Simulation_Panel_DM.R

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```
# Lecture 5

library(plm)
library(dplyr)
```

```
## Warning: package 'dplyr' was built under R version 3.6.2
```

```
##
## Attaching package: 'dplyr'
```

```
## The following objects are masked from 'package:plm':
##
##     between, lag, lead
```

```
## The following objects are masked from 'package:stats':
##
##     filter, lag
```

```
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```
set.seed(1001)

# We begin by simulating a panel dataset, with 500 individuals and 40 observations per individual
i = rep(1:500, each = 40)
t = rep(1:40, times = 500)
data = data.frame(i, t) %>%
  group_by(i) %>%
  mutate(weight = rnorm(1, mean = 180, sd=30)) %>%
  ungroup()

# generate a treatment variables that is correlated with the individual-specific "weight"
data = data %>%
  mutate(X = round(weight/max(weight) + runif(20000,0,1) - 1,0))
cor(data$X, data$weight)
```

```
## [1] 0.2925596
```

```
# generate the outcome
data = data %>%
  mutate(Y = 0.5 + 0.6*X + 0.3*weight + rnorm(20000,mean=0,sd=1))


# First, so let's start off by looking at the omitted variable bias again.
correct_reg = lm(Y ~ X + weight, data = data)
summary(correct_reg)
```

```
##
## Call:
## lm(formula = Y ~ X + weight, data = data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -4.1780 -0.6638  0.0113  0.6716  3.9397
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 0.5232221  0.0443725   11.79   <2e-16 ***
## X           0.5936966  0.0214157   27.72   <2e-16 ***
## weight      0.2998863  0.0002473 1212.48   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.9916 on 19997 degrees of freedom
## Multiple R-squared:  0.9879, Adjusted R-squared:  0.9879
## F-statistic: 8.15e+05 on 2 and 19997 DF,  p-value: < 2.2e-16
```

```
omitted_reg = lm(Y ~ X, data = data)
summary(omitted_reg)
```

```
##
## Call:
## lm(formula = Y ~ X, data = data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -24.335  -5.915  -0.262   5.459  36.034
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 53.56093    0.06427  833.33   <2e-16 ***
## X            8.19032    0.17677   46.33   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 8.559 on 19998 degrees of freedom
## Multiple R-squared:  0.09694,    Adjusted R-squared:  0.09689
## F-statistic:  2147 on 1 and 19998 DF,  p-value: < 2.2e-16
```

```
# Now, let's take advantage of our panel data and try a fixed effect regression.
# within estimator
within_reg = plm(Y ~ X, data = data, index=c("i"), effect="individual", model="within")
summary(within_reg)
```

```
## Oneway (individual) effect Within Model
##
## Call:
## plm(formula = Y ~ X, data = data, effect = "individual", model = "within",
##     index = c("i"))
##
```

```
## Balanced Panel: n = 500, T = 40, N = 20000
##
## Residuals:
##      Min.   1st Qu.    Median   3rd Qu.      Max.
## -4.313811 -0.654257  0.009003  0.657629  3.808233
##
## Coefficients:
##   Estimate Std. Error t-value  Pr(>|t|)
## X 0.591178   0.021634  27.327 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Total Sum of Squares:    19873
## Residual Sum of Squares: 19140
## R-Squared:      0.036884
## Adj. R-Squared: 0.012187
## F-statistic: 746.744 on 1 and 19499 DF, p-value: < 2.22e-16
```

```r
# dummy variables - check if the results are identical to within estimator
dummy_reg = lm(Y ~ X + factor(i), data = data)
summary(dummy_reg)
```

```
##
## Call:
## lm(formula = Y ~ X + factor(i), data = data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -4.3138 -0.6543  0.0090  0.6576  3.8082
##
## Coefficients:
##               Estimate Std. Error  t value Pr(>|t|)
## (Intercept)   74.44850    0.15674  474.968  < 2e-16 ***
## X              0.59118    0.02163   27.327  < 2e-16 ***
## factor(i)2   -21.83519    0.22157  -98.548  < 2e-16 ***
## factor(i)3   -21.64281    0.22159  -97.670  < 2e-16 ***
## factor(i)4   -42.68790    0.22169 -192.560  < 2e-16 ***
## factor(i)5   -24.91621    0.22159 -112.442  < 2e-16 ***
## factor(i)6   -21.60853    0.22156  -97.528  < 2e-16 ***
## factor(i)7   -10.12897    0.22154  -45.721  < 2e-16 ***
## factor(i)8   -25.39146    0.22158 -114.593  < 2e-16 ***
## factor(i)9   -28.22954    0.22157 -127.407  < 2e-16 ***
## factor(i)10  -34.08874    0.22163 -153.807  < 2e-16 ***
## factor(i)11  -17.26931    0.22154  -77.950  < 2e-16 ***
## factor(i)12   -5.52346    0.22154  -24.932  < 2e-16 ***
## factor(i)13  -25.57714    0.22157 -115.436  < 2e-16 ***
## factor(i)14  -15.51056    0.22156  -70.006  < 2e-16 ***
## factor(i)15   -7.46569    0.22154  -33.699  < 2e-16 ***
## factor(i)16  -18.92867    0.22155  -85.438  < 2e-16 ***
## factor(i)17   -3.03096    0.22155  -13.680  < 2e-16 ***
## factor(i)18  -29.06540    0.22160 -131.159  < 2e-16 ***
## factor(i)19  -32.08481    0.22160 -144.785  < 2e-16 ***
## factor(i)20  -14.86747    0.22154  -67.110  < 2e-16 ***
## factor(i)21  -20.69308    0.22158  -93.389  < 2e-16 ***
```

