Difference in differences: A methodological illustration

Meghan K. Cain, Ph.D.

StataCorp, LLC

MMM 2023

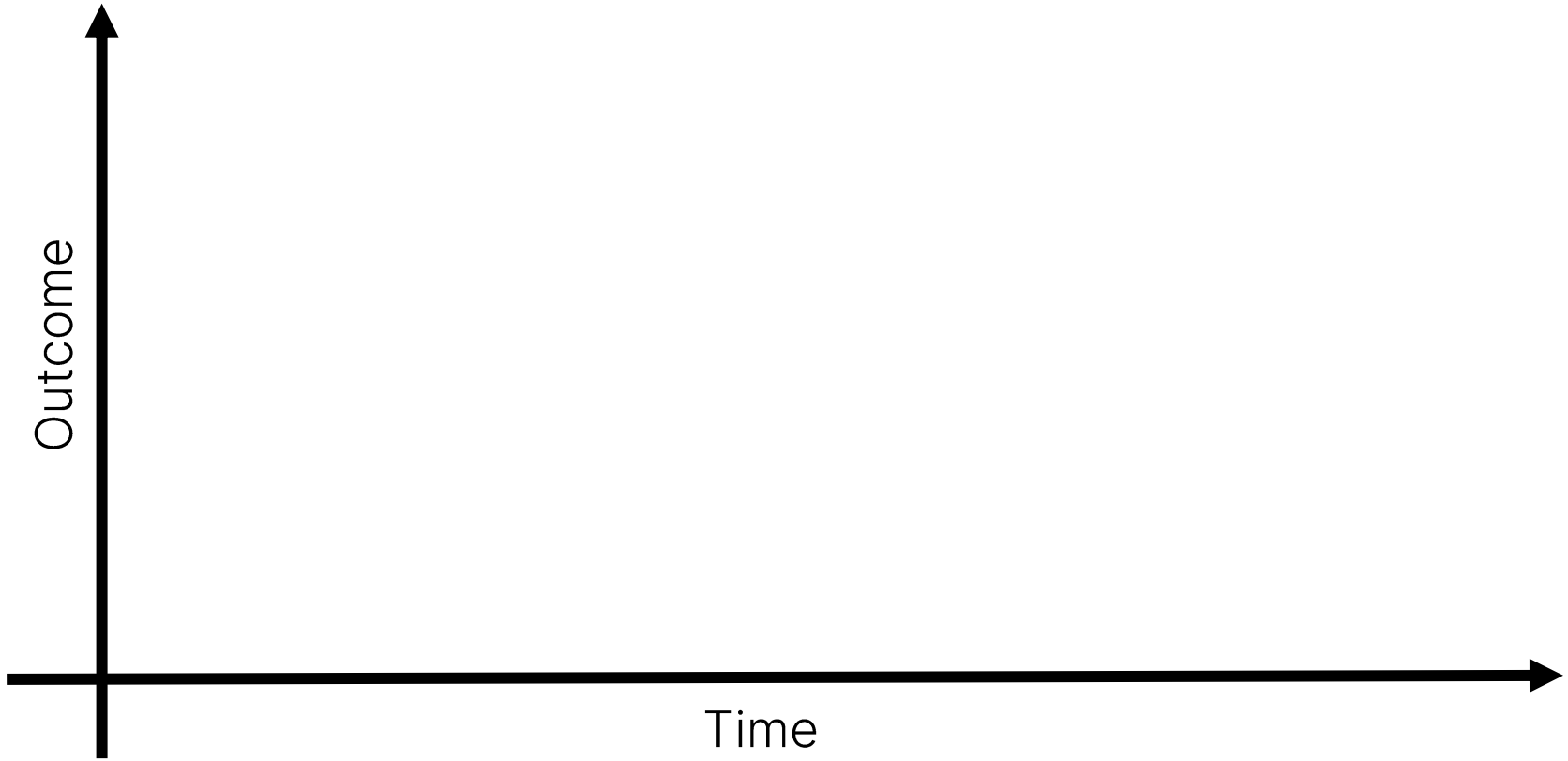
Outline

- Conceptual introduction
- Motivating example
- Difference-in-differences analysis
  - Model formulation
  - Standard errors
  - Diagnostics
- Heterogeneous difference in differences
  - Model formulation
  - Aggregating results
  - Diagnostics

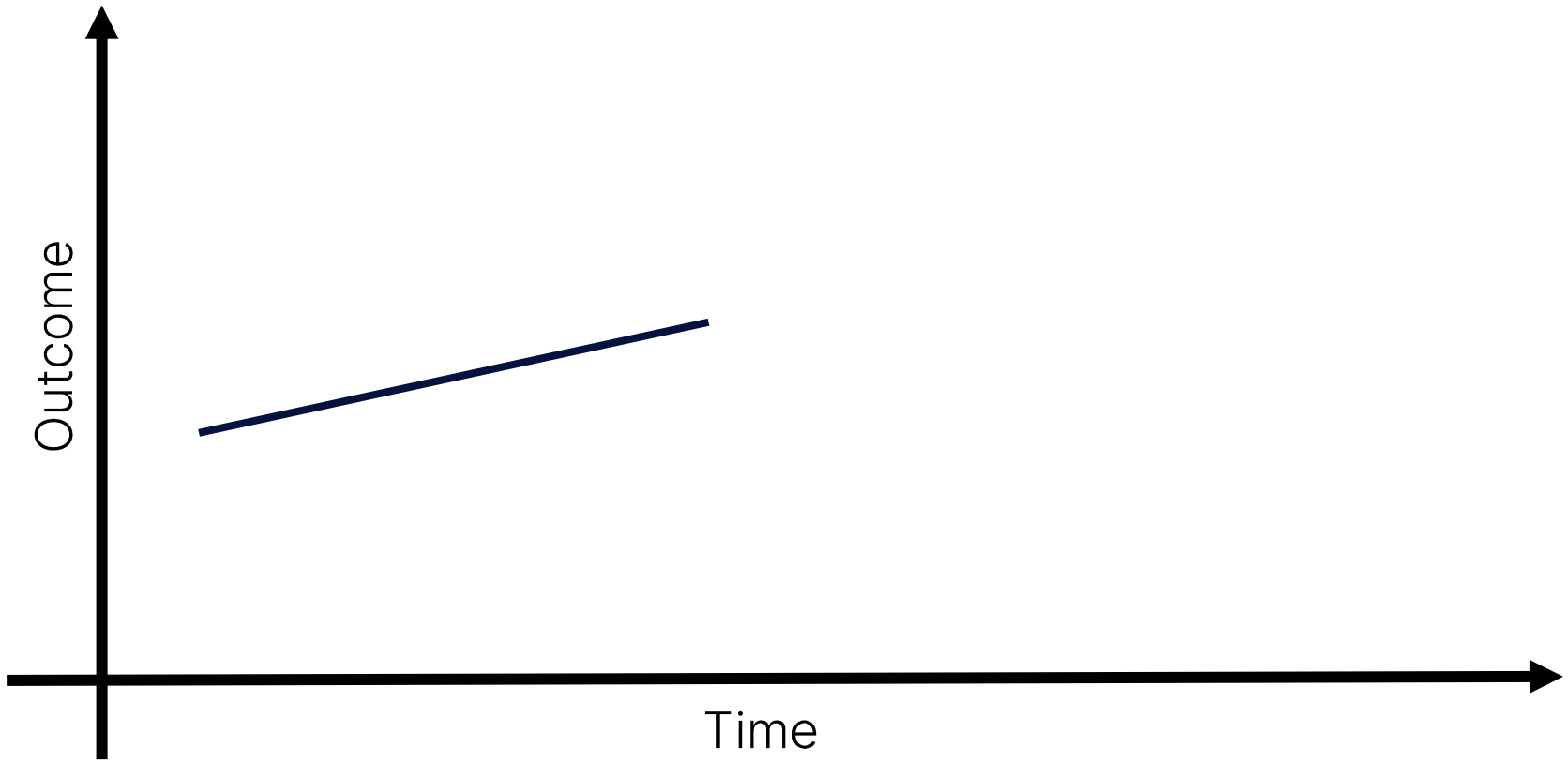
What is difference in differences?

