Component 2, Stage 1

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```
knitr::opts_chunk$set(
  echo = TRUE, warning = FALSE, message = FALSE,
  tidy = TRUE, tidy.opts = list(width.cutoff = 60)
)
```

1 Set up

```
# set working directory
setwd("~/Documents/GitHub/QMSS_Thesis_Sanchez")

# load libraries/packages
source("packages.R")

# load data
source("Comp2_panel_wrangling.R")
panel_data1 <- panel_data %>%
    dplyr::select(country_name, country_code, year, spi_comp,
        di_score, log_gdppc, income_level_recoded, di_score_reverse) %>%
    dplyr::arrange(country_code, year)

# how many countries
length(unique(panel_data1$country_code))
```

```
## [1] 162
```

```
# check dimensions
dim(panel_data1)
```

```
## [1] 1296    8
```

```
# testing dataframes for sensitivity of results panel_data
# <- panel_data_spi
```

sensitivity analysis [REVISE -USING PLM::LAGs] Basing analysis of dataset sensitivity on FE model of the second order (fe_spi_di_L2)

- Dataset = panel_data_comp1_data, 1336 obs, 167 countries, FE models (di_score_lag2) showed p = 0.07598 (marginally significant)

- Dataset = panel_data_sdg, 1336 obs, 167 countries, FE models (di_score_lag2) showed p = 0.07598 (marginally significant)
- Dataset = panel_data_exclusive, 1296 obs, 162 countries, FE models (di_score_lag2) showed p = 0.079 (marginally significant)
- Dataset = panel_data_spi, 1392 obs, 174 countries, FE models (di_score_lag2) showed p = 0.1497 (not significant)

2 Stage 1 Models:

ols_spi_di ols_spi_di_L1 ols_spi_di_L2

fd_spi_di fd_spi_di_L1 fd_spi_di_L2

fe_spi_di fe_spi_di_L1 fe_spi_di_L2

2.1 Converting to panel data frame

```
panel_data <- pdata.frame(panel_data1, index = c("country_code",
    "year"))
pdim(panel_data)  # check panel dimensions
```

```
## Balanced Panel: n = 162, T = 8, N = 1296
```

3 1.1) POLS [Stage 1]: SPI ~ DI

The effect of democracy on SPI Performance

```
# Contemporaneous Effect: SPI ~ DI
ols_spi_di <- plm(
  formula = spi_comp ~ di_score
  + log_gdppc
  #+ factor(income_level_recoded)
  + factor(year),
  model = "pooling",
  data = panel_data)
summary(ols_spi_di, vcov = vcovHC(ols_spi_di, cluster = "group", type = "HC1"))
```

```
## Pooling Model
##
## Note: Coefficient variance-covariance matrix supplied: vcovHC(ols_spi_di, cluster = "group", type =
##
## Call:
## plm(formula = spi_comp ~ di_score + log_gdppc + factor(year),
##     data = panel_data, model = "pooling")
##
## Unbalanced Panel: n = 155, T = 6-8, N = 1234
##
## Residuals:
```

```
##      Min.   1st Qu.    Median   3rd Qu.      Max.
## -32.83487  -5.58135   0.82944   6.50077  27.89241
##
## Coefficients:
##                   Estimate Std. Error t-value  Pr(>|t|)
## (Intercept)      10.90623    3.89985  2.7966  0.005246 **
## di_score          3.57390    0.55766  6.4087 2.089e-10 ***
## log_gdppc         3.42650    0.71356  4.8020 1.765e-06 ***
## factor(year)2017  2.41527    0.25917  9.3192 < 2.2e-16 ***
## factor(year)2018  4.66006    0.39591 11.7705 < 2.2e-16 ***
## factor(year)2019  5.05045    0.45343 11.1383 < 2.2e-16 ***
## factor(year)2020  7.86974    0.53008 14.8463 < 2.2e-16 ***
## factor(year)2021 12.61948    0.65597 19.2378 < 2.2e-16 ***
## factor(year)2022 11.84161    0.68579 17.2671 < 2.2e-16 ***
## factor(year)2023 13.37865    0.74154 18.0417 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Total Sum of Squares:    330440
## Residual Sum of Squares: 132890
## R-Squared:      0.59785
## Adj. R-Squared: 0.59489
## F-statistic: 149.872 on 9 and 154 DF, p-value: < 2.22e-16
```

```r
# Adding Lag1: SPI ~ DI
ols_spi_di_L1 <- plm(
  formula = spi_comp ~ di_score + plm::lag(di_score, 1)
  + log_gdppc
  #+ factor(income_level_recoded)
  + factor(year),
  model = "pooling",
  data = panel_data)
summary(ols_spi_di_L1, vcov = vcovHC(ols_spi_di_L1, cluster = "group", type = "HC1"))
```