```
## factor(i)22  -19.02860    0.22155  -85.889  < 2e-16 ***
## factor(i)23   -5.94999    0.22154  -26.858  < 2e-16 ***
## factor(i)24  -12.58013    0.22154  -56.785  < 2e-16 ***
## factor(i)25  -14.91605    0.22154  -67.329  < 2e-16 ***
## factor(i)26  -25.48154    0.22156 -115.009  < 2e-16 ***
## factor(i)27  -36.76920    0.22163 -165.901  < 2e-16 ***
## factor(i)28  -18.11132    0.22155  -81.749  < 2e-16 ***
## factor(i)29  -25.23968    0.22157 -113.913  < 2e-16 ***
## factor(i)30  -33.71078    0.22162 -152.112  < 2e-16 ***
## factor(i)31  -15.53760    0.22154  -70.133  < 2e-16 ***
## factor(i)32  -18.10895    0.22154  -81.740  < 2e-16 ***
## factor(i)33  -21.14094    0.22159  -95.405  < 2e-16 ***
## factor(i)34    1.97706    0.22159    8.922  < 2e-16 ***
## factor(i)35  -37.13374    0.22165 -167.534  < 2e-16 ***
## factor(i)36   -4.98296    0.22154  -22.492  < 2e-16 ***
## factor(i)37   -0.72946    0.22154   -3.293 0.000994 ***
## factor(i)38  -21.53535    0.22156  -97.198  < 2e-16 ***
## factor(i)39  -39.47303    0.22173 -178.024  < 2e-16 ***
## factor(i)40  -17.55370    0.22154  -79.234  < 2e-16 ***
## factor(i)41  -25.56722    0.22159 -115.380  < 2e-16 ***
## factor(i)42  -15.00678    0.22154  -67.737  < 2e-16 ***
## factor(i)43  -18.54650    0.22155  -83.711  < 2e-16 ***
## factor(i)44  -26.32301    0.22157 -118.802  < 2e-16 ***
## factor(i)45  -20.24244    0.22155  -91.368  < 2e-16 ***
## factor(i)46  -13.83980    0.22154  -62.470  < 2e-16 ***
## factor(i)47  -35.38136    0.22167 -159.615  < 2e-16 ***
## factor(i)48  -17.90595    0.22154  -80.824  < 2e-16 ***
## factor(i)49  -15.54367    0.22156  -70.155  < 2e-16 ***
## factor(i)50   10.19860    0.22159   46.024  < 2e-16 ***
## factor(i)51  -29.11270    0.22159 -131.380  < 2e-16 ***
## factor(i)52  -36.05183    0.22163 -162.665  < 2e-16 ***
## factor(i)53  -34.50664    0.22160 -155.713  < 2e-16 ***
## factor(i)54  -11.61433    0.22156  -52.420  < 2e-16 ***
## factor(i)55  -17.64970    0.22155  -79.665  < 2e-16 ***
## factor(i)56  -14.92782    0.22154  -67.383  < 2e-16 ***
## factor(i)57  -29.63684    0.22160 -133.738  < 2e-16 ***
## factor(i)58   -9.63438    0.22154  -43.487  < 2e-16 ***
## factor(i)59   -0.97711    0.22157   -4.410 1.04e-05 ***
## factor(i)60  -25.64662    0.22159 -115.738  < 2e-16 ***
## factor(i)61  -28.41723    0.22155 -128.266  < 2e-16 ***
## factor(i)62  -12.82867    0.22154  -57.907  < 2e-16 ***
## factor(i)63  -24.17597    0.22157 -109.112  < 2e-16 ***
## factor(i)64  -22.96754    0.22155 -103.668  < 2e-16 ***
## factor(i)65  -11.65142    0.22154  -52.593  < 2e-16 ***
## factor(i)66   -4.64014    0.22154  -20.945  < 2e-16 ***
## factor(i)67   -4.91221    0.22155  -22.172  < 2e-16 ***
## factor(i)68  -12.80780    0.22154  -57.812  < 2e-16 ***
## factor(i)69   -7.84232    0.22154  -35.399  < 2e-16 ***
## factor(i)70  -27.76545    0.22160 -125.293  < 2e-16 ***
## factor(i)71  -32.90360    0.22160 -148.479  < 2e-16 ***
## factor(i)72  -23.87550    0.22158 -107.751  < 2e-16 ***
## factor(i)73  -25.31661    0.22158 -114.255  < 2e-16 ***
## factor(i)74  -37.70190    0.22163 -170.110  < 2e-16 ***
## factor(i)75   -5.90244    0.22154  -26.643  < 2e-16 ***
```