- Difference in differences (DID) is a causal inference method derived using the potential-outcomes framework.
- The intervention “treatment” variable can be binary or continuous.
- It estimates the average treatment effect on the treated (ATET) in a quasi-experimental pre/post design.
- ATETs can be homogenous or heterogeneous.
- DID can be applied to two types of observational data:
  - Repeated cross-sectional data
  - Panel data

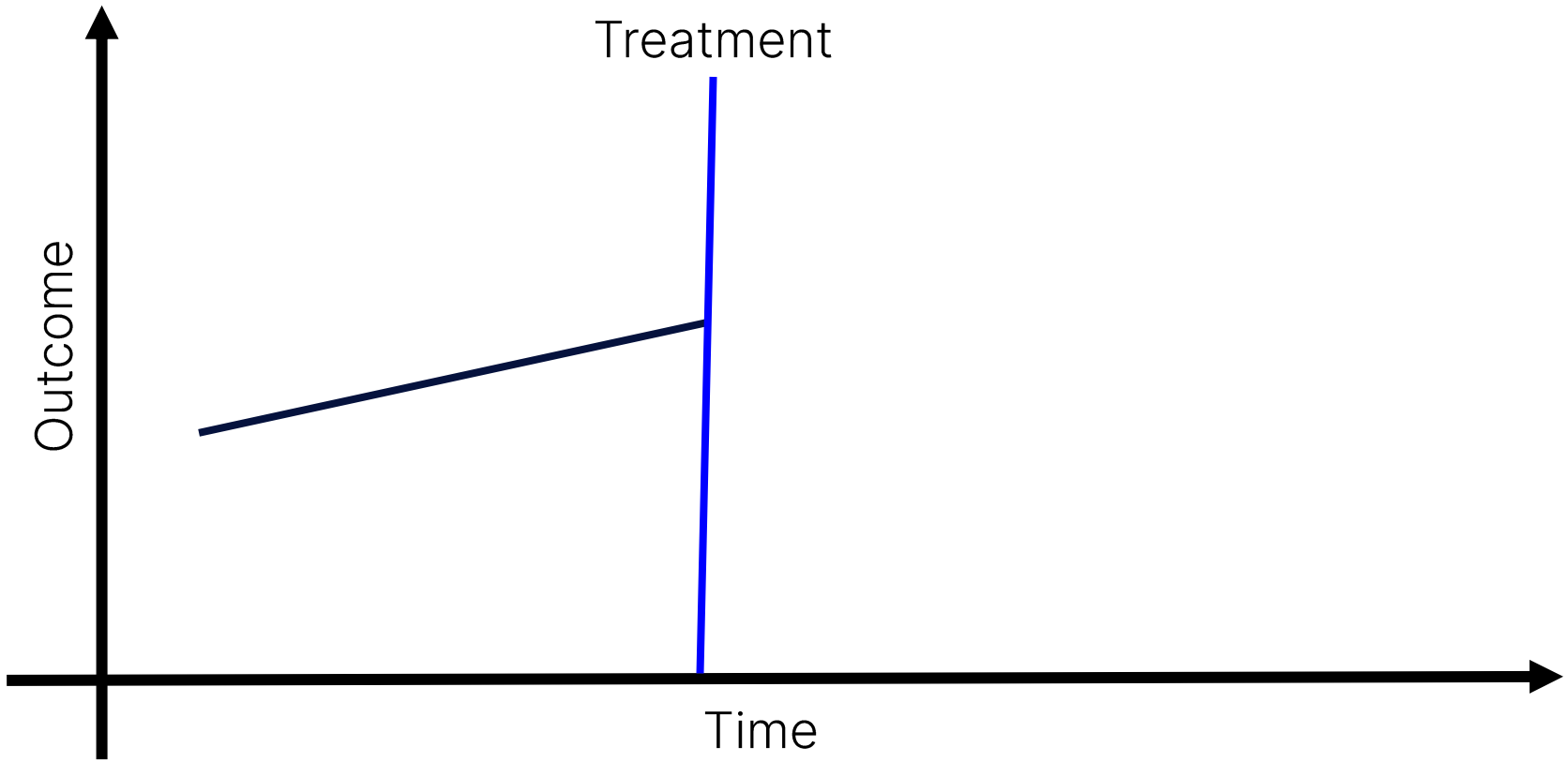
Difference in differences (DID)