```
## Pooling Model
##
## Note: Coefficient variance-covariance matrix supplied: vcovHC(ols_spi_di_L1, cluster = "group", type
##
## Call:
## plm(formula = spi_comp ~ di_score + plm::lag(di_score, 1) + log_gdppc +
##     factor(year), data = panel_data, model = "pooling")
##
## Unbalanced Panel: n = 155, T = 6-7, N = 1082
##
## Residuals:
##      Min.   1st Qu.    Median   3rd Qu.      Max.
## -32.38842  -5.21201   0.91248   6.28462  25.86064
##
## Coefficients:
##                        Estimate Std. Error t-value  Pr(>|t|)
## (Intercept)           12.49441    3.94091  3.1704  0.001565 **
## di_score               0.27964    1.56482  0.1787  0.858201
## plm::lag(di_score, 1)  3.21368    1.52475  2.1077  0.035291 *
## log_gdppc              3.55933    0.71171  5.0011 6.655e-07 ***
```

```
## factor(year)2018       2.40687    0.31168  7.7223 2.611e-14 ***
## factor(year)2019       2.66471    0.37015  7.1991 1.139e-12 ***
## factor(year)2020       5.33644    0.46283 11.5300 < 2.2e-16 ***
## factor(year)2021      10.01367    0.55913 17.9094 < 2.2e-16 ***
## factor(year)2022       9.56654    0.60823 15.7285 < 2.2e-16 ***
## factor(year)2023      10.83316    0.64972 16.6735 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Total Sum of Squares:    279550
## Residual Sum of Squares: 112770
## R-Squared:      0.59661
## Adj. R-Squared: 0.59322
## F-statistic: 128.403 on 9 and 154 DF, p-value: < 2.22e-16
```

```r
# Adding Lag2: SPI ~ DI
ols_spi_di_L2 <- plm(
  formula = spi_comp ~ di_score + plm::lag(di_score, 1) + plm::lag(di_score, 2)
  + log_gdppc
  #+ factor(income_level_recoded)
  + factor(year),
  model = "pooling",
  data = panel_data)
summary(ols_spi_di_L2, vcov = vcovHC(ols_spi_di_L2, cluster = "group", type = "HC1"))
```