```
## factor(i)76  -27.11834    0.22157 -122.392  < 2e-16 ***
## factor(i)77  -13.88256    0.22154  -62.664  < 2e-16 ***
## factor(i)78  -30.30131    0.22160 -136.736  < 2e-16 ***
## factor(i)79  -25.17273    0.22157 -113.611  < 2e-16 ***
## factor(i)80  -18.42248    0.22156  -83.148  < 2e-16 ***
## factor(i)81  -17.54244    0.22155  -79.181  < 2e-16 ***
## factor(i)82  -18.46076    0.22154  -83.330  < 2e-16 ***
## factor(i)83  -20.37038    0.22156  -91.940  < 2e-16 ***
## factor(i)84  -25.35298    0.22155 -114.435  < 2e-16 ***
## factor(i)85  -24.96198    0.22156 -112.664  < 2e-16 ***
## factor(i)86  -13.49782    0.22154  -60.928  < 2e-16 ***
## factor(i)87  -27.88549    0.22158 -125.848  < 2e-16 ***
## factor(i)88  -11.35861    0.22155  -51.268  < 2e-16 ***
## factor(i)89  -29.43844    0.22160 -132.843  < 2e-16 ***
## factor(i)90  -30.26991    0.22160 -136.595  < 2e-16 ***
## factor(i)91  -17.49526    0.22154  -78.971  < 2e-16 ***
## factor(i)92  -28.19173    0.22159 -127.224  < 2e-16 ***
## factor(i)93  -29.09959    0.22159 -131.321  < 2e-16 ***
## factor(i)94  -11.36862    0.22155  -51.314  < 2e-16 ***
## factor(i)95  -32.48459    0.22162 -146.579  < 2e-16 ***
## factor(i)96  -11.77338    0.22155  -53.140  < 2e-16 ***
## factor(i)97  -31.75150    0.22160 -143.280  < 2e-16 ***
## factor(i)98  -18.08423    0.22157  -81.619  < 2e-16 ***
## factor(i)99  -12.68415    0.22154  -57.255  < 2e-16 ***
## factor(i)100 -13.43618    0.22154  -60.650  < 2e-16 ***
## factor(i)101 -18.95982    0.22155  -85.576  < 2e-16 ***
## factor(i)102 -28.87239    0.22159 -130.296  < 2e-16 ***
## factor(i)103 -30.40851    0.22160 -137.220  < 2e-16 ***
## factor(i)104  -4.23335    0.22154  -19.109  < 2e-16 ***
## factor(i)105 -13.18847    0.22155  -59.529  < 2e-16 ***
## factor(i)106 -17.10489    0.22158  -77.195  < 2e-16 ***
## factor(i)107 -29.63015    0.22160 -133.708  < 2e-16 ***
## factor(i)108 -13.16987    0.22154  -59.447  < 2e-16 ***
## factor(i)109 -15.81365    0.22155  -71.376  < 2e-16 ***
## factor(i)110 -30.18958    0.22160 -136.232  < 2e-16 ***
## factor(i)111 -30.32820    0.22160 -136.858  < 2e-16 ***
## factor(i)112 -26.45439    0.22158 -119.390  < 2e-16 ***
## factor(i)113 -27.02962    0.22157 -121.991  < 2e-16 ***
## factor(i)114 -14.38526    0.22154  -64.933  < 2e-16 ***
## factor(i)115 -19.62108    0.22156  -88.558  < 2e-16 ***
## factor(i)116 -16.49796    0.22155  -74.467  < 2e-16 ***
## factor(i)117 -25.96818    0.22157 -117.201  < 2e-16 ***
## factor(i)118 -24.52706    0.22157 -110.697  < 2e-16 ***
## factor(i)119 -15.89751    0.22155  -71.754  < 2e-16 ***
## factor(i)120 -28.09958    0.22158 -126.815  < 2e-16 ***
## factor(i)121  -8.42132    0.22154  -38.013  < 2e-16 ***
## factor(i)122  -8.95989    0.22154  -40.444  < 2e-16 ***
## factor(i)123  -2.78840    0.22154  -12.587  < 2e-16 ***
## factor(i)124 -19.12607    0.22157  -86.321  < 2e-16 ***
## factor(i)125 -17.90307    0.22154  -80.811  < 2e-16 ***
## factor(i)126 -10.45781    0.22154  -47.206  < 2e-16 ***
## factor(i)127 -18.99167    0.22155  -85.720  < 2e-16 ***
## factor(i)128 -22.61744    0.22155 -102.088  < 2e-16 ***
## factor(i)129  -6.72377    0.22154  -30.350  < 2e-16 ***
```

