580 -10.195163  31.085042  -0.328 0.743099
## factor(msa)1600  26.294442  11.438957   2.299 0.022032 *
## factor(msa)1640  36.387408  11.709949   3.107 0.002020 **
## factor(msa)1760  15.083255  31.256948   0.483 0.629671
## factor(msa)1840  19.093520  16.350461   1.168 0.243588
## factor(msa)1920  66.763254  18.895713   3.533 0.000458 ***
## factor(msa)1960 -12.900505  31.245657  -0.413 0.679918
## factor(msa)2000  -0.866381  22.580151  -0.038 0.969412
## factor(msa)2080  55.007789  16.902772   3.254 0.001232 **
## factor(msa)2160  16.201016   9.963173   1.626 0.104708
## factor(msa)2240 -11.210043  22.377367  -0.501 0.616675
## factor(msa)2320  67.009437  31.185486   2.149 0.032247 *
## factor(msa)2400  -6.492459  18.550872  -0.350 0.726535
## factor(msa)2520  -5.155625  22.392018  -0.230 0.818019
## factor(msa)2560   0.476998  31.199730   0.015 0.987810
## factor(msa)2680  13.727898  23.287744   0.589 0.555861
```

```
## factor(msa)2720  37.717821  31.167269   1.210 0.226918
## factor(msa)2760  -9.707061  31.072977  -0.312 0.754901
## factor(msa)2840 -11.455069  31.144842  -0.368 0.713215
## factor(msa)2900  -0.075184  31.264916  -0.002 0.998082
## factor(msa)2920 -10.195163  31.085042  -0.328 0.743099
## factor(msa)2975  -9.605237  31.088671  -0.309 0.757509
## factor(msa)2995  -9.553375  22.329498  -0.428 0.668998
## factor(msa)3000  56.112706  31.181888   1.800 0.072679 .
## factor(msa)3060   0.241988  31.269056   0.008 0.993829
## factor(msa)3080 -10.195163  31.085042  -0.328 0.743099
## factor(msa)3120  31.981947  18.532781   1.726 0.085165 .
## factor(msa)3150  -1.255259  31.072297  -0.040 0.967796
## factor(msa)3160  22.367775  31.133809   0.718 0.472900
## factor(msa)3280  -5.340784  31.260781  -0.171 0.864430
## factor(msa)3320  12.696324  15.140994   0.839 0.402222
## factor(msa)3360  39.878405  22.462436   1.775 0.076593 .
## factor(msa)3400 -10.640533  22.398819  -0.475 0.635008
## factor(msa)3480  -8.929173  18.674315  -0.478 0.632800
## factor(msa)3520  -9.707061  31.072977  -0.312 0.754901
## factor(msa)3560  -9.490862  31.080022  -0.305 0.760242
## factor(msa)3600  -4.594232  18.574667  -0.247 0.804772
## factor(msa)3605  89.763303  31.113179   2.885 0.004123 **
## factor(msa)3610 -12.995731  22.516863  -0.577 0.564155
## factor(msa)3620 -10.195163  31.085042  -0.328 0.743099
## factor(msa)3640  -7.587954  14.772603  -0.514 0.607777
## factor(msa)3660 -10.195163  31.085042  -0.328 0.743099
## factor(msa)3760  55.386396  22.408590   2.472 0.013859 *
## factor(msa)3800  -9.896986  31.076444  -0.318 0.750291
## factor(msa)3810  -9.588592  31.072297  -0.309 0.757792
## factor(msa)3850  -9.605237  31.088671  -0.309 0.757509
## factor(msa)3980  -9.896986  31.076444  -0.318 0.750291
## factor(msa)4000 -14.027673  31.213816  -0.449 0.653379
## factor(msa)4040   0.005291  31.265887   0.000 0.999865
## factor(msa)4080  -9.605237  31.088671  -0.309 0.757509
## factor(msa)4100  -9.612609  22.327516  -0.431 0.667041
## factor(msa)4120 -13.670117  16.428778  -0.832 0.405852
## factor(msa)4200  23.854716  31.077365   0.768 0.443177
## factor(msa)4240   7.148509  31.082845   0.230 0.818222
## factor(msa)4280  -4.243591  31.252447  -0.136 0.892059
## factor(msa)4320 -10.236697  31.113179  -0.329 0.742315
## factor(msa)4400  -4.891515  31.165409  -0.157 0.875360
## factor(msa)4480   1.767368  11.327737   0.156 0.876094
## factor(msa)4520  -6.792289  22.735088  -0.299 0.765278
## factor(msa)4560  -9.490862  31.080022  -0.305 0.760242
## factor(msa)4600 -10.157708  31.110670  -0.327 0.744213
## factor(msa)4720  -6.967245  22.414783  -0.311 0.756088
## factor(msa)4900 -11.288861  22.338231  -0.505 0.613581
## factor(msa)4920  29.627492  31.250214   0.948 0.343658
## factor(msa)5015  33.530276  13.691905   2.449 0.014752 *
## factor(msa)5080  -0.486916  12.324185  -0.040 0.968504
## factor(msa)5120  -9.958299  22.345828  -0.446 0.656092
## factor(msa)5140   0.614772  31.307602   0.020 0.984343
## factor(msa)5160   8.948322  22.406125   0.399 0.689832
## factor(msa)5190  21.282168  18.538992   1.148 0.251659
```