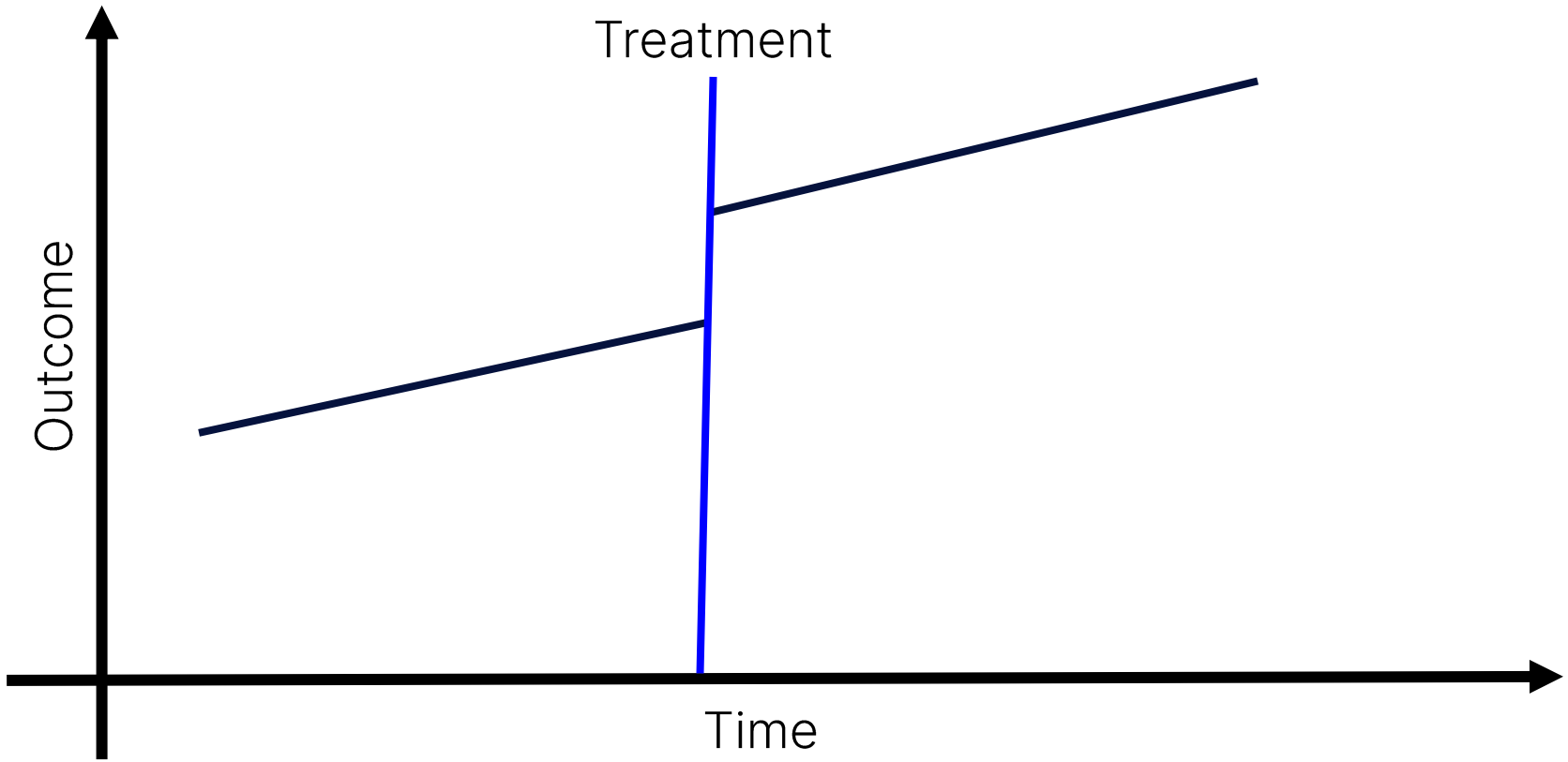
Difference in differences (DID)



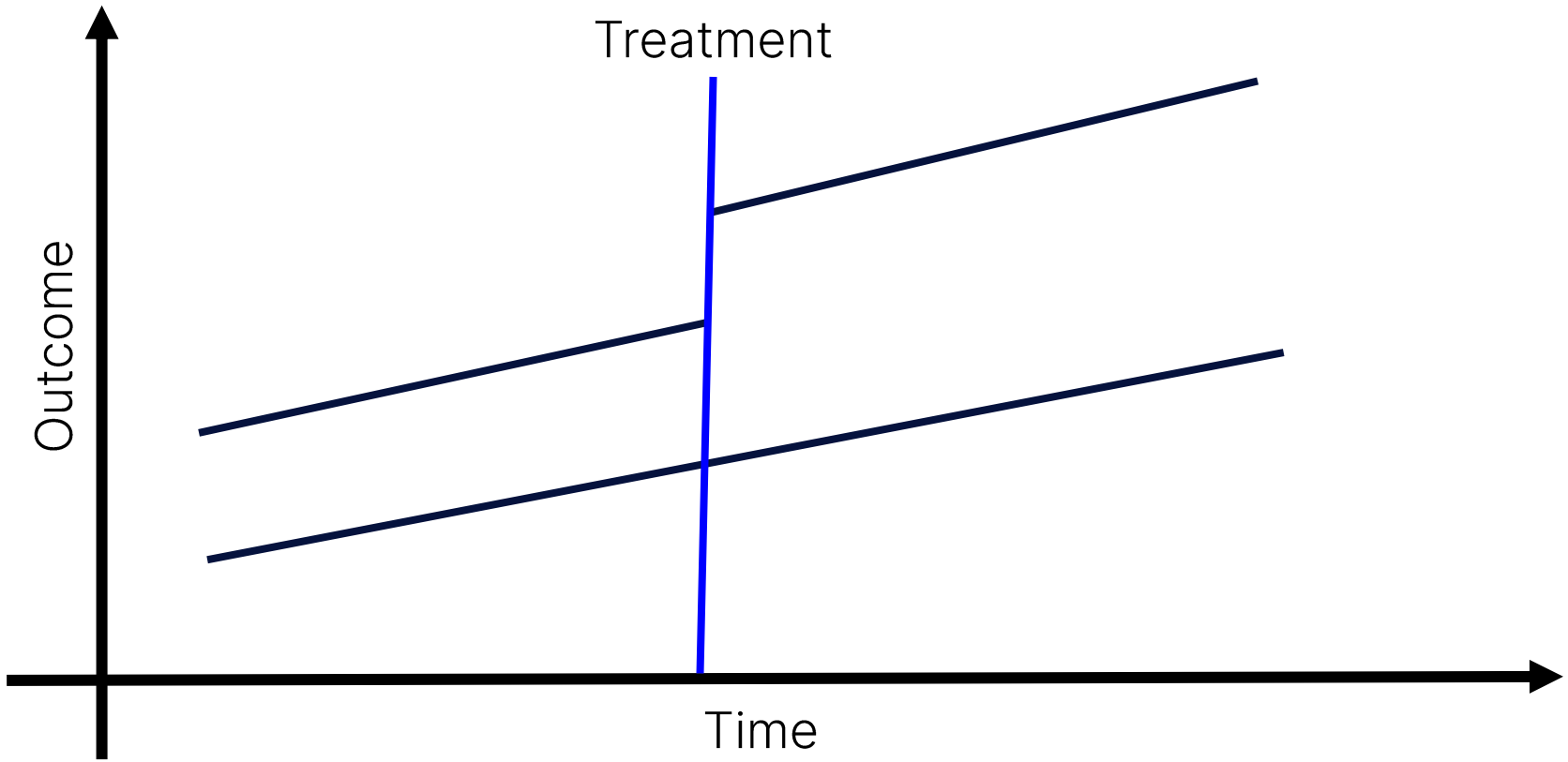
Difference in differences (DID)