```
## Pooling Model
##
## Note: Coefficient variance-covariance matrix supplied: vcovHC(ols_spi_di_L2, cluster = "group", type
##
## Call:
## plm(formula = spi_comp ~ di_score + plm::lag(di_score, 1) + plm::lag(di_score,
##     2) + log_gdppc + factor(year), data = panel_data, model = "pooling")
##
## Unbalanced Panel: n = 155, T = 5-6, N = 927
##
## Residuals:
##     Min.  1st Qu.   Median  3rd Qu.     Max.
## -32.3217  -5.2488   1.0721   6.4803  25.1165
##
## Coefficients:
##                        Estimate Std. Error t-value  Pr(>|t|)
## (Intercept)            13.46484    3.90965  3.4440 0.0005991 ***
## di_score                0.68247    1.48490  0.4596 0.6459095
## plm::lag(di_score, 1) -1.51143    0.86389 -1.7496 0.0805303 .
## plm::lag(di_score, 2)  4.25058    1.61197  2.6369 0.0085088 **
## log_gdppc              3.75030    0.71236  5.2646  1.75e-07 ***
## factor(year)2019       0.49798    0.23192  2.1472 0.0320377 *
## factor(year)2020       3.02739    0.34616  8.7457 < 2.2e-16 ***
## factor(year)2021       7.48329    0.48479 15.4360 < 2.2e-16 ***
## factor(year)2022       6.90966    0.50016 13.8148 < 2.2e-16 ***
## factor(year)2023       8.65912    0.60242 14.3739 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## Total Sum of Squares:    233500
## Residual Sum of Squares: 93657
## R-Squared:      0.5989
## Adj. R-Squared: 0.59496
## F-statistic: 116.61 on 9 and 154 DF, p-value: < 2.22e-16
```

3.1 POLS Scatterplots

General relationship between SPI and DI

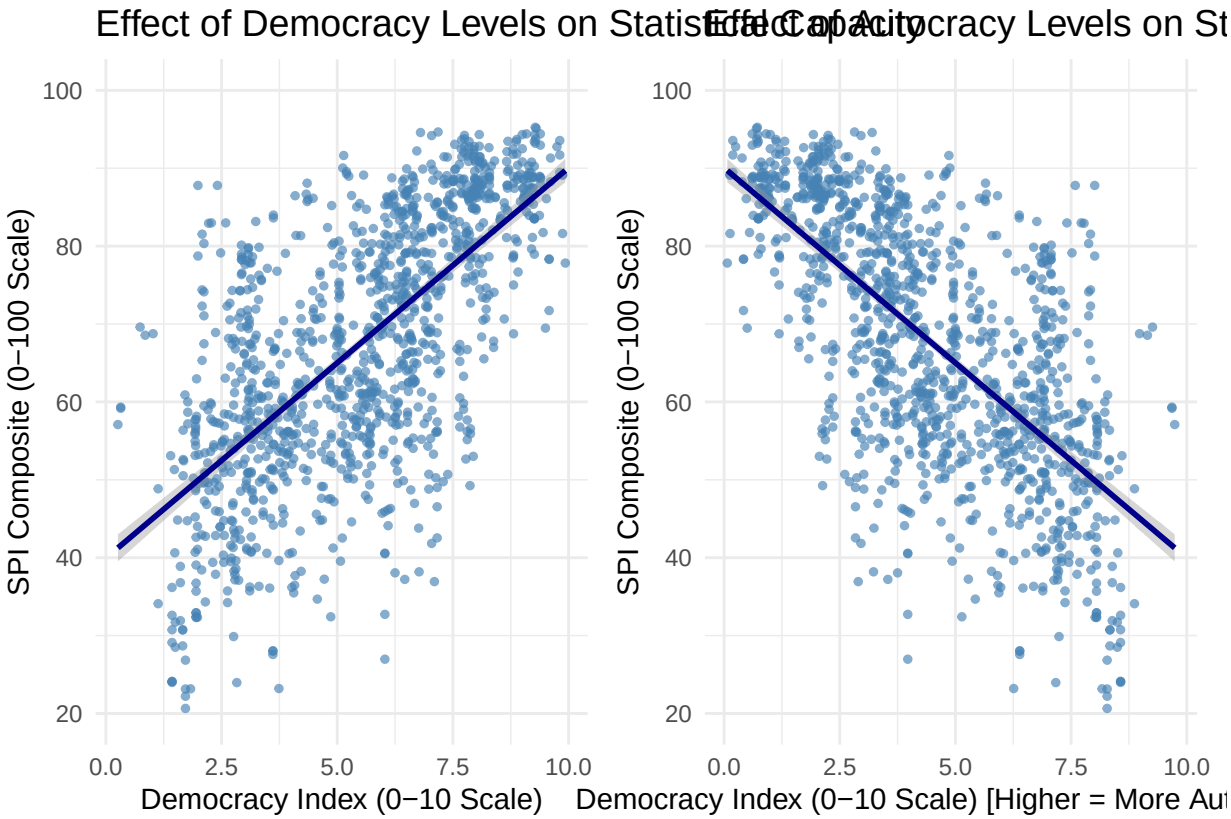
```
# Contemporaneous Relationship: SPI ~ DI
spi_di_s1_scatter <- ggplot(panel_data1, aes(x = di_score, y = spi_comp)) +
    geom_point(color = "steelblue", size = 1, alpha = 0.65) +
    geom_smooth(method = "lm", se = TRUE, color = "darkblue",
        size = 1) + labs(title = "Effect of Democracy Levels on Statistical Capacity",
    x = "Democracy Index (0-10 Scale)", y = "SPI Composite (0-100 Scale)") +
    theme_minimal() + theme(plot.title = element_text(size = 14)) +
    ylim(20, 100)

# Save to specific folder
# ggsave('figures/stage_1_n_2_scatterplots/spi_di_s1_scatterplot.png',
# spi_di_s1_scatter, width = 6, height = 8)

# Contemporaneous Relationship: SPI ~ DI_Reversed
spi_di_rev_scatter <- ggplot(panel_data1, aes(x = di_score_reverse,
    y = spi_comp)) + geom_point(color = "steelblue", size = 1,
    alpha = 0.65) + geom_smooth(method = "lm", se = TRUE, color = "darkblue",
    size = 1) + labs(title = "Effect of Autocracy Levels on Statistical Capacity (reversed DI)",
    x = "Democracy Index (0-10 Scale) [Higher = More Autocratic]",
    y = "SPI Composite (0-100 Scale)") + theme_minimal() + theme(plot.title = element_text(size = 14)) +
    # adjust y axis to start from y = 10
ylim(20, 100)

# Save to specific folder
# ggsave('figures/stage_1_n_2_scatterplots/spi_di_rev_scatter.png',
# spi_di_rev_scatter, width = 6, height = 8)

# side by side comparison using patchwork
library(patchwork)
spi_di_s1_scatter + spi_di_rev_scatter + plot_layout(ncol = 2)
```




```
# ggsave('figures/stage_1_n_2_scatterplots/spi_di_s1_scatterplots.png',
# width = 12, height = 8)
```

3.2 POLS Summary Table

4 1.2) First Difference [Stage 1]: SPI ~ DI

```
# Contemporaneous Effect: SPI ~ DI
fd_spi_di <- plm(
  formula = spi_comp ~ di_score
  + log_gdppc,
  #+ factor(income_level_recoded),
  #+ factor(year),
  data = fd_data,
  model = "fd"
)
summary(fd_spi_di, vcov = vcovHC(fd_spi_di, cluster = "group", type = "HC1"))
```