```
## factor(msa)5200   0.465207  31.272697   0.015 0.988139    
## factor(msa)5330 -10.668569  31.103768  -0.343 0.731777    
## factor(msa)5345  -9.490862  31.080022  -0.305 0.760242    
## factor(msa)5380  -3.191774  10.604272  -0.301 0.763577    
## factor(msa)5400  -1.270511  22.339514  -0.057 0.954675    
## factor(msa)5480   1.196967  22.369538   0.054 0.957353    
## factor(msa)5560  31.073725  18.696843   1.662 0.097291 .  
## factor(msa)5600  41.489552  10.876540   3.815 0.000158 ***
## factor(msa)5640   4.424069  13.813544   0.320 0.748929    
## factor(msa)5660  -9.505222  22.330393  -0.426 0.670580    
## factor(msa)5720 -10.218472  13.828429  -0.739 0.460367    
## factor(msa)5775  23.789338  10.192060   2.334 0.020078 *  
## factor(msa)5800  -9.112704  18.534493  -0.492 0.623225    
## factor(msa)5920  -5.077944  22.583745  -0.225 0.822210    
## factor(msa)5945  -6.089332  31.269477  -0.195 0.845696    
## factor(msa)6080  -1.238671  22.344039  -0.055 0.955818    
## factor(msa)6120  -5.841000  22.388877  -0.261 0.794311    
## factor(msa)6160   4.781868  12.244719   0.391 0.696354    
## factor(msa)6200  15.254947  12.336787   1.237 0.216974    
## factor(msa)6280 -11.530757  18.563669  -0.621 0.534853    
## factor(msa)6320  -9.557124  31.085746  -0.307 0.758664    
## factor(msa)6340   0.424847  31.317905   0.014 0.989183    
## factor(msa)6400  -9.525769  18.523380  -0.514 0.607353    
## factor(msa)6440  31.198837   9.661068   3.229 0.001342 ** 
## factor(msa)6480  10.197977  22.328419   0.457 0.648113    
## factor(msa)6640  44.260565  14.790047   2.993 0.002936 ** 
## factor(msa)6680 -10.984777  18.578709  -0.591 0.554679    
## factor(msa)6760  -3.520278  22.383272  -0.157 0.875108    
## factor(msa)6780   6.686464  14.838531   0.451 0.652508    
## factor(msa)6800  -7.948482  22.394713  -0.355 0.722829    
## factor(msa)6840  89.460909  22.379393   3.997 7.61e-05 ***
## factor(msa)6920  40.134531  12.931179   3.104 0.002045 ** 
## factor(msa)6960  -9.518157  22.340248  -0.426 0.670295    
## factor(msa)7040  -3.903501  13.725501  -0.284 0.776251    
## factor(msa)7080 -10.079845  31.108108  -0.324 0.746085    
## factor(msa)7160  27.636760  18.611153   1.485 0.138333    
## factor(msa)7200  -9.518157  31.082845  -0.306 0.759595    
## factor(msa)7240  -0.269025  22.383567  -0.012 0.990416    
## factor(msa)7320  18.031659  10.586529   1.703 0.089286 .  
## factor(msa)7360  14.678316  12.046036   1.219 0.223736    
## factor(msa)7400  30.457513  22.495125   1.354 0.176504    
## factor(msa)7485   0.164125  31.267953   0.005 0.995815    
## factor(msa)7490  -0.237313  31.263089  -0.008 0.993947    
## factor(msa)7520  10.517674  22.330859   0.471 0.637899    
## factor(msa)7560  -9.896986  31.076444  -0.318 0.750291    
## factor(msa)7600  45.914967  15.314750   2.998 0.002884 ** 
## factor(msa)7620  -9.588592  31.072297  -0.309 0.757792    
## factor(msa)7680  11.281230  22.416778   0.503 0.615063    
## factor(msa)7760 -10.159987  22.378505  -0.454 0.650067    
## factor(msa)7800  29.109676  18.546165   1.570 0.117294    
## factor(msa)7840  30.399450  31.263984   0.972 0.331458    
## factor(msa)8040  22.667746  18.563769   1.221 0.222768    
## factor(msa)8120 -11.523655  31.148165  -0.370 0.711604    
## factor(msa)8160   5.170458  16.283003   0.318 0.751000    
```