```
## factor(i)130 -20.31605    0.22154  -91.702  < 2e-16 ***
## factor(i)131 -24.41007    0.22154 -110.182  < 2e-16 ***
## factor(i)132 -19.66484    0.22158  -88.748  < 2e-16 ***
## factor(i)133 -26.89589    0.22159 -121.376  < 2e-16 ***
## factor(i)134 -29.32491    0.22160 -132.330  < 2e-16 ***
## factor(i)135 -27.09647    0.22159 -122.281  < 2e-16 ***
## factor(i)136 -14.50277    0.22154  -65.464  < 2e-16 ***
## factor(i)137 -25.92283    0.22159 -116.985  < 2e-16 ***
## factor(i)138 -23.76598    0.22155 -107.269  < 2e-16 ***
## factor(i)139 -17.87223    0.22155  -80.670  < 2e-16 ***
## factor(i)140 -24.86748    0.22155 -112.244  < 2e-16 ***
## factor(i)141 -13.39842    0.22154  -60.478  < 2e-16 ***
## factor(i)142 -18.80174    0.22155  -84.865  < 2e-16 ***
## factor(i)143 -26.41636    0.22158 -119.218  < 2e-16 ***
## factor(i)144 -23.37001    0.22158 -105.470  < 2e-16 ***
## factor(i)145 -22.40252    0.22158 -101.103  < 2e-16 ***
## factor(i)146  -1.18795    0.22154   -5.362 8.32e-08 ***
## factor(i)147 -10.85277    0.22154  -48.988  < 2e-16 ***
## factor(i)148 -21.51988    0.22155  -97.131  < 2e-16 ***
## factor(i)149 -29.58376    0.22159 -133.506  < 2e-16 ***
## factor(i)150 -19.70769    0.22155  -88.952  < 2e-16 ***
## factor(i)151 -19.44496    0.22157  -87.760  < 2e-16 ***
## factor(i)152 -19.35460    0.22157  -87.352  < 2e-16 ***
## factor(i)153 -26.87801    0.22159 -121.295  < 2e-16 ***
## factor(i)154 -30.13833    0.22160 -136.001  < 2e-16 ***
## factor(i)155 -21.68726    0.22158  -97.875  < 2e-16 ***
## factor(i)156 -19.38432    0.22156  -87.490  < 2e-16 ***
## factor(i)157 -15.13727    0.22154  -68.326  < 2e-16 ***
## factor(i)158 -14.30570    0.22154  -64.574  < 2e-16 ***
## factor(i)159 -17.90165    0.22155  -80.800  < 2e-16 ***
## factor(i)160 -14.73631    0.22155  -66.513  < 2e-16 ***
## factor(i)161 -21.76554    0.22155  -98.240  < 2e-16 ***
## factor(i)162 -24.58984    0.22159 -110.969  < 2e-16 ***
## factor(i)163 -30.91605    0.22160 -139.510  < 2e-16 ***
## factor(i)164 -25.68594    0.22159 -115.916  < 2e-16 ***
## factor(i)165 -11.19564    0.22154  -50.535  < 2e-16 ***
## factor(i)166 -26.93136    0.22158 -121.542  < 2e-16 ***
## factor(i)167 -17.62027    0.22155  -79.530  < 2e-16 ***
## factor(i)168  -4.12141    0.22155  -18.602  < 2e-16 ***
## factor(i)169 -21.49158    0.22154  -97.008  < 2e-16 ***
## factor(i)170 -25.25298    0.22160 -113.956  < 2e-16 ***
## factor(i)171 -16.57347    0.22154  -74.811  < 2e-16 ***
## factor(i)172 -17.52816    0.22154  -79.119  < 2e-16 ***
## factor(i)173 -26.34170    0.22157 -118.886  < 2e-16 ***
## factor(i)174 -18.08603    0.22156  -81.630  < 2e-16 ***
## factor(i)175 -26.29313    0.22158 -118.662  < 2e-16 ***
## factor(i)176 -12.60239    0.22154  -56.885  < 2e-16 ***
## factor(i)177 -32.56580    0.22162 -146.946  < 2e-16 ***
## factor(i)178 -33.01712    0.22163 -148.972  < 2e-16 ***
## factor(i)179 -17.12712    0.22156  -77.302  < 2e-16 ***
## factor(i)180 -27.85916    0.22157 -125.735  < 2e-16 ***
## factor(i)181 -23.17893    0.22155 -104.620  < 2e-16 ***
## factor(i)182 -29.20644    0.22160 -131.796  < 2e-16 ***
## factor(i)183 -19.08817    0.22157  -86.150  < 2e-16 ***
```