```
## Oneway (individual) effect First-Difference Model
##
## Note: Coefficient variance-covariance matrix supplied: vcovHC(fd_spi_di, cluster = "group", type = "
##
## Call:
## plm(formula = spi_comp ~ di_score + log_gdppc, data = fd_data,
```

```
##     model = "fd")
##
## Unbalanced Panel: n = 155, T = 6-8, N = 1234
## Observations used in estimation: 1079
##
## Residuals:
##      Min.   1st Qu.    Median   3rd Qu.      Max.
## -10.76962  -1.97302  -0.53025   1.73174  14.87242
##
## Coefficients:
##              Estimate Std. Error t-value  Pr(>|t|)
## (Intercept)  1.763329   0.093767 18.8055 < 2.2e-16 ***
## di_score    -0.703689   0.333219 -2.1118  0.034934 *
## log_gdppc    2.466664   0.841780  2.9303  0.003458 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Total Sum of Squares:    11236
## Residual Sum of Squares: 11129
## R-Squared:      0.009438
## Adj. R-Squared: 0.0075968
## F-statistic: 5.91662 on 2 and 154 DF, p-value: 0.0033449
```

```r
# Adding Lag1: SPI ~ DI
fd_spi_di_L1 <- plm(
  formula = spi_comp ~ di_score + plm::lag(di_score, 1)
  + log_gdppc,
  #+ factor(income_level_recoded),
  #+ factor(year),
  data = fd_data,
  model = "fd"
)
summary(fd_spi_di_L1, vcov = vcovHC(fd_spi_di_L1, cluster = "group", type = "HC1"))
```

```
## Oneway (individual) effect First-Difference Model
##
## Note: Coefficient variance-covariance matrix supplied: vcovHC(fd_spi_di_L1, cluster = "group", type =
##
## Call:
## plm(formula = spi_comp ~ di_score + plm::lag(di_score, 1) + log_gdppc,
##     data = fd_data, model = "fd")
##
## Unbalanced Panel: n = 155, T = 5-7, N = 1079
## Observations used in estimation: 924
##
## Residuals:
##      Min.   1st Qu.    Median   3rd Qu.      Max.
## -10.89959  -1.93429  -0.53814   1.66731  14.83495
##
## Coefficients:
##                         Estimate Std. Error t-value Pr(>|t|)
## (Intercept)             1.630254   0.098787 16.5027  < 2e-16 ***
## di_score               -0.817510   0.354976 -2.3030  0.02150 *
## plm::lag(di_score, 1) -0.620626   0.379412 -1.6358  0.10223
```

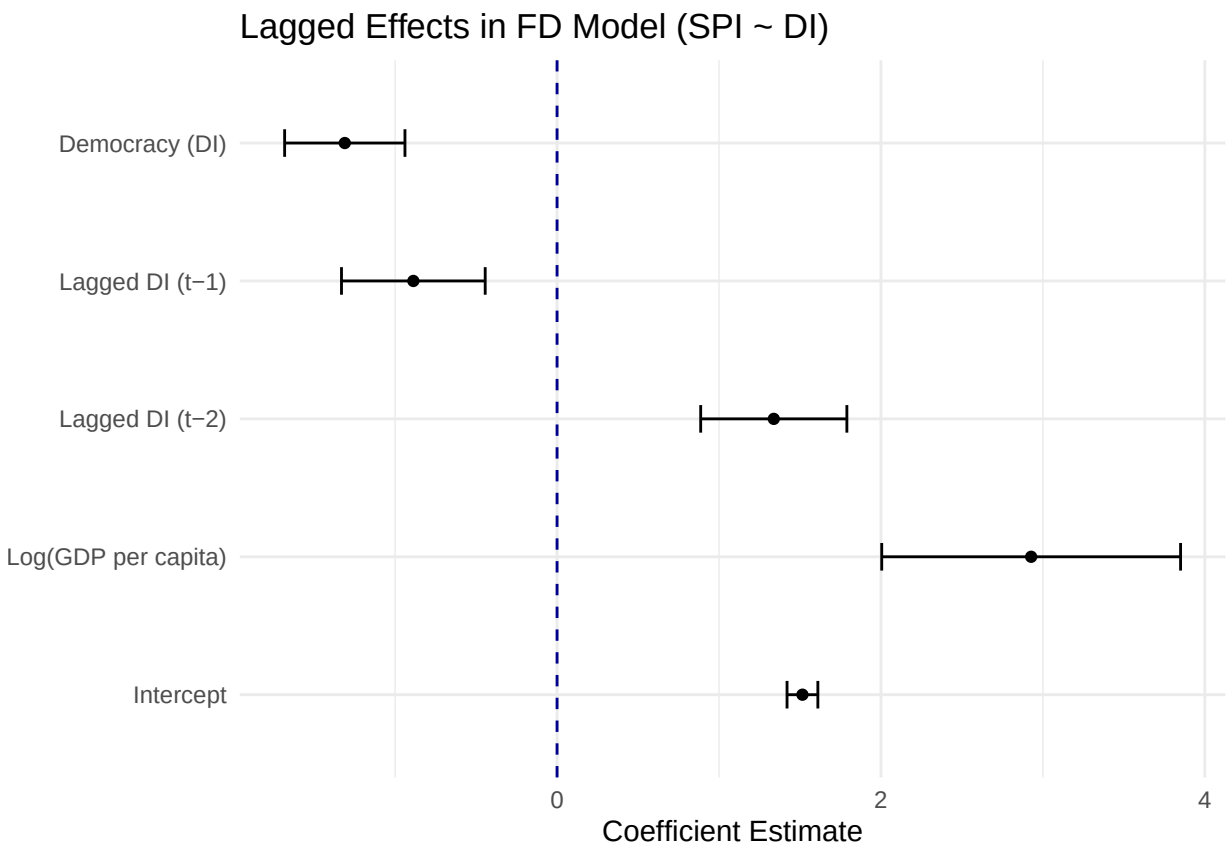
```
## log_gdppc              2.352569   1.000289  2.3519  0.01889 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Total Sum of Squares:    10003
## Residual Sum of Squares: 9881.1
## R-Squared:      0.012168
## Adj. R-Squared: 0.0089467
## F-statistic: 5.86215 on 3 and 154 DF, p-value: 0.00081221
```