```
## factor(msa)8240   5.131228  31.249264   0.164 0.869653
## factor(msa)8280  -3.485327  15.122396  -0.230 0.817839
## factor(msa)8400  41.888537  22.373838   1.872 0.061898 .
## factor(msa)8560  63.057113  18.549710   3.399 0.000742 ***
## factor(msa)8640  -9.928865  31.102819  -0.319 0.749719
## factor(msa)8720  -9.486035  31.075014  -0.305 0.760323
## factor(msa)8735  -4.976588  22.372581  -0.222 0.824082
## factor(msa)8760  89.996568  31.105491   2.893 0.004018 **
## factor(msa)8800  -9.486035  31.075014  -0.305 0.760323
## factor(msa)8840  37.943572  10.538579   3.600 0.000357 ***
## factor(msa)8960  -5.109816  22.713672  -0.225 0.822119
## factor(msa)9000  87.099495  31.245657   2.788 0.005561 **
## factor(msa)9040  20.380365  31.250649   0.652 0.514669
## factor(msa)9140  -9.519582  31.073197  -0.306 0.759488
## factor(msa)9240  -9.283290  22.447013  -0.414 0.679412
## factor(msa)9320  45.054594  31.080022   1.450 0.147935
## factor(msa)9999   1.571479   6.856911   0.229 0.818843
## evercmptr       -10.321833   4.200104  -2.458 0.014408 *
## logtaxis         -5.712892   3.854468  -1.482 0.139079
## logtaxisq         1.198826   0.581455   2.062 0.039867 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 30.56 on 405 degrees of freedom
## Multiple R-squared:  0.3852, Adjusted R-squared:  0.1272
## F-statistic: 1.493 on 170 and 405 DF,  p-value: 0.0007044
```

```
coeftest(treatment_msa, vcov = vcovHC(treatment_msa, "HC1"))
```

```
##
## t test of coefficients:
##
##                    Estimate Std. Error t value  Pr(>|t|)
## (Intercept)       16.284401  10.337202  1.5753 0.1159634
## factor(msa)80      0.424847   6.434626  0.0660 0.9473904
## factor(msa)160    19.344142  23.635008  0.8185 0.4135799
## factor(msa)200     0.126669   6.658892  0.0190 0.9848324
## factor(msa)220     0.465207   5.864267  0.0793 0.9368101
## factor(msa)240   -10.079845   4.962519 -2.0312 0.0428878 *
## factor(msa)280     2.911408   4.881686  0.5964 0.5512453
## factor(msa)460     0.464176   5.885436  0.0789 0.9371761
## factor(msa)520    19.846804  17.334079  1.1450 0.2529024
## factor(msa)560     4.218403  10.896018  0.3872 0.6988479
## factor(msa)600    24.096704  19.953883  1.2076 0.2278983
## factor(msa)640    48.179157  20.069083  2.4007 0.0168156 *
## factor(msa)720    12.998090  16.024219  0.8112 0.4177543
## factor(msa)730     0.600180   5.879546  0.1021 0.9187443
## factor(msa)760     3.196467   5.844891  0.5469 0.5847609
## factor(msa)870    -9.518157   4.808837 -1.9793 0.0484584 *
## factor(msa)875    -8.511729   5.906508 -1.4411 0.1503358
## factor(msa)1010  -11.126842   5.193664 -2.1424 0.0327579 *
## factor(msa)1120   -3.715275   7.635044 -0.4866 0.6267993
## factor(msa)1260   21.878263   6.283659  3.4818 0.0005523 ***
## factor(msa)1280    9.283253  11.944091  0.7772 0.4374795
```