```
## factor(i)184 -23.74548    0.22158 -107.164  < 2e-16 ***
## factor(i)185 -24.41272    0.22158 -110.176  < 2e-16 ***
## factor(i)186 -16.93634    0.22156  -76.441  < 2e-16 ***
## factor(i)187 -23.56791    0.22157 -106.368  < 2e-16 ***
## factor(i)188  -0.24373    0.22155   -1.100 0.271302
## factor(i)189 -15.68033    0.22155  -70.774  < 2e-16 ***
## factor(i)190 -21.28824    0.22154  -96.093  < 2e-16 ***
## factor(i)191  -8.95634    0.22155  -40.426  < 2e-16 ***
## factor(i)192 -14.56598    0.22155  -65.746  < 2e-16 ***
## factor(i)193 -13.75995    0.22154  -62.109  < 2e-16 ***
## factor(i)194 -21.09557    0.22159  -95.200  < 2e-16 ***
## factor(i)195 -22.26383    0.22157 -100.482  < 2e-16 ***
## factor(i)196 -24.45861    0.22159 -110.377  < 2e-16 ***
## factor(i)197 -18.90086    0.22154  -85.316  < 2e-16 ***
## factor(i)198 -15.16143    0.22155  -68.432  < 2e-16 ***
## factor(i)199 -10.83064    0.22154  -48.888  < 2e-16 ***
## factor(i)200 -16.47413    0.22155  -74.359  < 2e-16 ***
## factor(i)201 -29.24454    0.22159 -131.975  < 2e-16 ***
## factor(i)202 -25.31422    0.22156 -114.254  < 2e-16 ***
## factor(i)203 -26.87056    0.22159 -121.262  < 2e-16 ***
## factor(i)204  -4.91264    0.22154  -22.175  < 2e-16 ***
## factor(i)205 -11.23533    0.22154  -50.715  < 2e-16 ***
## factor(i)206 -21.26177    0.22157  -95.960  < 2e-16 ***
## factor(i)207  -9.57691    0.22155  -43.227  < 2e-16 ***
## factor(i)208 -18.12332    0.22157  -81.795  < 2e-16 ***
## factor(i)209 -17.49850    0.22154  -78.984  < 2e-16 ***
## factor(i)210 -18.60490    0.22155  -83.977  < 2e-16 ***
## factor(i)211 -15.82381    0.22154  -71.425  < 2e-16 ***
## factor(i)212 -15.46199    0.22155  -69.791  < 2e-16 ***
## factor(i)213  -9.12839    0.22156  -41.200  < 2e-16 ***
## factor(i)214  -7.57653    0.22156  -34.196  < 2e-16 ***
## factor(i)215   2.99376    0.22156   13.512  < 2e-16 ***
## factor(i)216  -0.30018    0.22154   -1.355 0.175452
## factor(i)217 -32.95760    0.22162 -148.714  < 2e-16 ***
## factor(i)218 -19.60283    0.22157  -88.472  < 2e-16 ***
## factor(i)219 -23.25990    0.22155 -104.985  < 2e-16 ***
## factor(i)220 -22.87256    0.22157 -103.229  < 2e-16 ***
## factor(i)221 -18.29506    0.22155  -82.576  < 2e-16 ***
## factor(i)222  -6.94835    0.22154  -31.364  < 2e-16 ***
## factor(i)223 -17.05581    0.22156  -76.980  < 2e-16 ***
## factor(i)224 -25.38602    0.22159 -114.562  < 2e-16 ***
## factor(i)225 -35.01645    0.22160 -158.014  < 2e-16 ***
## factor(i)226  -5.15091    0.22154  -23.251  < 2e-16 ***
## factor(i)227 -22.65537    0.22157 -102.249  < 2e-16 ***
## factor(i)228 -18.87220    0.22155  -85.181  < 2e-16 ***
## factor(i)229 -36.68938    0.22162 -165.553  < 2e-16 ***
## factor(i)230 -19.68306    0.22156  -88.838  < 2e-16 ***
## factor(i)231 -10.62959    0.22155  -47.979  < 2e-16 ***
## factor(i)232 -12.16383    0.22155  -54.904  < 2e-16 ***
## factor(i)233 -15.78732    0.22154  -71.262  < 2e-16 ***
## factor(i)234 -26.87304    0.22158 -121.279  < 2e-16 ***
## factor(i)235 -21.37890    0.22157  -96.488  < 2e-16 ***
## factor(i)236 -11.26054    0.22155  -50.827  < 2e-16 ***
## factor(i)237 -17.85362    0.22155  -80.583  < 2e-16 ***
```

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## factor(i)238 -26.44852    0.22160 -119.350  < 2e-16 ***
## factor(i)239 -28.55295    0.22159 -128.854  < 2e-16 ***
## factor(i)240 -21.85202    0.22157  -98.623  < 2e-16 ***
## factor(i)241 -23.71869    0.22159 -107.038  < 2e-16 ***
## factor(i)242 -11.70932    0.22154  -52.853  < 2e-16 ***
## factor(i)243 -11.95247    0.22154  -53.952  < 2e-16 ***
## factor(i)244 -23.44287    0.22157 -105.803  < 2e-16 ***
## factor(i)245 -33.73871    0.22162 -152.238  < 2e-16 ***
## factor(i)246 -22.06632    0.22155  -99.598  < 2e-16 ***
## factor(i)247 -13.68715    0.22154  -61.782  < 2e-16 ***
## factor(i)248 -29.36464    0.22160 -132.510  < 2e-16 ***
## factor(i)249 -12.99493    0.22154  -58.657  < 2e-16 ***
## factor(i)250  -8.04155    0.22155  -36.297  < 2e-16 ***
## factor(i)251 -14.08144    0.22155  -63.558  < 2e-16 ***
## factor(i)252 -35.14446    0.22165 -158.559  < 2e-16 ***
## factor(i)253  -8.15221    0.22154  -36.798  < 2e-16 ***
## factor(i)254 -14.93353    0.22154  -67.408  < 2e-16 ***
## factor(i)255 -15.25701    0.22155  -68.864  < 2e-16 ***
## factor(i)256 -26.89330    0.22155 -121.388  < 2e-16 ***
## factor(i)257 -16.06633    0.22154  -72.522  < 2e-16 ***
## factor(i)258 -13.38065    0.22155  -60.396  < 2e-16 ***
## factor(i)259 -18.45337    0.22155  -83.293  < 2e-16 ***
## factor(i)260 -24.81524    0.22155 -112.008  < 2e-16 ***
## factor(i)261 -28.38795    0.22159 -128.110  < 2e-16 ***
## factor(i)262 -37.60612    0.22169 -169.637  < 2e-16 ***
## factor(i)263 -15.71964    0.22155  -70.954  < 2e-16 ***
## factor(i)264 -20.55840    0.22156  -92.789  < 2e-16 ***
## factor(i)265 -17.17240    0.22154  -77.512  < 2e-16 ***
## factor(i)266 -17.20848    0.22154  -77.677  < 2e-16 ***
## factor(i)267 -25.67793    0.22159 -115.880  < 2e-16 ***
## factor(i)268 -23.28025    0.22155 -105.080  < 2e-16 ***
## factor(i)269 -21.21865    0.22159  -95.756  < 2e-16 ***
## factor(i)270  -7.65296    0.22154  -34.545  < 2e-16 ***
## factor(i)271 -26.98936    0.22158 -121.804  < 2e-16 ***
## factor(i)272 -19.21275    0.22155  -86.720  < 2e-16 ***
## factor(i)273 -18.68315    0.22156  -84.325  < 2e-16 ***
## factor(i)274 -22.38750    0.22154 -101.052  < 2e-16 ***
## factor(i)275 -26.83124    0.22157 -121.096  < 2e-16 ***
## factor(i)276 -22.13703    0.22155  -99.920  < 2e-16 ***
## factor(i)277  -9.26408    0.22154  -41.817  < 2e-16 ***
## factor(i)278 -27.42735    0.22160 -123.767  < 2e-16 ***
## factor(i)279 -11.53805    0.22154  -52.081  < 2e-16 ***
## factor(i)280 -15.01713    0.22154  -67.786  < 2e-16 ***
## factor(i)281 -22.36041    0.22157 -100.918  < 2e-16 ***
## factor(i)282 -34.64898    0.22162 -156.346  < 2e-16 ***
## factor(i)283 -40.58307    0.22169 -183.065  < 2e-16 ***
## factor(i)284 -19.34633    0.22157  -87.315  < 2e-16 ***
## factor(i)285 -38.31188    0.22169 -172.820  < 2e-16 ***
## factor(i)286 -26.42750    0.22160 -119.256  < 2e-16 ***
## factor(i)287 -17.29056    0.22155  -78.044  < 2e-16 ***
## factor(i)288 -28.82803    0.22159 -130.095  < 2e-16 ***
## factor(i)289  12.88153    0.22169   58.107  < 2e-16 ***
## factor(i)290 -20.60903    0.22155  -93.020  < 2e-16 ***
## factor(i)291 -34.65164    0.22163 -156.347  < 2e-16 ***
```

