

Gov 50: 15. Multiple Regression and Interpretation

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Roadmap

1. Multiple regression
2. Categorical independent variables

1/ Multiple regression

Multiple predictors

What if we want to predict Y as a function of many variables?

$$\text{seat_change}_i = \alpha + \beta_1 \text{approval}_i + \beta_2 \text{rdi_change}_i + \epsilon_i$$

Why?

- Better predictions (at least in-sample).
- Better interpretation as **ceteris paribus** relationships:
 - β_1 is the relationship between approval and seat_change holding rdi_change constant.
 - **Statistical control** in a cross-sectional study.

Multiple regression in R

```
mult.fit <- lm(seat_change ~ approval + rdi_change,  
               data = midterms)  
mult.fit
```

```
##  
## Call:  
## lm(formula = seat_change ~ approval + rdi_change, data = midterms)  
##  
## Coefficients:  
## (Intercept)      approval      rdi_change  
##      -117.23           1.53           3.22
```

- $\hat{\alpha} = -117.2$: average seat change president has 0% approval and no change in income levels.
- $\hat{\beta}_1 = 1.53$: average increase in seat change for additional percentage point of approval, **holding RDI change fixed**
- $\hat{\beta}_2 = 3.217$: average increase in seat change for each additional percentage point increase of RDI, **holding approval fixed**

Least squares with multiple regression

- How do we estimate the coefficients?
- The same exact way as before: minimize prediction error!
- Residuals (aka prediction error) with multiple predictors:

$$Y_i - \hat{Y}_i = \text{seat_change}_i - \hat{\alpha} - \hat{\beta}_1 \text{approval}_i - \hat{\beta}_2 \text{rdi_change}_i$$

- Find the coefficients that minimizes the **sum of the squared residuals**:

$$\text{SSR} = \sum_{i=1}^n \hat{\epsilon}_i^2 = (Y_i - \hat{\alpha} - \hat{\beta}_1 X_{i1} - \hat{\beta}_2 X_{i2})^2$$

Model fit with multiple predictors

- R^2 mechanically increases when you add a variables to the regression.
 - But this could be overfitting!!
- Solution: penalize regression models with more variables.
 - Occam's razor: **simpler models are preferred**
- Adjusted R^2 : lowers regular R^2 for each additional covariate.
 - If the added covariates doesn't help predict, adjusted R^2 goes down!

Comparing model fits

```
library(broom)
fit.app <- lm(seat_change ~ approval, data = midterms)
glance(fit.app) |>
  select(r.squared, adj.r.squared, sigma)
```

```
## # A tibble: 1 x 3
##   r.squared adj.r.squared sigma
##   <dbl>      <dbl> <dbl>
## 1    0.450      0.418  16.9
```

```
glance(mult.fit) |>
  select(r.squared, adj.r.squared, sigma)
```

```
## # A tibble: 1 x 3
##   r.squared adj.r.squared sigma
##   <dbl>      <dbl> <dbl>
## 1    0.468      0.397  16.7
```


Predicted values from R

We could plug in values into the equation, but R can do this for us. The `{modelr}` package gives some functions that allow us to predictions in a tidy way:

Let's use `add_predictions()` to predict the 2022 results

```
library(modelr)

midterms |>
  filter(year == 2022) |>
  add_predictions(mult.fit)

## # A tibble: 1 x 7
##   year president party approval seat_change rdi_change
##   <dbl> <chr>      <chr>    <dbl>      <dbl>      <dbl>
## 1  2022 Biden      D         42         NA        -0.003
## # i 1 more variable: pred <dbl>
```

Predictions from several models

The `gather_predictions()` will return one row for each model passed to it with the prediction for that model:

```
midterms |>
  filter(year == 2022) |>
  gather_predictions(fit.app, mult.fit)
```

```
## # A tibble: 2 x 8
##   model      year president party approval seat_change
##   <chr>    <dbl> <chr>    <chr>    <dbl>    <dbl>
## 1 fit.app  2022 Biden      D         42        NA
## 2 mult.fit 2022 Biden      D         42        NA
## # i 2 more variables: rdi_change <dbl>, pred <dbl>
```