```
## factor(msa)1305 -10.236697   5.000828 -2.0470 0.0413029 *
## factor(msa)1400 -10.195163   5.301689 -1.9230 0.0551806 .
## factor(msa)1440  14.917001   6.073399  2.4561 0.0144636 *
## factor(msa)1480 -10.884517   5.144262 -2.1159 0.0349668 *
## factor(msa)1520   6.568331  11.721970  0.5603 0.5755549
## factor(msa)1540  31.133557   5.492042  5.6688 2.735e-08 ***
## factor(msa)1580 -10.195163   5.301689 -1.9230 0.0551806 .
## factor(msa)1600  26.294442  14.695336  1.7893 0.0743128 .
## factor(msa)1640  36.387408  15.129441  2.4051 0.0166170 *
## factor(msa)1760  15.083255   6.084849  2.4788 0.0135880 *
## factor(msa)1840  19.093520  24.925356  0.7660 0.4441059
## factor(msa)1920  66.763254  20.696916  3.2258 0.0013584 **
## factor(msa)1960 -12.900505   7.481798 -1.7243 0.0854254 .
## factor(msa)2000  -0.866381   5.878276 -0.1474 0.8829000
## factor(msa)2080  55.007789   9.911963  5.5496 5.183e-08 ***
## factor(msa)2160  16.201016  11.845497  1.3677 0.1721663
## factor(msa)2240 -11.210043   5.923600 -1.8924 0.0591456 .
## factor(msa)2320  67.009437   5.544602 12.0855 < 2.2e-16 ***
## factor(msa)2400  -6.492459   6.120147 -1.0608 0.2893976
## factor(msa)2520  -5.155626   6.639058 -0.7766 0.4378718
## factor(msa)2560   0.476998   5.643716  0.0845 0.9326861
## factor(msa)2680  13.727898   9.503405  1.4445 0.1493648
## factor(msa)2720  37.717821   5.413899  6.9668 1.319e-11 ***
## factor(msa)2760  -9.707061   4.959581 -1.9572 0.0510065 .
## factor(msa)2840 -11.455069   6.283659 -1.8230 0.0690415 .
## factor(msa)2900  -0.075184   5.842344 -0.0129 0.9897388
## factor(msa)2920 -10.195163   5.301689 -1.9230 0.0551806 .
## factor(msa)2975  -9.605237   4.833703 -1.9871 0.0475803 *
## factor(msa)2995  -9.553375   4.812446 -1.9851 0.0478031 *
## factor(msa)3000  56.112706   5.519158 10.1669 < 2.2e-16 ***
## factor(msa)3060   0.241988   5.850593  0.0414 0.9670282
## factor(msa)3080 -10.195163   5.301689 -1.9230 0.0551806 .
## factor(msa)3120  31.981947  29.839422  1.0718 0.2844473
## factor(msa)3150  -1.255259   4.881686 -0.2571 0.7972041
## factor(msa)3160  22.367774   5.160979  4.3340 1.849e-05 ***
## factor(msa)3280  -5.340784   6.132262 -0.8709 0.3843072
## factor(msa)3320  12.696324  14.328725  0.8861 0.3761030
## factor(msa)3360  39.878405  41.891436  0.9519 0.3416919
## factor(msa)3400 -10.640533   5.092562 -2.0894 0.0372929 *
## factor(msa)3480  -8.929173   5.603607 -1.5935 0.1118352
## factor(msa)3520  -9.707061   4.959581 -1.9572 0.0510065 .
## factor(msa)3560  -9.490862   4.802450 -1.9763 0.0488041 *
## factor(msa)3600  -4.594232   5.820673 -0.7893 0.4304011
## factor(msa)3605  89.763303   5.000828 17.9497 < 2.2e-16 ***
## factor(msa)3610 -12.995731   7.595511 -1.7110 0.0878514 .
## factor(msa)3620 -10.195163   5.301689 -1.9230 0.0551806 .
## factor(msa)3640  -7.587954   5.237825 -1.4487 0.1481996
## factor(msa)3660 -10.195163   5.301689 -1.9230 0.0551806 .
## factor(msa)3760  55.386396  27.343917  2.0255 0.0434665 *
## factor(msa)3800  -9.896986   5.088768 -1.9449 0.0524826 .
## factor(msa)3810  -9.588592   4.881686 -1.9642 0.0501908 .
## factor(msa)3850  -9.605237   4.833703 -1.9871 0.0475803 *
## factor(msa)3980  -9.896986   5.088768 -1.9449 0.0524826 .
## factor(msa)4000 -14.027673   5.739493 -2.4441 0.0149487 *
```