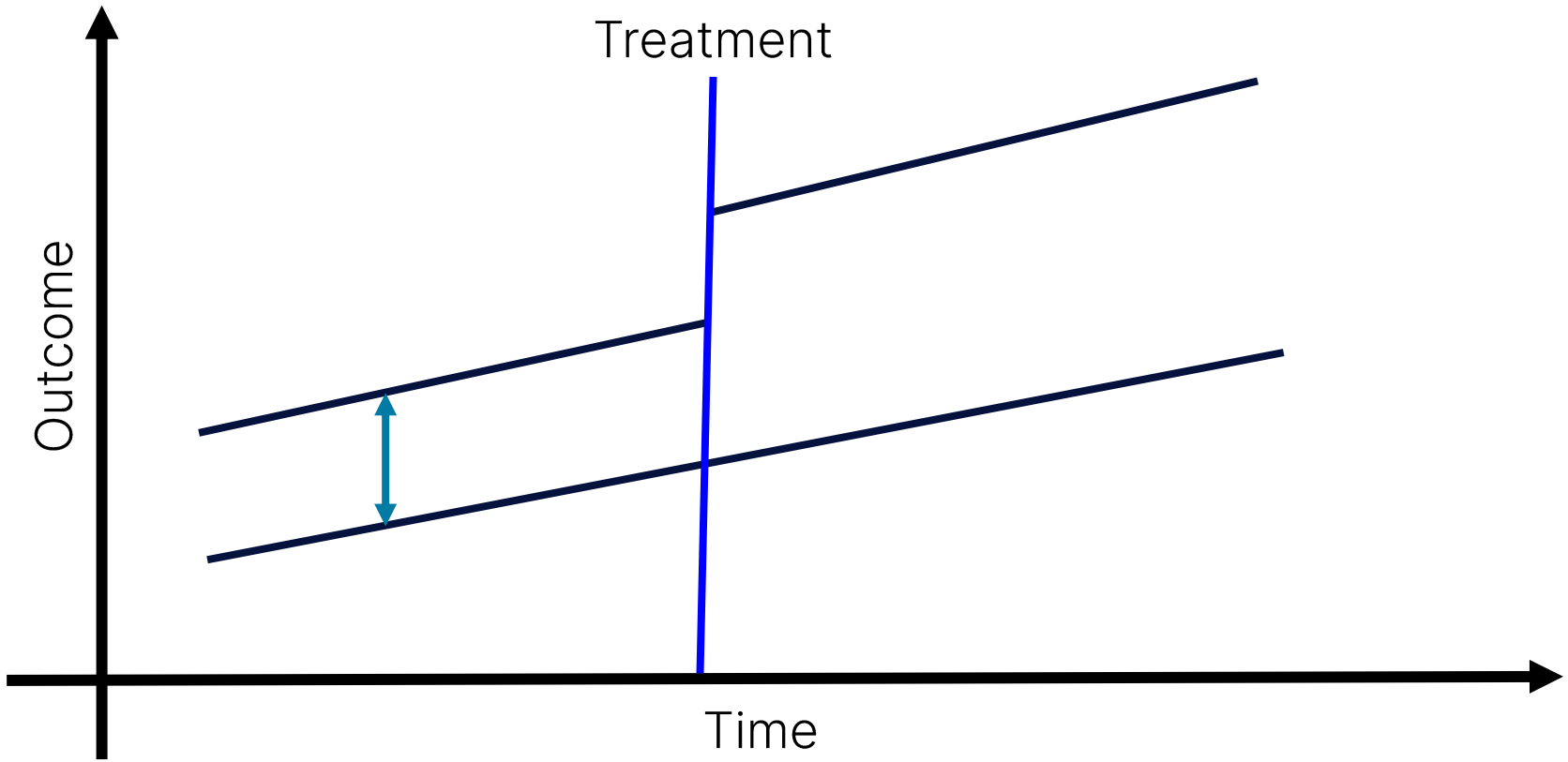
Difference in differences (DID)



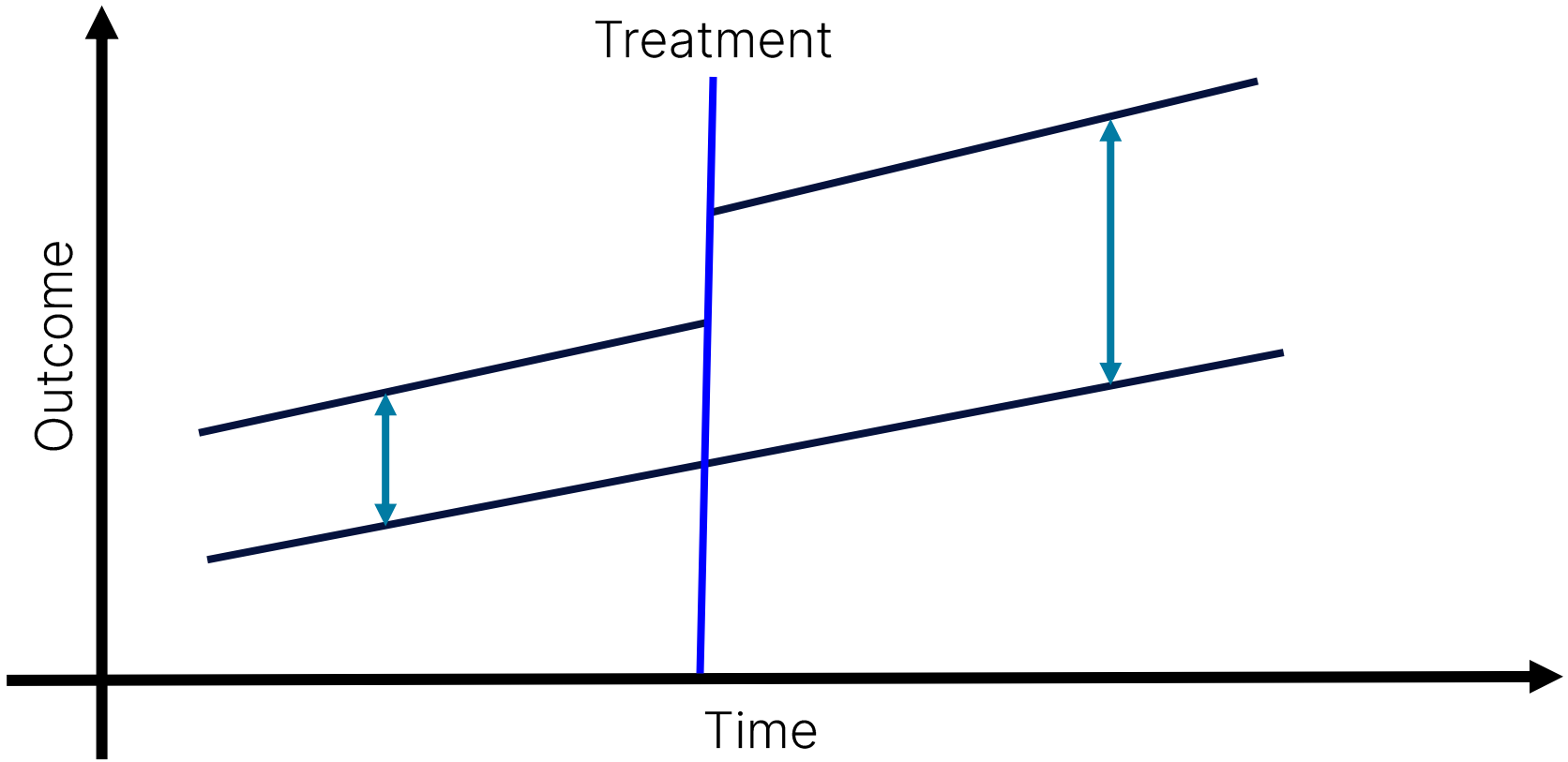
Difference in differences (DID)