Predictions from new data

What about predicted values not in data?

```
tibble(approval = c(50, 75), rdi_change = 0) |>  
  gather_predictions(fit.app, mult.fit)
```

```
## # A tibble: 4 x 4  
##   model      approval rdi_change    pred  
##   <chr>         <dbl>      <dbl>  <dbl>  
## 1 fit.app         50          0 -25.6  
## 2 fit.app         75          0  9.92  
## 3 mult.fit        50          0 -40.9  
## 4 mult.fit        75          0 -2.79
```

Predictions from `augment()`

We can also get predicted values from the `augment()` function using the `newdata` argument:

```
newdata <- tibble(approval = c(50, 75), rdi_change = 0)

augment(mult.fit, newdata = newdata)
```

```
## # A tibble: 2 x 3
##   approval rdi_change .fitted
##   <dbl>      <dbl>    <dbl>
## 1      50          0   -40.9
## 2      75          0    -2.79
```

2/ Categorical independent variables

Political effects of gov't programs



- *Progesa*: Mexican conditional cash transfer program (CCT) from ~2000
 - Welfare \$\$ given if kids enrolled in schools, get regular check-ups, etc.
- Do these programs have political effects?
 - Program had support from most parties.
 - Was implemented in a nonpartisan fashion.
 - Would the incumbent presidential party be rewarded?

The data

- Randomized roll-out of the CCT program:
 - treatment: receive CCT 21 months before 2000 election
 - control: receive CCT 6 months before 2000 election
- Does having CCT longer mobilize voters for incumbent PRI party?

Name	Description
treatment	early Progresa (1) or late Progresa (0)
pri2000s	PRI votes in the 2000 election as a share of adults in precinct
t2000	turnout in the 2000 election as share of adults in precinct

```
library(qss)
data("progres", package = "qss")
cct <- as_tibble(progres) |>
  select(treatment, pri2000s, t2000)
cct
```

```
## # A tibble: 417 x 3
##   treatment pri2000s t2000
##   <int>      <dbl> <dbl>
## 1         1      40.8  55.8
## 2         1      22.4  31.2
## 3         1      38.9  47.0
## 4         1      31.2  45.0
## 5         0      76.9 100
## 6         0      23.9  37.4
## 7         1      47.3  64.9
## 8         1      21.4  58.1
## 9         1      56.5  71.3
## 10        1      36.6  51.2
## # i 407 more rows
```


Difference in means estimates

Does CCT affect turnout?

```
cct |> group_by(treatment) |>
  summarize(t2000 = mean(t2000)) |>
  pivot_wider(names_from = treatment, values_from = t2000) |>
  mutate(ATE = `1` - `0`)
```

```
## # A tibble: 1 x 3
##   `0`   `1`   ATE
##   <dbl> <dbl> <dbl>
## 1  63.8  68.1  4.27
```

Does CCT affect PRI (incumbent) votes?

```
cct |> group_by(treatment) |>
  summarize(pri2000s = mean(pri2000s)) |>
  pivot_wider(names_from = treatment, values_from = pri2000s) |>
  mutate(ATE = `1` - `0`)
```

```
## # A tibble: 1 x 3
##   `0`   `1`   ATE
##   <dbl> <dbl> <dbl>
## 1  34.5  38.1  3.62
```

Binary independent variables

$$Y_i = \alpha + \beta X_i + \varepsilon_i$$

- When independent variable X_i is **binary**:
 - Intercept $\hat{\alpha}$ is the average outcome in the $X = 0$ group.
 - Slope $\hat{\beta}$ is the difference-in-means of Y between $X = 1$ group and $X = 0$ group.

$$\hat{\beta} = \overline{Y}_{\text{treated}} - \overline{Y}_{\text{control}}$$

- If there are other independent variables, this becomes the difference-in-means controlling for those covariates.