```r
# Adding Lag2: SPI ~ DI
fd_spi_di_L2 <- plm(
  formula = spi_comp ~ di_score + plm::lag(di_score, 1) + plm::lag(di_score, 2)
  + log_gdppc,
  #+ factor(income_level_recoded),
  #+ factor(year),
  data = fd_data,
  model = "fd"
)
summary(fd_spi_di_L2, vcov = vcovHC(fd_spi_di_L2, cluster = "group", type = "HC1"))
```

```
## Oneway (individual) effect First-Difference Model
##
## Note: Coefficient variance-covariance matrix supplied: vcovHC(fd_spi_di_L2, cluster = "group", type =
##
## Call:
## plm(formula = spi_comp ~ di_score + plm::lag(di_score, 1) + plm::lag(di_score,
##     2) + log_gdppc, data = fd_data, model = "fd")
##
## Unbalanced Panel: n = 155, T = 4-6, N = 924
## Observations used in estimation: 769
##
## Residuals:
##      Min.   1st Qu.    Median   3rd Qu.      Max.
## -10.64368  -1.84234  -0.44069   1.57447  15.82469
##
## Coefficients:
##                         Estimate Std. Error t-value  Pr(>|t|)
## (Intercept)             1.515191   0.095169 15.9211 < 2.2e-16 ***
## di_score               -1.310760   0.371455 -3.5287 0.0004425 ***
## plm::lag(di_score, 1) -0.887450   0.443631 -2.0004 0.0458079 *
## plm::lag(di_score, 2)  1.338215   0.451396  2.9646 0.0031249 **
## log_gdppc              2.927504   0.922686  3.1728 0.0015701 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Total Sum of Squares:    7724.4
## Residual Sum of Squares: 7458.6
## R-Squared:      0.03441
## Adj. R-Squared: 0.029354
## F-statistic: 8.5748 on 4 and 154 DF, p-value: 2.8353e-06
```

4.1 First Difference Error Bar Visualization

```
# Extract coefficients and robust standard errors from the
# FD model
fd_spi_di_L2_results <- summary(fd_spi_di_L2, vcov = vcovHC(fd_spi_di_L2,
    cluster = "group", type = "HC1"))
# Create a data frame for visualization
coef_fd_df <- data.frame(term = rownames(fd_spi_di_L2_results$coefficients),
    estimate = fd_spi_di_L2_results$coefficients[, "Estimate"],
    std.error = fd_spi_di_L2_results$coefficients[, "Std. Error"])
# Create a ggplot error bar chart
ebar_fd <- ggplot(coef_fd_df, aes(x = term, y = estimate)) +
    geom_point() + geom_errorbar(aes(ymin = estimate - std.error,
    ymax = estimate + std.error), width = 0.2) + labs(title = "Lagged Effects in FD Model (SPI ~ DI)",
    x = NULL, y = "Coefficient Estimate") + theme_minimal() +
    coord_flip() + geom_hline(yintercept = 0, linetype = "dashed",
    color = "darkblue") + scale_x_discrete(labels = c(di_score = "Democracy (DI)",
    `plm::lag(di_score, 1)` = "Lagged DI (t-1)", `plm::lag(di_score, 2)` = "Lagged DI (t-2)",
    log_gdppc = "Log(GDP per capita)", `(Intercept)` = "Intercept"),
    limits = c("(Intercept)", "log_gdppc", "plm::lag(di_score, 2)",
        "plm::lag(di_score, 1)", "di_score"))
ebar_fd
```