```
## factor(msa)4040   0.005291   5.843655  0.0009 0.9992780
## factor(msa)4080  -9.605237   4.833703 -1.9871 0.0475803 *
## factor(msa)4100  -9.612609   4.828556 -1.9908 0.0471763 *
## factor(msa)4120 -13.670117   6.064844 -2.2540 0.0247305 *
## factor(msa)4200  23.854716   4.802626  4.9670 1.004e-06 ***
## factor(msa)4240   7.148509   4.808837  1.4865 0.1379155
## factor(msa)4280  -4.243591   6.018853 -0.7050 0.4811845
## factor(msa)4320 -10.236697   5.000828 -2.0470 0.0413029 *
## factor(msa)4400  -4.891515   5.400276 -0.9058 0.3655856
## factor(msa)4480   1.767368   7.849326  0.2252 0.8219670
## factor(msa)4520  -6.792289   7.054818 -0.9628 0.3362287
## factor(msa)4560  -9.490862   4.802450 -1.9763 0.0488041 *
## factor(msa)4600 -10.157708   4.981758 -2.0390 0.0421008 *
## factor(msa)4720  -6.967245   6.593131 -1.0567 0.2912588
## factor(msa)4900 -11.288861   4.942743 -2.2839 0.0228927 *
## factor(msa)4920  29.627492   5.974091  4.9593 1.043e-06 ***
## factor(msa)5015  33.530276  21.765991  1.5405 0.1242221
## factor(msa)5080  -0.486916   6.956531 -0.0700 0.9442329
## factor(msa)5120  -9.958299   4.845167 -2.0553 0.0404903 *
## factor(msa)5140   0.614772   6.282833  0.0978 0.9221002
## factor(msa)5160   8.948322   5.170208  1.7307 0.0842586 .
## factor(msa)5190  21.282168  26.248741  0.8108 0.4179635
## factor(msa)5200   0.465207   5.864267  0.0793 0.9368101
## factor(msa)5330 -10.668569   5.658614 -1.8854 0.0600957 .
## factor(msa)5345  -9.490862   4.802450 -1.9763 0.0488041 *
## factor(msa)5380  -3.191774  11.010004 -0.2899 0.7720429
## factor(msa)5400  -1.270511   8.433171 -0.1507 0.8803218
## factor(msa)5480   1.196967  10.480846  0.1142 0.9091317
## factor(msa)5560  31.073725   9.574814  3.2454 0.0012705 **
## factor(msa)5600  41.489552  16.184752  2.5635 0.0107225 *
## factor(msa)5640   4.424069  14.691778  0.3011 0.7634733
## factor(msa)5660  -9.505222   4.808037 -1.9769 0.0487257 *
## factor(msa)5720 -10.218472   5.664065 -1.8041 0.0719603 .
## factor(msa)5775  23.789338  15.380854  1.5467 0.1227202
## factor(msa)5800  -9.112704   4.886519 -1.8649 0.0629232 .
## factor(msa)5920  -5.077944   6.102336 -0.8321 0.4058252
## factor(msa)5945  -6.089332   6.227197 -0.9779 0.3287269
## factor(msa)6080  -1.238671   8.997216 -0.1377 0.8905675
## factor(msa)6120  -5.841000   5.993650 -0.9745 0.3303745
## factor(msa)6160   4.781868   9.514610  0.5026 0.6155316
## factor(msa)6200  15.254947  15.893898  0.9598 0.3377290
## factor(msa)6280 -11.530757   5.656207 -2.0386 0.0421387 *
## factor(msa)6320  -9.557124   4.819727 -1.9829 0.0480517 *
## factor(msa)6340   0.424847   6.434626  0.0660 0.9473904
## factor(msa)6400  -9.525769   4.802371 -1.9836 0.0479803 *
## factor(msa)6440  31.198837  12.354445  2.5253 0.0119402 *
## factor(msa)6480  10.197977  17.519913  0.5821 0.5608372
## factor(msa)6640  44.260565  16.241584  2.7251 0.0067061 **
## factor(msa)6680 -10.984777   5.044597 -2.1775 0.0300174 *
## factor(msa)6760  -3.520278   7.279489 -0.4836 0.6289392
## factor(msa)6780   6.686464  11.174536  0.5984 0.5499301
## factor(msa)6800  -7.948482   5.898086 -1.3476 0.1785284
## factor(msa)6840  89.460909   5.095879 17.5555 < 2.2e-16 ***
## factor(msa)6920  40.134531  19.615233  2.0461 0.0413928 *
```