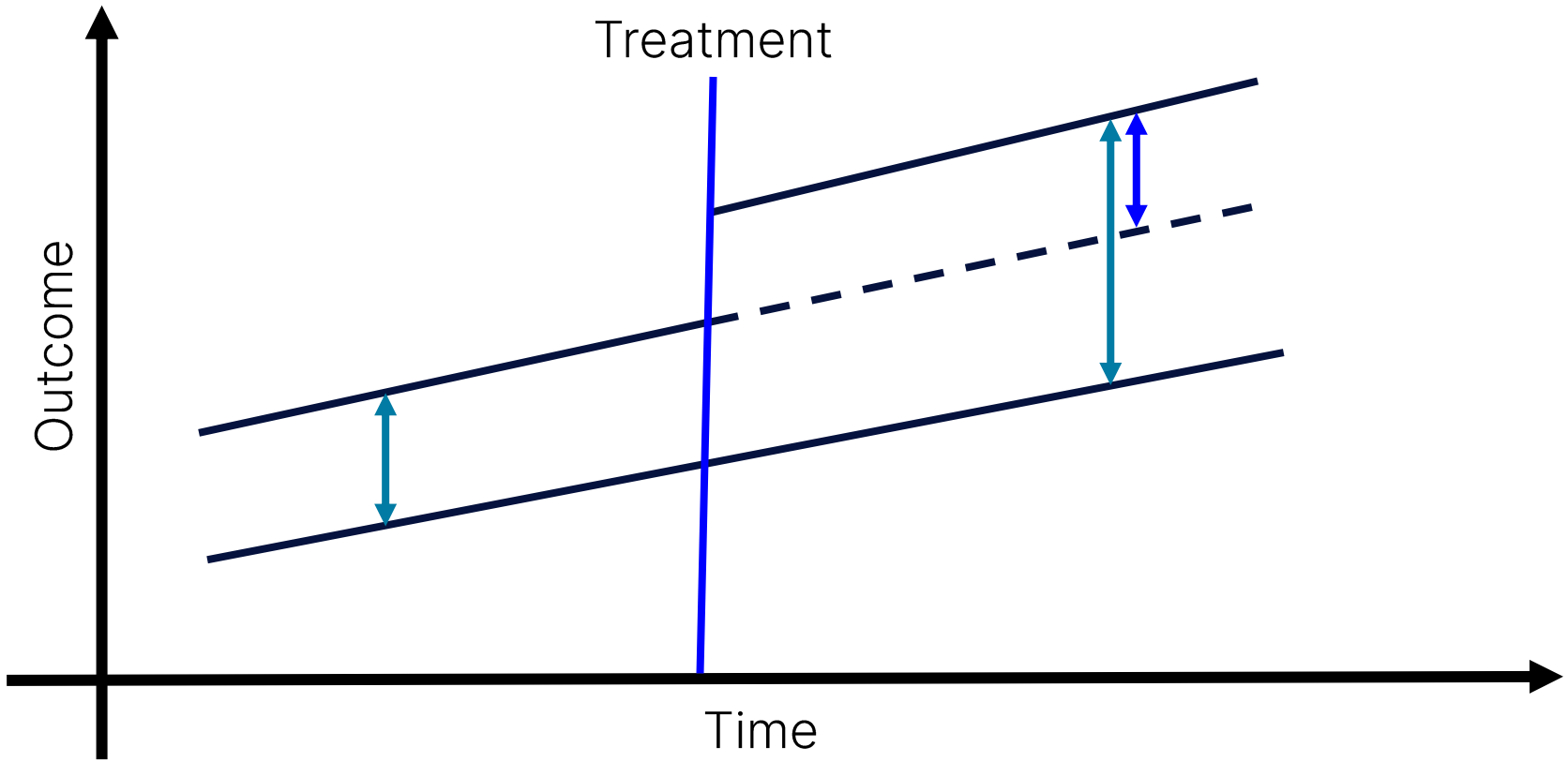
Difference in differences (DID)



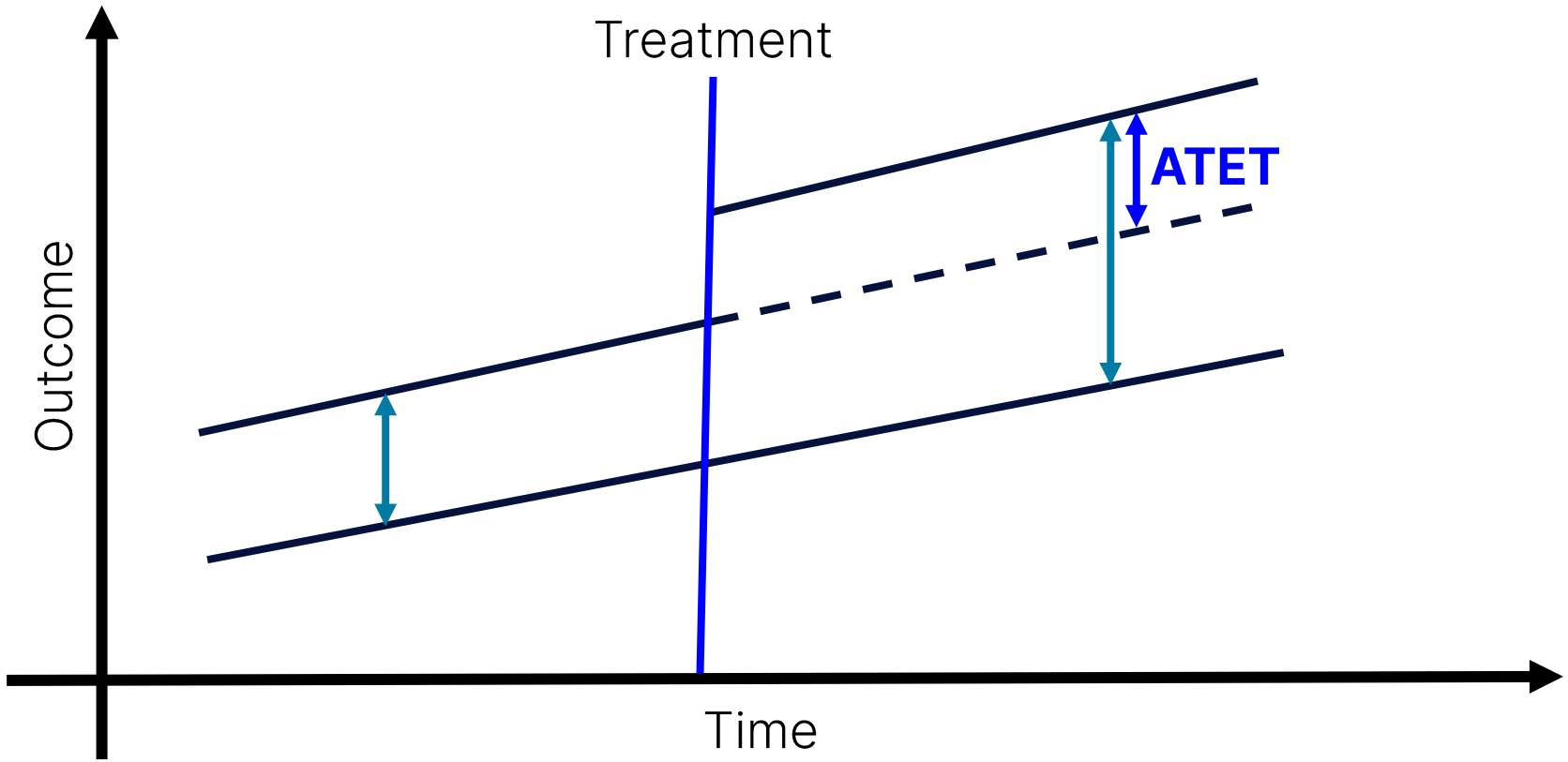
Difference in differences (DID)