```
# Save the plot
# ggsave('component_2/figures/stage1/error_bar_fd_spi_di_L2.png',
# ebar_fd, width = 10, height = 6)
```

4.2 First Difference Summary Table

5 1.3) Fixed Effects [Stage 1]: SPI ~ DI

```
# Contemporaneous Effect: SPI ~ DI
fe_spi_di <- plm(
  formula = spi_comp ~ di_score
  + log_gdppc
  #+ factor(income_level_recoded)
  + factor(year),
  data = panel_data,
  model = "within")
summary(fe_spi_di, vcov = vcovHC(fe_spi_di, cluster = "group", type = "HC1"))
```

```
## Oneway (individual) effect Within Model
##
## Note: Coefficient variance-covariance matrix supplied: vcovHC(fe_spi_di, cluster = "group", type = "
##
## Call:
## plm(formula = spi_comp ~ di_score + log_gdppc + factor(year),
##     data = panel_data, model = "within")
##
## Unbalanced Panel: n = 155, T = 6-8, N = 1234
##
## Residuals:
##       Min.    1st Qu.     Median    3rd Qu.       Max.
## -15.599271  -2.012044   0.026745   2.034042  15.044393
##
## Coefficients:
##                   Estimate Std. Error t-value Pr(>|t|)
## di_score         -0.098521   0.550666 -0.1789   0.8580
## log_gdppc         0.614503   1.732569  0.3547   0.7229
## factor(year)2017  2.537886   0.260767  9.7324   <2e-16 ***
## factor(year)2018  4.977623   0.447103 11.1331   <2e-16 ***
## factor(year)2019  5.257074   0.498000 10.5564   <2e-16 ***
## factor(year)2020  7.600929   0.536622 14.1644   <2e-16 ***
## factor(year)2021 12.349788   0.721917 17.1069   <2e-16 ***
## factor(year)2022 11.804139   0.790076 14.9405   <2e-16 ***
## factor(year)2023 12.952828   0.867039 14.9392   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Total Sum of Squares:    38471
## Residual Sum of Squares: 12811
## R-Squared:      0.66699
## Adj. R-Squared: 0.61626
## F-statistic: 77.6701 on 9 and 154 DF, p-value: < 2.22e-16
```

```
# Adding Lag1: SPI ~ DI
fe_spi_di_L1 <- plm(
  formula = spi_comp ~ di_score + plm::lag(di_score, 1)
```

```
  + log_gdppc
  #+ factor(income_level_recoded)
  + factor(year),
  data = panel_data,
  model = "within")
summary(fe_spi_di_L1, vcov = vcovHC(fe_spi_di_L1, cluster = "group", type = "HC1"))
```

```
## Oneway (individual) effect Within Model
##
## Note: Coefficient variance-covariance matrix supplied: vcovHC(fe_spi_di_L1, cluster = "group", type =
##
## Call:
## plm(formula = spi_comp ~ di_score + plm::lag(di_score, 1) + log_gdppc +
##     factor(year), data = panel_data, model = "within")
##
## Unbalanced Panel: n = 155, T = 6-7, N = 1082
##
## Residuals:
##       Min.    1st Qu.     Median    3rd Qu.       Max.
## -14.330754  -1.686187   0.042262   1.814537  13.057740
##
## Coefficients:
##                       Estimate Std. Error t-value  Pr(>|t|)
## di_score              -0.30937    0.52763 -0.5863    0.5578
## plm::lag(di_score, 1)  0.15005    0.51773  0.2898    0.7720
## log_gdppc              0.38938    1.60487  0.2426    0.8083
## factor(year)2018       2.46051    0.31754  7.7487 2.455e-14 ***
## factor(year)2019       2.73176    0.38172  7.1565 1.693e-12 ***
## factor(year)2020       5.04823    0.44937 11.2340 < 2.2e-16 ***
## factor(year)2021       9.81600    0.57936 16.9428 < 2.2e-16 ***
## factor(year)2022       9.30148    0.63101 14.7405 < 2.2e-16 ***
## factor(year)2023      10.45690    0.68905 15.1759 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Total Sum of Squares:    25920
## Residual Sum of Squares: 9413.8
## R-Squared:      0.63681
## Adj. R-Squared: 0.57232
## F-statistic: 64.242 on 9 and 154 DF, p-value: < 2.22e-16
```