Linear regression for experiments

- Under **randomization**, we can estimate the ATE with regression:

```
cct |> group_by(treatment) |>
  summarize(pri2000s = mean(pri2000s)) |>
  pivot_wider(names_from = treatment, values_from = pri2000s) |>
  mutate(ATE = `1` - `0`)
```

```
## # A tibble: 1 x 3
##   `0`   `1`   ATE
##   <dbl> <dbl> <dbl>
## 1  34.5  38.1  3.62
```

```
lm(pri2000s ~ treatment, data = cct) |> coef()
```

```
## (Intercept)   treatment
##      34.49         3.62
```

Categorical variables in regression

- We often have **categorical variables**:
 - Race/ethnicity: white, Black, Latino, Asian.
 - Partisanship: Democrat, Republican, Independent
- Strategy for including in a regression: create a **series of binary variables**

Unit	Party	Democrat	Republican	Independent
1	Democrat	1	0	0
2	Democrat	1	0	0
3	Independent	0	0	1
4	Republican	0	1	0
⋮	⋮	⋮	⋮	⋮

- Then include **all but one** of these binary variables:

$$\text{turnout}_i = \alpha + \beta_1 \text{Republican}_i + \beta_2 \text{Independent}_i + \varepsilon_i$$

Interpreting categorical variables

$$\text{turnout}_i = \alpha + \beta_1 \text{Republican}_i + \beta_2 \text{Independent}_i + \varepsilon_i$$

- $\hat{\alpha}$: average outcome in the **omitted group/baseline** (Democrats).
- $\hat{\beta}$ coefficients: average difference between each group and the baseline.
 - $\hat{\beta}_1$: average difference in turnout between Republicans and Democrats
 - $\hat{\beta}_2$: average difference in turnout between Independents and Democrats

CCES data

```
library(gov50data)
cces_2020
```

```
## # A tibble: 51,551 x 6
##   gender race  educ          pid3 turnout_self pres_vote
##   <fct>  <fct> <fct>          <fct>         <dbl> <fct>
## 1 Male   White 2-year    Repu~             1 Donald J~
## 2 Female White Post-grad Demo~            NA <NA>
## 3 Female White 4-year    Inde~             1 Joe Bide~
## 4 Female White 4-year    Demo~             1 Joe Bide~
## 5 Male   White 4-year    Inde~             1 Other
## 6 Male   White Some college Repu~             1 Donald J~
## 7 Male   Black Some college Not ~            NA <NA>
## 8 Female White Some college Inde~             1 Donald J~
## 9 Female White High school gr~ Repu~             1 Donald J~
## 10 Female White 4-year    Demo~             1 Joe Bide~
## # i 51,541 more rows
```

Categorical variables in the CCES data

```
turnout_pred <- lm(turnout_self ~ pid3, data = cces_2020)
turnout_pred
```

```
##
## Call:
## lm(formula = turnout_self ~ pid3, data = cces_2020)
##
## Coefficients:
##      (Intercept)  pid3Republican  pid3Independent
##           0.9635          -0.0103           -0.0394
##      pid3Other    pid3Not sure
##      -0.0066          -0.3331
```

What R does internally with factor variables in `lm`

```
cces_2020 |> drop_na(turnout_self, pid3) |> select(pid3) |> pull() |>
head()
```

```
## [1] Republican Independent Democrat Independent
## [5] Republican Independent
## 7 Levels: Democrat Republican Independent ... not asked
```

```
model.matrix(turnout_pred) |>
head()
```

```
##      (Intercept) pid3Republican pid3Independent pid3Other
## 1              1              1              0          0
## 3              1              0              1          0
## 4              1              0              0          0
## 5              1              0              1          0
## 6              1              1              0          0
## 8              1              0              1          0
## pid3Not sure
## 1              0
## 3              0
## 4              0
## 5              0
## 6              0
```