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## factor(i)292 -27.60559    0.22160 -124.572  < 2e-16 ***
## factor(i)293 -23.60423    0.22155 -106.539  < 2e-16 ***
## factor(i)294 -20.37952    0.22155  -91.984  < 2e-16 ***
## factor(i)295 -20.87149    0.22154  -94.211  < 2e-16 ***
## factor(i)296 -16.44670    0.22156  -74.231  < 2e-16 ***
## factor(i)297 -29.30378    0.22158 -132.249  < 2e-16 ***
## factor(i)298 -17.85548    0.22155  -80.592  < 2e-16 ***
## factor(i)299 -24.23726    0.22158 -109.384  < 2e-16 ***
## factor(i)300 -21.89770    0.22157  -98.830  < 2e-16 ***
## factor(i)301 -32.19466    0.22160 -145.280  < 2e-16 ***
## factor(i)302 -15.91729    0.22154  -71.849  < 2e-16 ***
## factor(i)303  -8.23149    0.22154  -37.156  < 2e-16 ***
## factor(i)304 -24.04711    0.22158 -108.526  < 2e-16 ***
## factor(i)305 -26.49782    0.22158 -119.586  < 2e-16 ***
## factor(i)306 -21.64192    0.22159  -97.666  < 2e-16 ***
## factor(i)307 -37.38268    0.22165 -168.657  < 2e-16 ***
## factor(i)308 -23.16481    0.22155 -104.556  < 2e-16 ***
## factor(i)309 -17.94578    0.22155  -80.999  < 2e-16 ***
## factor(i)310 -15.05536    0.22154  -67.958  < 2e-16 ***
## factor(i)311 -13.59434    0.22154  -61.363  < 2e-16 ***
## factor(i)312 -23.00370    0.22155 -103.832  < 2e-16 ***
## factor(i)313 -19.31781    0.22156  -87.189  < 2e-16 ***
## factor(i)314 -23.08050    0.22158 -104.163  < 2e-16 ***
## factor(i)315 -36.41019    0.22162 -164.293  < 2e-16 ***
## factor(i)316   0.62284    0.22154    2.811 0.004938 **
## factor(i)317 -23.14327    0.22155 -104.459  < 2e-16 ***
## factor(i)318 -27.59340    0.22156 -124.541  < 2e-16 ***
## factor(i)319 -10.01645    0.22154  -45.213  < 2e-16 ***
## factor(i)320 -35.57106    0.22167 -160.471  < 2e-16 ***
## factor(i)321 -33.94861    0.22162 -153.185  < 2e-16 ***
## factor(i)322 -16.11698    0.22154  -72.750  < 2e-16 ***
## factor(i)323 -24.97903    0.22158 -112.731  < 2e-16 ***
## factor(i)324  -4.59776    0.22154  -20.754  < 2e-16 ***
## factor(i)325 -17.06809    0.22154  -77.043  < 2e-16 ***
## factor(i)326 -26.08987    0.22159 -117.739  < 2e-16 ***
## factor(i)327 -21.73021    0.22156  -98.078  < 2e-16 ***
## factor(i)328 -27.37612    0.22157 -123.555  < 2e-16 ***
## factor(i)329  -0.08880    0.22154   -0.401 0.688539
## factor(i)330 -23.70610    0.22160 -106.975  < 2e-16 ***
## factor(i)331 -25.25617    0.22156 -113.992  < 2e-16 ***
## factor(i)332 -16.51045    0.22154  -74.527  < 2e-16 ***
## factor(i)333 -20.99938    0.22156  -94.779  < 2e-16 ***
## factor(i)334 -28.37202    0.22160 -128.030  < 2e-16 ***
## factor(i)335 -28.88064    0.22159 -130.333  < 2e-16 ***
## factor(i)336  -7.20722    0.22154  -32.532  < 2e-16 ***
## factor(i)337 -33.40337    0.22160 -150.735  < 2e-16 ***
## factor(i)338 -29.67946    0.22159 -133.938  < 2e-16 ***
## factor(i)339 -20.91861    0.22154  -94.425  < 2e-16 ***
## factor(i)340 -25.98337    0.22160 -117.251  < 2e-16 ***
## factor(i)341 -28.34457    0.22160 -127.907  < 2e-16 ***
## factor(i)342 -15.09930    0.22154  -68.155  < 2e-16 ***
## factor(i)343   0.32139    0.22154    1.451 0.146887
## factor(i)344 -16.92389    0.22157  -76.382  < 2e-16 ***
## factor(i)345 -27.54062    0.22158 -124.292  < 2e-16 ***
```

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## factor(i)346 -11.65088    0.22154  -52.590  < 2e-16 ***
## factor(i)347 -18.46616    0.22155  -83.348  < 2e-16 ***
## factor(i)348 -21.51893    0.22155  -97.127  < 2e-16 ***
## factor(i)349 -11.52093    0.22154  -52.004  < 2e-16 ***
## factor(i)350 -11.55880    0.22155  -52.173  < 2e-16 ***
## factor(i)351 -20.43989    0.22154  -92.261  < 2e-16 ***
## factor(i)352 -10.59714    0.22154  -47.833  < 2e-16 ***
## factor(i)353  -9.48802    0.22154  -42.828  < 2e-16 ***
## factor(i)354  -5.84521    0.22154  -26.385  < 2e-16 ***
## factor(i)355 -27.02486    0.22159 -121.958  < 2e-16 ***
## factor(i)356 -42.73083    0.22173 -192.717  < 2e-16 ***
## factor(i)357 -18.58684    0.22155  -83.895  < 2e-16 ***
## factor(i)358 -13.78203    0.22154  -62.211  < 2e-16 ***
## factor(i)359 -16.10185    0.22154  -72.680  < 2e-16 ***
## factor(i)360 -15.72366    0.22154  -70.975  < 2e-16 ***
## factor(i)361  -4.47136    0.22156  -20.181  < 2e-16 ***
## factor(i)362 -34.09458    0.22165 -153.822  < 2e-16 ***
## factor(i)363 -21.66707    0.22156  -97.793  < 2e-16 ***
## factor(i)364 -21.16427    0.22157  -95.519  < 2e-16 ***
## factor(i)365 -21.28660    0.22155  -96.081  < 2e-16 ***
## factor(i)366 -21.89324    0.22157  -98.810  < 2e-16 ***
## factor(i)367 -20.97246    0.22156  -94.657  < 2e-16 ***
## factor(i)368 -18.65913    0.22155  -84.219  < 2e-16 ***
## factor(i)369  -3.07743    0.22155  -13.890  < 2e-16 ***
## factor(i)370 -20.86117    0.22156  -94.155  < 2e-16 ***
## factor(i)371 -21.18776    0.22157  -95.625  < 2e-16 ***
## factor(i)372  -4.01396    0.22154  -18.118  < 2e-16 ***
## factor(i)373 -22.66434    0.22157 -102.290  < 2e-16 ***
## factor(i)374 -20.00331    0.22155  -90.286  < 2e-16 ***
## factor(i)375 -20.77433    0.22157  -93.760  < 2e-16 ***
## factor(i)376  -3.61601    0.22154  -16.322  < 2e-16 ***
## factor(i)377 -22.49835    0.22156 -101.544  < 2e-16 ***
## factor(i)378 -11.69779    0.22156  -52.797  < 2e-16 ***
## factor(i)379 -18.35131    0.22156  -82.827  < 2e-16 ***
## factor(i)380 -28.01896    0.22159 -126.444  < 2e-16 ***
## factor(i)381 -29.94124    0.22160 -135.112  < 2e-16 ***
## factor(i)382 -13.16245    0.22155  -59.410  < 2e-16 ***
## factor(i)383 -22.88649    0.22158 -103.288  < 2e-16 ***
## factor(i)384 -20.19781    0.22154  -91.171  < 2e-16 ***
## factor(i)385  -2.49342    0.22154  -11.255  < 2e-16 ***
## factor(i)386  -7.02645    0.22154  -31.717  < 2e-16 ***
## factor(i)387 -13.89031    0.22154  -62.699  < 2e-16 ***
## factor(i)388 -30.02652    0.22159 -135.504  < 2e-16 ***
## factor(i)389 -18.89234    0.22155  -85.274  < 2e-16 ***
## factor(i)390 -39.23822    0.22163 -177.042  < 2e-16 ***
## factor(i)391 -21.49205    0.22155  -97.006  < 2e-16 ***
## factor(i)392 -21.77546    0.22155  -98.288  < 2e-16 ***
## factor(i)393 -18.87070    0.22154  -85.179  < 2e-16 ***
## factor(i)394 -32.64226    0.22160 -147.300  < 2e-16 ***
## factor(i)395 -37.14730    0.22163 -167.607  < 2e-16 ***
## factor(i)396  -9.28406    0.22154  -41.907  < 2e-16 ***
## factor(i)397  -7.69143    0.22154  -34.718  < 2e-16 ***
## factor(i)398 -26.18502    0.22159 -118.168  < 2e-16 ***
## factor(i)399 -16.83334    0.22154  -75.984  < 2e-16 ***
```