```
# Adding Lag2: SPI ~ DI
fe_spi_di_L2 <- plm(
  formula = spi_comp ~ di_score + plm::lag(di_score, 1) + plm::lag(di_score, 2)
  + log_gdppc
  #+ factor(income_level_recoded)
  + factor(year),
  data = panel_data,
  model = "within")
summary(fe_spi_di_L2, vcov = vcovHC(fe_spi_di_L2, cluster = "group", type = "HC1"))
```

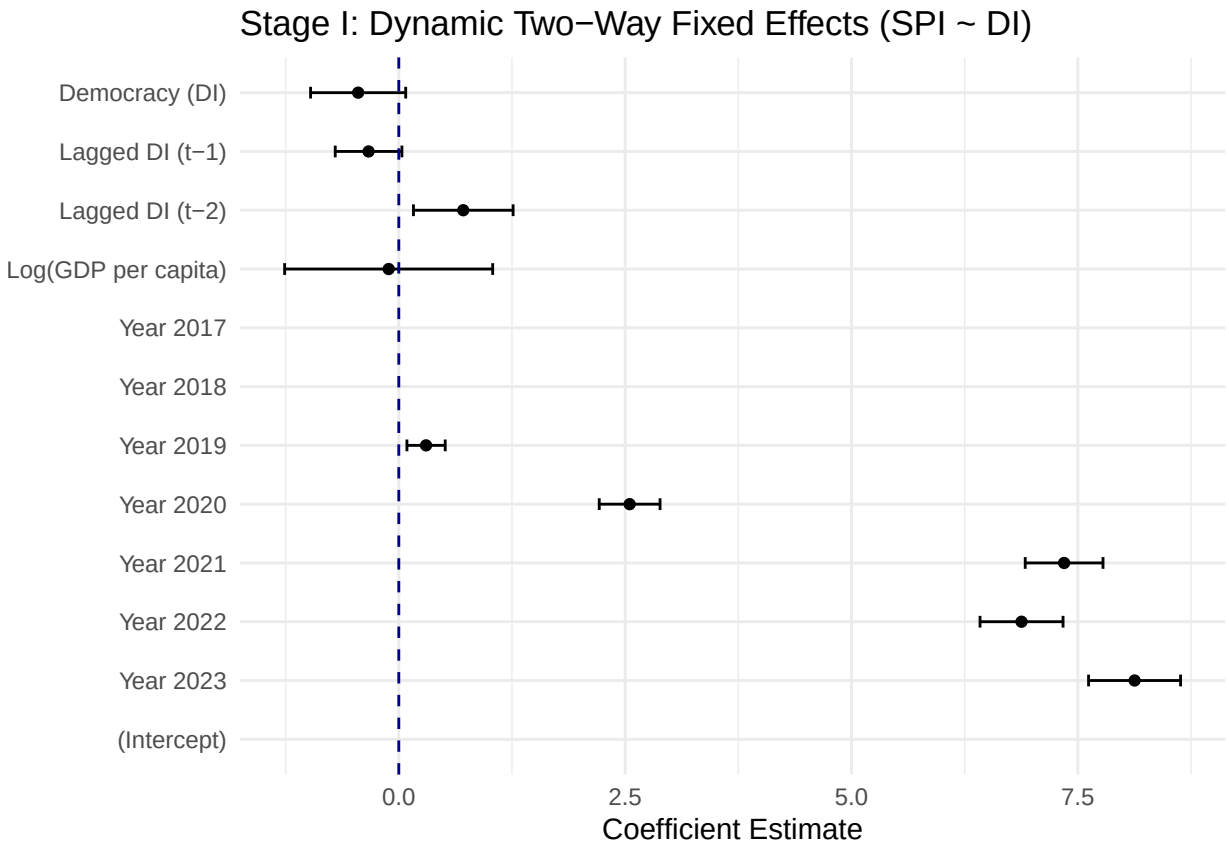
```
## Oneway (individual) effect Within Model
##
```

```
## Note: Coefficient variance-covariance matrix supplied: vcovHC(fe_spi_di_L2, cluster = "group", type =
##
## Call:
## plm(formula = spi_comp ~ di_score + plm::lag(di_score, 1) + plm::lag(di_score,
##     2) + log_gdppc + factor(year), data = panel_data, model = "within")
##
## Unbalanced Panel: n = 155, T = 5-6, N = 927
##
## Residuals:
##       Min.    1st Qu.     Median    3rd Qu.       Max.
## -12.253528  -1.371080  -0.066626   1.562429  10.444775
##
## Coefficients:
##                       Estimate Std. Error t-value  Pr(>|t|)
## di_score              -0.44904    0.52526 -0.8549    0.3929
## plm::lag(di_score, 1) -0.33377    0.36824 -0.9064    0.3650
## plm::lag(di_score, 2)  0.71220    0.55023  1.2944    0.1959
## log_gdppc             -0.11182    1.14894 -0.0973    0.9225
## factor(year)2019       0.30110    0.21130  1.4250    0.1546
## factor(year)2020       2.54965    0.33585  7.5916 9.234e-14 ***
## factor(year)2021       7.34821    0.42952 17.1081 < 2.2e-16 ***
## factor(year)2022       6.87782    0.45847 15.0017 < 2.2e-16 ***
## factor(year)2023       8.12648    0.50809 15.9940 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Total Sum of Squares:    16634
## Residual Sum of Squares: 6022.2
## R-Squared:      0.63797
## Adj. R-Squared: 0.56063
## F-statistic: 57.9356 on 9 and 154 DF, p-value: < 2.22e-16
```

5.1 Fixed Effects Error Bar Visualization