```
## factor(msa)6960  -9.518157   4.808837 -1.9793 0.0484584 *
## factor(msa)7040  -3.903501   5.470028 -0.7136 0.4758755
## factor(msa)7080 -10.079845   4.962519 -2.0312 0.0428878 *
## factor(msa)7160  27.636760  32.206480  0.8581 0.3913383
## factor(msa)7200  -9.518157   4.808837 -1.9793 0.0484584 *
## factor(msa)7240  -0.269025   5.439177 -0.0495 0.9605766
## factor(msa)7320  18.031659  13.650660  1.3209 0.1872683
## factor(msa)7360  14.678316  12.857676  1.1416 0.2542951
## factor(msa)7400  30.457513  19.595548  1.5543 0.1208921
## factor(msa)7485   0.164125   5.847697  0.0281 0.9776229
## factor(msa)7490  -0.237313   5.840842 -0.0406 0.9676110
## factor(msa)7520  10.517674   9.703538  1.0839 0.2790535
## factor(msa)7560  -9.896986   5.088768 -1.9449 0.0524826 .
## factor(msa)7600  45.914967  16.885457  2.7192 0.0068254 **
## factor(msa)7620  -9.588592   4.881686 -1.9642 0.0501908 .
## factor(msa)7680  11.281230   6.821190  1.6539 0.0989327 .
## factor(msa)7760 -10.159987   4.981177 -2.0397 0.0420310 *
## factor(msa)7800  29.109676  20.247200  1.4377 0.1512875
## factor(msa)7840  30.399450   5.841422  5.2041 3.104e-07 ***
## factor(msa)8040  22.667746  32.361375  0.7005 0.4840443
## factor(msa)8120 -11.523654   5.271439 -2.1861 0.0293835 *
## factor(msa)8160   5.170458  16.120814  0.3207 0.7485790
## factor(msa)8240   5.131228   5.942534  0.8635 0.3883875
## factor(msa)8280  -3.485327   7.351024 -0.4741 0.6356641
## factor(msa)8400  41.888537  43.605830  0.9606 0.3373175
## factor(msa)8560  63.057113  24.707831  2.5521 0.0110735 *
## factor(msa)8640  -9.928865   4.923817 -2.0165 0.0444076 *
## factor(msa)8720  -9.486035   4.812411 -1.9712 0.0493859 *
## factor(msa)8735  -4.976588   6.690435 -0.7438 0.4574069
## factor(msa)8760  89.996568   4.943174 18.2062 < 2.2e-16 ***
## factor(msa)8800  -9.486035   4.812411 -1.9712 0.0493859 *
## factor(msa)8840  37.943572  13.979036  2.7143 0.0069250 **
## factor(msa)8960  -5.109816   6.972867 -0.7328 0.4640956
## factor(msa)9000  87.099495   7.481798 11.6415 < 2.2e-16 ***
## factor(msa)9040  20.380365   5.877113  3.4678 0.0005811 ***
## factor(msa)9140  -9.519582   4.836398 -1.9683 0.0497128 *
## factor(msa)9240  -9.283290   8.592978 -1.0803 0.2806362
## factor(msa)9320  45.054594   4.802450  9.3816 < 2.2e-16 ***
## factor(msa)9999   1.571479   6.829477  0.2301 0.8181284
## evercmptr       -10.321833   4.259647 -2.4232 0.0158234 *
## logtaxis         -5.712892   5.478506 -1.0428 0.2976709
## logtaxisq         1.198826   0.767675  1.5616 0.1191556
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Q3)

a) The coefficient for evercmptr is about -8.776, which implies that when computer is adopted, the driver ownership rate decreases by about 8.776%.

b) This might be beacause the within-cluster correlation is 0. In other words, geographical variation does not help explain driver ownership.