Difference in differences (DID)



Difference in differences (DID)

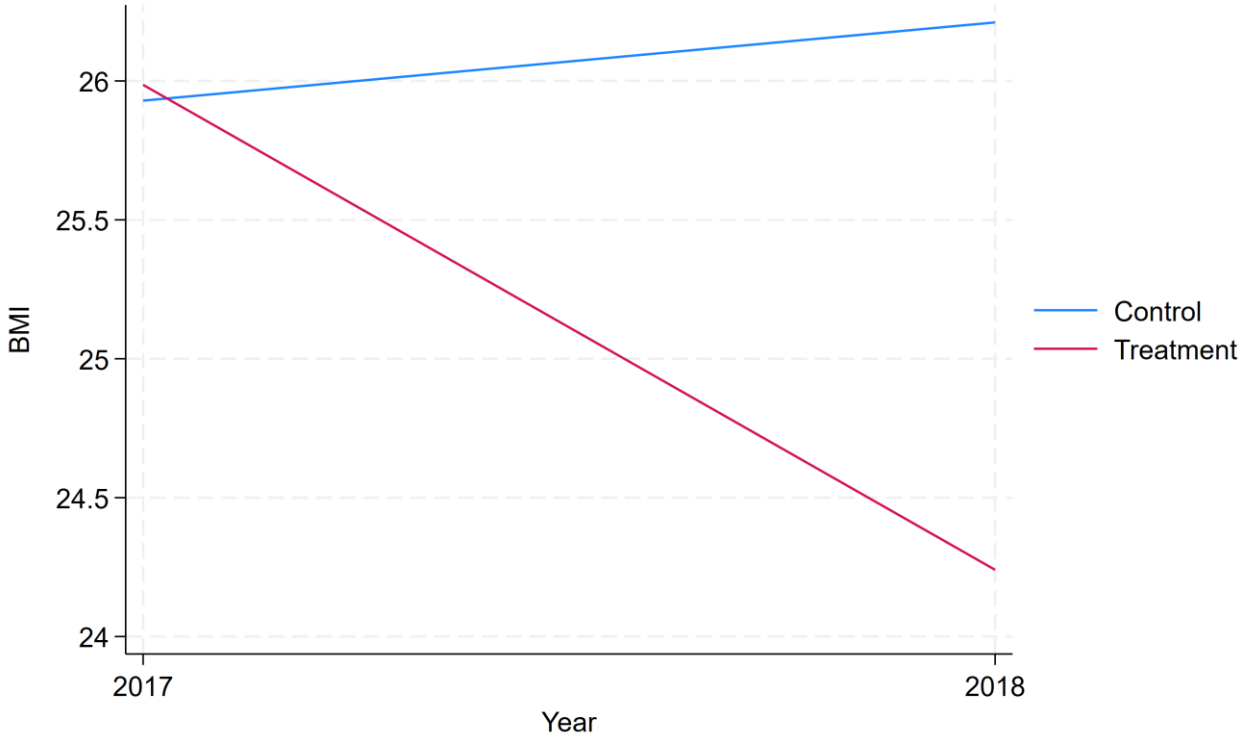


Healthy Habits program

- Several school districts in the state have implemented a new program called Healthy Habits that incorporates more exercise time and augments the intake of fruits and vegetables at lunch time.

- Does the Healthy Habits program reduce students' body mass index (BMI) in 11 to 14 year olds?
- What is the average decrease in BMI for students who participate in the program?

Study design – 2 x 2



Repeated cross-sectional data

```
. use hhabit1
(Fictional children BMI and school district data)

. list in 42/51
```

	district	year	hhabit	parksd	medu	girl	sports	bmi
42.	1	2017	No	6	8	Yes	Yes	26.92559
43.	1	2017	No	6	11	No	No	27.12172
44.	1	2017	No	6	8	Yes	Yes	24.77188
45.	1	2017	No	6	10	No	Yes	22.20161
46.	1	2017	No	6	9	No	Yes	18.3871
47.	1	2018	Yes	6	10	Yes	No	23.56391
48.	1	2018	Yes	6	13	No	No	28.9242
49.	1	2018	Yes	6	9	No	No	32.02917
50.	1	2018	Yes	6	0	No	Yes	21.86985
51.	1	2018	Yes	6	9	Yes	No	23.77382

Repeated cross-sectional data

```
. bysort district: egen treatment = max(hhabit)

. dtable i.district bmi parksd medu i.girl i.sports if treatment, by(year)
  novarlabel sample( , statistics(frequency))
```