```r
# Extract coefficients and robust standard errors from the FE model
fe_spi_di_L2_results <- summary(fe_spi_di_L2, vcov = vcovHC(fe_spi_di_L2, cluster = "group", type = "HC
# Create a data frame for visualization
coef_df <- data.frame(
  term = rownames(fe_spi_di_L2_results$coefficients),
  estimate = fe_spi_di_L2_results$coefficients[, "Estimate"],
  std.error = fe_spi_di_L2_results$coefficients[, "Std. Error"]
)
# Create a ggplot error bar chart
ebar_fe <- ggplot(coef_df, aes(x = term, y = estimate)) +
  geom_point() +
  geom_errorbar(aes(ymin = estimate - std.error, ymax = estimate + std.error), width = 0.2) +
  labs(title = "Stage I: Dynamic Two-Way Fixed Effects (SPI ~ DI)",
       x = NULL,
       y = "Coefficient Estimate") +
  theme_minimal() +
  coord_flip() +  # Flip coordinates for better readability
  geom_hline(yintercept = 0, linetype = "dashed", color = "darkblue") +
```

```
  # re-labeling x variable lables
  scale_x_discrete(labels = c("di_score" = "Democracy (DI)",
                              "plm::lag(di_score, 1)" = "Lagged DI (t-1)",
                              "plm::lag(di_score, 2)" = "Lagged DI (t-2)",
                              "log_gdppc" = "Log(GDP per capita)",
                              "factor(year)2017" = "Year 2017",
                              "factor(year)2018" = "Year 2018",
                              "factor(year)2019" = "Year 2019",
                              "factor(year)2020" = "Year 2020",
                              "factor(year)2021" = "Year 2021",
                              "factor(year)2022" = "Year 2022",
                              "factor(year)2023" = "Year 2023",
                              "Intercept" = "Intercept"
                              ),
                   limits = c(
                   "(Intercept)",
                   "factor(year)2023",
                   "factor(year)2022",
                   "factor(year)2021",
                   "factor(year)2020",
                   "factor(year)2019",
                   "factor(year)2018",
                   "factor(year)2017",
                   "log_gdppc",
                   "plm::lag(di_score, 2)",
                   "plm::lag(di_score, 1)",
                   "di_score"
                  ))
ebar_fe
```




```
# Save the plot
#ggsave("component_2/figures/stage1/error_bar_fe_spi_di_L2.png", ebar_fe, width = 10, height = 6)
```

5.2 Fixed Effects Summary Table

5.2.1 stargazer table for only lag2 models

5.3 Check for Autocorrelation

```
# APPLY Wooldridge Test for AR(1) Errors in FE Panel
# Models: pwartest()
# https://search.r-project.org/CRAN/refmans/plm/html/pwartest.html
# This is MUCH BETTER for panel data with small T AND
# unbalanced panels!!!
pwartest(fe_spi_di_L2)  # [significant]
```

```
##
##  Wooldridge's test for serial correlation in FE panels
##
## data:  fe_spi_di_L2
## F = 322.27, df1 = 1, df2 = 770, p-value < 2.2e-16
## alternative hypothesis: serial correlation
```

Significant p-value indicates the presence of autocorrelation in the residuals of the fixed effects model. This suggests that the errors are correlated over time, which violates one of the key assumptions of linear regression models.

This is corrected by using robust standard errors clustered by country, which accounts for the potential autocorrelation in the residuals.

5.4 Check for Heteroskedasticity

```
# Apply Breusch-Pagan test for heteroskedasticity
bptest(fe_spi_di_L2, studentize = TRUE)  # Heteroskedasticity [significant]
```

```
##
##  studentized Breusch-Pagan test
##
## data:  fe_spi_di_L2
## BP = 64.177, df = 9, p-value = 2.085e-10
```

```
bptest(fd_spi_di_L2, studentize = TRUE)  # Heteroskedasticity [significant]
```

```
##
##  studentized Breusch-Pagan test
##
## data:  fd_spi_di_L2
## BP = 62.537, df = 4, p-value = 8.495e-13
```

The Breusch-Pagan test indicates the presence of heteroskedasticity in the residuals of the fixed effects model. This suggests that the variance of the errors is not constant across observations, which violates another key assumption of linear regression models.