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## factor(i)400  -3.21773    0.22154  -14.525  < 2e-16 ***
## factor(i)401 -27.67601    0.22159 -124.897  < 2e-16 ***
## factor(i)402 -25.89394    0.22157 -116.866  < 2e-16 ***
## factor(i)403 -17.85565    0.22156  -80.590  < 2e-16 ***
## factor(i)404 -24.87840    0.22156 -112.287  < 2e-16 ***
## factor(i)405 -26.74399    0.22158 -120.697  < 2e-16 ***
## factor(i)406 -21.46662    0.22156  -96.888  < 2e-16 ***
## factor(i)407  -9.79282    0.22154  -44.204  < 2e-16 ***
## factor(i)408 -31.55883    0.22160 -142.411  < 2e-16 ***
## factor(i)409 -19.92567    0.22155  -89.936  < 2e-16 ***
## factor(i)410 -39.51450    0.22165 -178.275  < 2e-16 ***
## factor(i)411  -8.63135    0.22154  -38.961  < 2e-16 ***
## factor(i)412 -30.69951    0.22160 -138.533  < 2e-16 ***
## factor(i)413 -24.81002    0.22160 -111.957  < 2e-16 ***
## factor(i)414 -11.34360    0.22155  -51.201  < 2e-16 ***
## factor(i)415 -17.25019    0.22154  -77.866  < 2e-16 ***
## factor(i)416 -19.40383    0.22154  -87.586  < 2e-16 ***
## factor(i)417 -22.32281    0.22156 -100.752  < 2e-16 ***
## factor(i)418 -26.66787    0.22158 -120.353  < 2e-16 ***
## factor(i)419 -22.46821    0.22157 -101.404  < 2e-16 ***
## factor(i)420 -16.89048    0.22155  -76.238  < 2e-16 ***
## factor(i)421 -25.91868    0.22157 -116.977  < 2e-16 ***
## factor(i)422 -25.50629    0.22157 -115.116  < 2e-16 ***
## factor(i)423 -22.24161    0.22156 -100.386  < 2e-16 ***
## factor(i)424 -38.47124    0.22165 -173.568  < 2e-16 ***
## factor(i)425 -18.63500    0.22158  -84.101  < 2e-16 ***
## factor(i)426 -16.72786    0.22157  -75.497  < 2e-16 ***
## factor(i)427 -18.92100    0.22155  -85.403  < 2e-16 ***
## factor(i)428 -23.44984    0.22157 -105.835  < 2e-16 ***
## factor(i)429 -21.64601    0.22157  -97.694  < 2e-16 ***
## factor(i)430 -18.39096    0.22155  -83.011  < 2e-16 ***
## factor(i)431 -27.80129    0.22159 -125.462  < 2e-16 ***
## factor(i)432  -8.54951    0.22154  -38.592  < 2e-16 ***
## factor(i)433 -32.98004    0.22162 -148.815  < 2e-16 ***
## factor(i)434 -11.72350    0.22155  -52.916  < 2e-16 ***
## factor(i)435 -28.00863    0.22159 -126.398  < 2e-16 ***
## factor(i)436 -15.94423    0.22156  -71.963  < 2e-16 ***
## factor(i)437 -37.07196    0.22167 -167.242  < 2e-16 ***
## factor(i)438 -24.80872    0.22160 -111.951  < 2e-16 ***
## factor(i)439 -22.88401    0.22159 -103.271  < 2e-16 ***
## factor(i)440 -20.00600    0.22156  -90.295  < 2e-16 ***
## factor(i)441 -33.08160    0.22160 -149.283  < 2e-16 ***
## factor(i)442 -21.12875    0.22158  -95.355  < 2e-16 ***
## factor(i)443 -11.52311    0.22154  -52.014  < 2e-16 ***
## factor(i)444 -17.37313    0.22154  -78.420  < 2e-16 ***
## factor(i)445  -8.58367    0.22154  -38.746  < 2e-16 ***
## factor(i)446 -36.49619    0.22163 -164.670  < 2e-16 ***
## factor(i)447 -37.04433    0.22163 -167.143  < 2e-16 ***
## factor(i)448 -15.63248    0.22154  -70.563  < 2e-16 ***
## factor(i)449 -19.26202    0.22156  -86.938  < 2e-16 ***
## factor(i)450 -22.10149    0.22155  -99.757  < 2e-16 ***
## factor(i)451 -31.02268    0.22160 -139.992  < 2e-16 ***
## factor(i)452 -26.35697    0.22159 -118.944  < 2e-16 ***
## factor(i)453 -30.43895    0.22160 -137.358  < 2e-16 ***
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## factor(i)454 -15.84516    0.22154  -71.523  < 2e-16 ***
## factor(i)455 -16.37371    0.22154  -73.907  < 2e-16 ***
## factor(i)456 -11.86096    0.22154  -53.539  < 2e-16 ***
## factor(i)457 -26.58920    0.22159 -119.992  < 2e-16 ***
## factor(i)458 -22.22866    0.22154 -100.337  < 2e-16 ***
## factor(i)459  -8.74126    0.22155  -39.454  < 2e-16 ***
## factor(i)460 -27.63787    0.22160 -124.717  < 2e-16 ***
## factor(i)461 -38.41788    0.22167 -173.313  < 2e-16 ***
## factor(i)462 -11.91714    0.22156  -53.787  < 2e-16 ***
## factor(i)463  -3.89430    0.22154  -17.578  < 2e-16 ***
## factor(i)464 -30.83400    0.22160 -139.140  < 2e-16 ***
## factor(i)465 -13.66156    0.22154  -61.665  < 2e-16 ***
## factor(i)466 -14.40938    0.22154  -65.042  < 2e-16 ***
## factor(i)467 -15.73331    0.22154  -71.017  < 2e-16 ***
## factor(i)468 -15.40416    0.22155  -69.528  < 2e-16 ***
## factor(i)469 -18.32722    0.22155  -82.723  < 2e-16 ***
## factor(i)470 -10.93351    0.22154  -49.351  < 2e-16 ***
## factor(i)471  -5.95990    0.22155  -26.901  < 2e-16 ***
## factor(i)472 -20.67355    0.22156  -93.308  < 2e-16 ***
## factor(i)473 -17.74822    0.22155  -80.108  < 2e-16 ***
## factor(i)474 -16.66630    0.22154  -75.229  < 2e-16 ***
## factor(i)475 -13.91788    0.22154  -62.822  < 2e-16 ***
## factor(i)476 -12.45442    0.22154  -56.217  < 2e-16 ***
## factor(i)477 -10.28836    0.22154  -46.440  < 2e-16 ***
## factor(i)478 -14.31614    0.22154  -64.621  < 2e-16 ***
## factor(i)479 -12.51776    0.22155  -56.501  < 2e-16 ***
## factor(i)480 -10.52138    0.22154  -47.492  < 2e-16 ***
## factor(i)481 -25.04753    0.22158 -113.041  < 2e-16 ***
## factor(i)482 -14.64583    0.22154  -66.109  < 2e-16 ***
## factor(i)483  -5.51268    0.22154  -24.884  < 2e-16 ***
## factor(i)484  -8.37602    0.22154  -37.808  < 2e-16 ***
## factor(i)485 -17.93407    0.22155  -80.949  < 2e-16 ***
## factor(i)486 -11.97776    0.22155  -54.064  < 2e-16 ***
## factor(i)487 -15.14902    0.22154  -68.381  < 2e-16 ***
## factor(i)488 -22.92032    0.22156 -103.449  < 2e-16 ***
## factor(i)489 -19.32286    0.22155  -87.217  < 2e-16 ***
## factor(i)490 -27.88808    0.22158 -125.860  < 2e-16 ***
## factor(i)491 -27.30083    0.22158 -123.210  < 2e-16 ***
## factor(i)492 -25.70536    0.22159 -116.003  < 2e-16 ***
## factor(i)493 -13.39202    0.22154  -60.450  < 2e-16 ***
## factor(i)494 -30.33926    0.22160 -136.908  < 2e-16 ***
## factor(i)495 -17.00421    0.22155  -76.752  < 2e-16 ***
## factor(i)496 -13.89760    0.22154  -62.732  < 2e-16 ***
## factor(i)497 -11.91284    0.22154  -53.773  < 2e-16 ***
## factor(i)498 -29.36193    0.22159 -132.505  < 2e-16 ***
## factor(i)499 -29.68203    0.22160 -133.942  < 2e-16 ***
## factor(i)500 -18.75013    0.22155  -84.630  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.9907 on 19499 degrees of freedom
## Multiple R-squared:  0.9882, Adjusted R-squared:  0.9879
## F-statistic:  3266 on 500 and 19499 DF,  p-value: < 2.2e-16
```