	Year		
	2017	2018	Total
N	149	145	294
district			
1	46 (30.9%)	44 (30.3%)	90 (30.6%)
2	52 (34.9%)	45 (31.0%)	97 (33.0%)
3	51 (34.2%)	56 (38.6%)	107 (36.4%)
bmi	25.986 (4.891)	24.240 (4.914)	25.125 (4.972)
parksd	5.658 (0.476)	5.614 (0.489)	5.636 (0.482)
medu	9.852 (2.820)	9.469 (2.438)	9.663 (2.641)
girl			
No	74 (49.7%)	78 (53.8%)	152 (51.7%)
Yes	75 (50.3%)	67 (46.2%)	142 (48.3%)
sports			
No	39 (26.2%)	49 (33.8%)	88 (29.9%)
Yes	110 (73.8%)	96 (66.2%)	206 (70.1%)

Two-way fixed effects (TWFE)

$$y_{igt} = \gamma_g + \gamma_t + \boldsymbol{z_{igt}}\beta + D_{gt}\delta + \epsilon_{igt}$$

i observation
g group
t time

γ_g are the group fixed effects

γ_t are the time fixed effects

$\boldsymbol{z_{igt}}$ are the covariates

β are nuisance parameters

D_{gt} is the treatment (varies by group and time)

δ is the average treatment effect on the treated (ATET)

Two-way fixed effects (TWFE)

$$y_{igt} = \gamma_g + \gamma_t + \boldsymbol{z_{igt}}\beta + D_{gt}\delta + \epsilon_{igt}$$

i observation
g group
t time

```
. regress bmi i.(district year girl sports hhabit), vce(cluster district)
```

Two-way fixed effects (TWFE)

$$y_{igt} = \gamma_g + \gamma_t + \boldsymbol{z_{igt}}\beta + D_{gt}\delta + \epsilon_{igt}$$

i observation
g group
t time

```
. regress bmi i.(district year girl sports hhabit), vce(cluster district)

. didregress (bmi i.girl i.sports) (hhabit), group(district) time(year)
```

DID with `regress`

```
. regress bmi i.(district year girl sports hhabit), vce(cluster district)

Linear regression                               Number of obs     =      2,815
                                                F(3, 29)          =          .
                                                Prob > F          =          .
                                                R-squared         =     0.0446
                                                Root MSE          =     4.8028

                                   (Std. err. adjusted for 30 clusters in district)
------------------------------------------------------------------------------
             |               Robust
         bmi |  Coefficient  std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
    district |
           1 |          0  (base)
           2 |    1.14331   .0084414   135.44   0.000     1.126046    1.160575
           3 |   .2090071   .0234695     8.91   0.000     .1610065    .2570077
           4 |   .1247919   .1658403     0.75   0.458    -.2143895    .4639733
           5 |     .46288   .1566941     2.95   0.006     .1424046    .7833554
           6 |  -.1512917   .1712865    -0.88   0.384    -.5016119    .1990286
           7 |   .8683145   .1643517     5.28   0.000     .5321775    1.204451
           8 |   .1420385   .1602934     0.89   0.383    -.1857983    .4698752
           9 |  -.3473355   .1476729    -2.35   0.026    -.6493605   -.0453106
          10 |  -.1224466   .1502409    -0.82   0.422    -.4297237    .1848305
          11 |  -.0971328   .1411213    -0.69   0.497    -.3857582    .1914925
          12 |   .2576859   .1569112     1.64   0.111    -.0632336    .5786054
```

18	-.5640486	.1529064	-3.69	0.001	-.8767772	-.25132
19	.4654356	.1526969	3.05	0.005	.1531354	.7777358
20	.5854752	.1537438	3.81	0.001	.2710338	.8999166
21	.2617872	.1628856	1.61	0.119	-.0713512	.5949257
22	.778589	.153641	5.07	0.000	.4643579	1.09282
23	1.334889	.1515312	8.81	0.000	1.024972	1.644805
24	.647442	.1552261	4.17	0.000	.329969	.9649149
25	.2337309	.1585146	1.47	0.151	-.0904679	.5579298
26	.0524395	.1578669	0.33	0.742	-.2704346	.3753136
27	-.0520582	.1613677	-0.32	0.749	-.3820921	.2779757
28	-.2484144	.1546527	-1.61	0.119	-.5647148	.0678859
29	.5323953	.1527937	3.48	0.002	.2198971	.8448934
30	.4268822	.1539278	2.77	0.010	.1120645	.7416998
year						
2017	0	(base)				
2018	.3300558	.2144101	1.54	0.135	-.1084622	.7685738
girl						
No	0	(base)				
Yes	.9947139	.1583773	6.28	0.000	.6707959	1.318632
sports						
No	0	(base)				
Yes	-1.377504	.2129341	-6.47	0.000	-1.813003	-.9420045
hhabit						
No	0	(base)				
Yes	-2.104804	.3071655	-6.85	0.000	-2.733028	-1.47658
_cons	26.03178	.1716093	151.69	0.000	25.6808	26.38276

18	-.5640486	.1529064	-3.69	0.001	-.8767772	-.25132
19	.4654356	.1526969	3.05	0.005	.1531354	.7777358
20	.5854752	.1537438	3.81	0.001	.2710338	.8999166
21	.2617872	.1628856	1.61	0.119	-.0713512	.5949257
22	.778589	.153641	5.07	0.000	.4643579	1.09282
23	1.334889	.1515312	8.81	0.000	1.024972	1.644805
24	.647442	.1552261	4.17	0.000	.329969	.9649149
25	.2337309	.1585146	1.47	0.151	-.0904679	.5579298
26	.0524395	.1578669	0.33	0.742	-.2704346	.3753136
27	-.0520582	.1613677	-0.32	0.749	-.3820921	.2779757
28	-.2484144	.1546527	-1.61	0.119	-.5647148	.0678859
29	.5323953	.1527937	3.48	0.002	.2198971	.8448934
30	.4268822	.1539278	2.77	0.010	.1120645	.7416998
year						
2017	0	(base)				
2018	.3300558	.2144101	1.54	0.135	-.1084622	.7685738
girl						
No	0	(base)				
Yes	.9947139	.1583773	6.28	0.000	.6707959	1.318632
sports						
No	0	(base)				
Yes	-1.377504	.2129341	-6.47	0.000	-1.813003	-.9420045
hhabit						
No	0	(base)				
Yes	-2.104804	.3071655	-6.85	0.000	-2.733028	-1.47658
_cons	26.03178	.1716093	151.69	0.000	25.6808	26.38276

DID with `didregress`

```
. didregress (bmi i.girl i.sports) (hhabit), group(district) time(year)

Difference-in-differences regression                    Number of obs = 2,815
Data type: Repeated cross-sectional

                                (Std. err. adjusted for 30 clusters in district)
```

bmi	Coefficient	Robust std. err.	t	P>|t|	[95% conf.	interval]
ATET						
hhabit (Yes vs No)	-2.104804	.3071655	-6.85	0.000	-2.733028	-1.47658