c) After adding in the MSA fixed effects, the model's R^2 becomes larger, and the model's AIC becomes smaller, suggesting that adding the MSA fixed effects did improve the model. Comparing the results based on robust standard errors, we can also see that, after adding in the MSA fixed effects, the coefficients for logtaxis and logtaxisq are no longer significant at 0.05 level, while the coefficient for evercmptr, although still significant at 0.05 level, becomes less significant than before. This suggests that firm size (logtaxis and logtaxisq) might be explained by local market variation (MSA).

d) From the results, we can see that the higher the computer adoption rate is, the lower the driver ownership rate is. In other words, the taxis are more likely to be owned by the contracting firm rather the drivers themselves when computers are adopted more and more. This might be because computers allow companies to better monitor how drivers drive their cars.

e) Firm size might actually determine whether the firm adopts technologies or not. So adoption might actually be endogenous.

```
## Q4

# 2SLS
# 1st stage: regress endogenous regressor on instruments
first_stage <- lm(evercmptr ~ northeast + midwestdum + southdum + worktransit, data = taxi_no_nas)
summary(first_stage)
```

```
##
## Call:
## lm(formula = evercmptr ~ northeast + midwestdum + southdum +
##     worktransit, data = taxi_no_nas)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -0.7895 -0.3236 -0.2696  0.5574  0.9120
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.320852   0.034698   9.247  < 2e-16 ***
## northeast   -0.245484   0.048966  -5.013 7.15e-07 ***
## midwestdum  -0.051971   0.051399  -1.011    0.312
## southdum    -0.046390   0.055326  -0.838    0.402
## worktransit  0.013990   0.002424   5.772 1.28e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.4438 on 571 degrees of freedom
## Multiple R-squared:  0.0771, Adjusted R-squared:  0.07063
## F-statistic: 11.92 on 4 and 571 DF,  p-value: 2.595e-09
```

```
# 2nd stage: regress dependent variable on fitted values from 1st stage along with other independent va
second_stage <- lm(downrt ~ first_stage$fitted.values + logtaxis + logtaxisq, data = taxi_no_nas)
summary(second_stage)
```

```
##
## Call:
## lm(formula = downrt ~ first_stage$fitted.values + logtaxis +
##     logtaxisq, data = taxi_no_nas)
##
## Residuals:
```

```
##    Min     1Q Median     3Q    Max
## -53.88 -18.62 -13.36   8.28  91.93
##
## Coefficients:
##                          Estimate Std. Error t value Pr(>|t|)
## (Intercept)               12.4980     6.1282   2.039  0.04187 *
## first_stage$fitted.values  45.4410    11.0107   4.127 4.22e-05 ***
## logtaxis                  -7.4006     3.3042  -2.240  0.02549 *
## logtaxisq                  1.4263     0.4938   2.888  0.00402 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 31.63 on 572 degrees of freedom
## Multiple R-squared:  0.07026,    Adjusted R-squared:  0.06538
## F-statistic: 14.41 on 3 and 572 DF,  p-value: 4.634e-09
```

Q4)

a) The F-statistics for the first stage model is 11.92, with a p-value of 2.595e-09, suggesting that the model is significantly different from a null model. The coefficient for northeast is about -0.245, with a p-value of 7.15e-07, indicating that northeast has a higher computer adoption rate. The coefficient for worktransit is about 0.014, with a p-value of 1.28e-08. The R^2 suggests that 7.71% of the variance of evercmptr is explained by the model.

b) The second stage least square has a F of 14.41 and a R^2 of 0.07026, which are both larger than their comparables in the OLS model, suggesting that the 2SLS performs better than the OLS. However, the coefficient for evercmptr_hat is 45.44, while it is -8.776 in the OLS model, indicating that the instruments we selected actually are important in our model. In other words, regions and worktransit is correlated with driver ownership only because it is correlated with computer adoption, so after we factor these instruments out, an increase in computer adoption actually leads to a increase in predicted driver ownership.

c) From the results, we can see that the higher the computer adoption rate is, the lower the driver ownership rate is, if we don't account for endogeneity. But if we do account for endogeneity, the effect reverses. In other words, the taxis are more likely to be owned by the contracting firm rather the drivers themselves when computers are less adopted, after we take endogeneity into account. An ideal experiment would be randomly assigning taxis to treatment and control conditions that differ in the level of computer adoption and observe how driver ownership change over time. It could be difficult to randomly assign computer technology to taxis, so the best we could do is perhaps use difference-in-difference to factor out taxi-specific and time-specific effects.