```r
# first differencing
fd_reg = plm(Y ~ X, data = data, index=c("i"), effect="individual", model="fd")
summary(fd_reg)
```

```
## Oneway (individual) effect First-Difference Model
##
## Call:
## plm(formula = Y ~ X, data = data, effect = "individual", model = "fd",
##     index = c("i"))
##
## Balanced Panel: n = 500, T = 40, N = 20000
## Observations used in estimation: 19500
##
## Residuals:
##      Min.   1st Qu.    Median   3rd Qu.      Max.
## -5.359690 -0.948618 -0.016545  0.950862  5.448988
##
## Coefficients:
##              Estimate Std. Error t-value Pr(>|t|)
## (Intercept) 0.0011785  0.0100759   0.117   0.9069
## X           0.5882696  0.0219101  26.849   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Total Sum of Squares:    40028
## Residual Sum of Squares: 38601
## R-Squared:      0.035654
## Adj. R-Squared: 0.035604
## F-statistic: 720.883 on 1 and 19498 DF, p-value: < 2.22e-16
```

```r
# Now, let's try a random effect model
random_reg = plm(Y ~ X, data = data, index=c("i"), effect="individual", model="random")
summary(random_reg)
```

```
## Oneway (individual) effect Random Effect Model
##    (Swamy-Arora's transformation)
##
## Call:
## plm(formula = Y ~ X, data = data, effect = "individual", model = "random",
##     index = c("i"))
##
## Balanced Panel: n = 500, T = 40, N = 20000
##
## Effects:
##                   var std.dev share
## idiosyncratic  0.9816  0.9907 0.062
## individual    14.8683  3.8559 0.938
## theta: 0.9594
##
## Residuals:
##       Min.    1st Qu.     Median    3rd Qu.       Max.
## -4.5826046 -0.6999876 -0.0034433  0.6957558  4.2463986
##
```

```
## Coefficients:
##              Estimate Std. Error z-value  Pr(>|z|)
## (Intercept) 54.489353   0.181668 299.940 < 2.2e-16 ***
## X            0.605172   0.022767  26.581 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Total Sum of Squares:    22513
## Residual Sum of Squares: 21745
## R-Squared:      0.034124
## Adj. R-Squared: 0.034076
## Chisq: 706.531 on 1 DF, p-value: < 2.22e-16
```

```
# Hausman test
phtest(within_reg, random_reg)
```

```
##
##  Hausman Test
##
## data:  Y ~ X
## chisq = 3.8905, df = 1, p-value = 0.04856
## alternative hypothesis: one model is inconsistent
```

```
# Next, let's simulate a case where the individual-specific weight is uncorrelated with X
set.seed(1001)
data2 = data.frame(i, t) %>%
  group_by(i) %>%
  mutate(weight = rnorm(1, mean = 180, sd=30)) %>%
  ungroup() %>%
  mutate(X = rbinom(n = 20000, size = 1, prob = 0.3)) %>%
  mutate(Y = 0.5 + 0.6*X + 0.3*weight + rnorm(20000,mean=0,sd=1))

cor(data2$X, data2$weight)
```

```
## [1] -0.002488978
```

```
# fixed effect
within_reg2 = plm(Y ~ X, data = data2, index=c("i"), effect="individual", model="within")
summary(within_reg2)
```

```
## Oneway (individual) effect Within Model
##
## Call:
## plm(formula = Y ~ X, data = data2, effect = "individual", model = "within",
##     index = c("i"))
##
## Balanced Panel: n = 500, T = 40, N = 20000
##
## Residuals:
##       Min.    1st Qu.     Median    3rd Qu.       Max.
## -4.3150414 -0.6533489  0.0096848  0.6576133  3.8095398
##
```

```
## Coefficients:
##   Estimate Std. Error t-value  Pr(>|t|)
## X 0.595535   0.015482  38.467 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Total Sum of Squares:    20592
## Residual Sum of Squares: 19140
## R-Squared:      0.070532
## Adj. R-Squared: 0.046698
## F-statistic: 1479.67 on 1 and 19499 DF, p-value: < 2.22e-16
```

```
random_reg2 = plm(Y ~ X, data = data2, index=c("i"), effect="individual", model="random")
summary(random_reg2)
```

```
## Oneway (individual) effect Random Effect Model
##    (Swamy-Arora's transformation)
##
## Call:
## plm(formula = Y ~ X, data = data2, effect = "individual", model = "random",
##     index = c("i"))
##
## Balanced Panel: n = 500, T = 40, N = 20000
##
## Effects:
##                   var std.dev share
## idiosyncratic  0.9816  0.9907 0.012
## individual    79.3183  8.9061 0.988
## theta: 0.9824
##
## Residuals:
##       Min.    1st Qu.     Median    3rd Qu.       Max.
## -4.4316589 -0.6637324  0.0081467  0.6649699  3.9975668
##
## Coefficients:
##              Estimate Std. Error z-value  Pr(>|z|)
## (Intercept) 54.491323   0.398372 136.785 < 2.2e-16 ***
## X            0.595520   0.015482  38.466 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Total Sum of Squares:    21081
## Residual Sum of Squares: 19629
## R-Squared:      0.068893
## Adj. R-Squared: 0.068847
## Chisq: 1479.67 on 1 DF, p-value: < 2.22e-16
```

```
# Hausman test
phtest(within_reg2, random_reg2)
```

```
##
##  Hausman Test
##
```

```
## data:  Y ~ X
## chisq = 0.01934, df = 1, p-value = 0.8894
## alternative hypothesis: one model is inconsistent
```