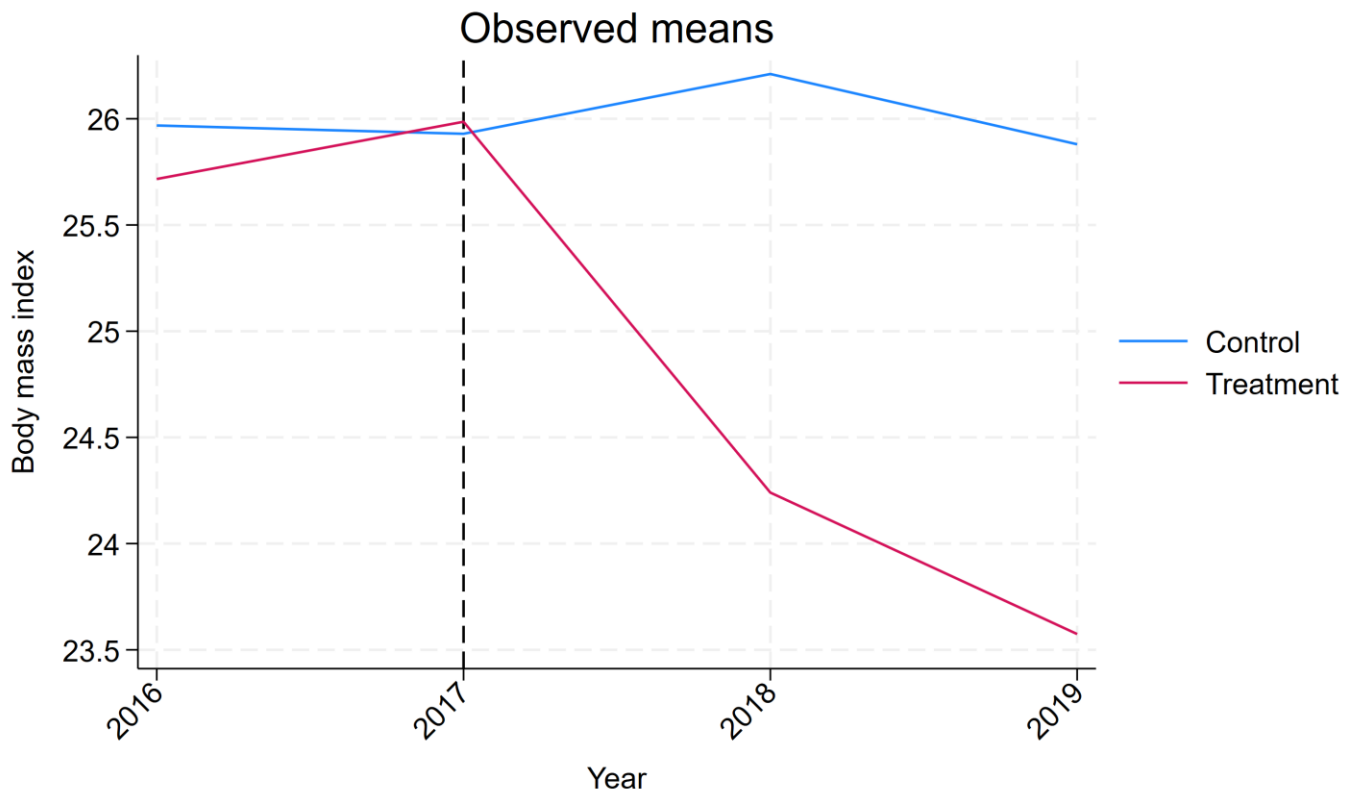
```
Note: ATET estimate adjusted for covariates, group effects, and time effects.
```

Auxiliary equations

```
. didregress (bmi i.girl i.sports) (hhabit), group(district) time(year) aeq

Difference-in-differences regression                    Number of obs = 2,815
Data type: Repeated cross-sectional

                              (Std. err. adjusted for 30 clusters in district)
------------------------------------------------------------------------------
             |               Robust
         bmi | Coefficient  std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
ATET         |
      hhabit |
(Yes vs No)  |  -2.104804   .3071655    -6.85   0.000    -2.733028    -1.47658
-------------+----------------------------------------------------------------
Controls     |
        girl |
         No  |          0  (base)
         Yes |   .9947139   .1583773     6.28   0.000     .6707959    1.318632
             |
      sports |
         No  |          0  (base)
         Yes |  -1.377504   .2129341    -6.47   0.000    -1.813003   -.9420045
             |
        year |
        2017 |          0  (base)
        2018 |   .3300558   .2144101     1.54   0.135    -.1084622    .7685738
------------------------------------------------------------------------------
```

Add additional time points

```
. use hhabit2
```



Add additional time points

```
. didregress (bmi i.girl i.sports) (hhabit), group(district) time(year)

Difference-in-differences regression                    Number of obs = 5,649
Data type: Repeated cross-sectional

                                (Std. err. adjusted for 30 clusters in district)
------------------------------------------------------------------------------
             |               Robust
         bmi |Coefficient  std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
ATET         |
      hhabit |
(Yes vs No)  |  -2.00429   .2231442    -8.98   0.000    -2.460671   -1.547909
------------------------------------------------------------------------------
Note: ATET estimate adjusted for covariates, group effects, and time effects.
```

Standard error considerations

- Treatment is administered at the group level
- Default standard errors are cluster-robust SEs at the group level (Bertrand, Dufflo, Mullainathan, 2004)
- When too few groups (<40-50):
  - Bias-corrected standard errors (HC2) with the Bell and McCaffrey (2002) degrees-of-freedom adjustment
  - Aggregation method
  - Wild-cluster bootstrap to obtain p-values and confidence intervals

Bias-corrected robust standard error

- Cluster generalization of HC2
  - Scale residuals inverse of square of diagonals from projection matrix
  - Higher weight to residuals of observations with high leverage
- Bell and McCaffrey (2002) suggest a degrees of freedom adjustment

Bias-corrected robust standard error

```
. didregress (bmi i.girl i.sports) (hhabit), group(district) time(year) vce(hc2)

Difference-in-differences regression                 Number of obs    = 5,649
                                                     No. of clusters =    30
Data type: Repeated cross-sectional
```

bmi	Coefficient	Robust HC2 std. err.	t	P>|t|	[95% conf.	interval]
ATET						
hhabit (Yes vs No)	-2.00429	.2512349	-7.98	0.008	-2.91349	-1.095089

Note: ATET estimate adjusted for covariates, group effects, and time effects.

Aggregation method

- Regress out observation-level covariates
- Aggregate at the g,t level
- Fit DID regression model to the aggregated data

$$y_{igt} = z_{1igt}\beta_1 + C_{gt} + \epsilon_{igt}$$

$$\hat{C}_{gt} = z_{2gt}\beta_2 + D_{gt}\delta + v_{gt}$$

- Use option `aggregate(standard)` to use the standard method with constant β_1
- Use option `aggregate(dlang, varying)` to use the method proposed by Donald and Lang (2007) to estimate β_1 separately by group

Aggregation method

```
. didregress (bmi i.girl i.sports) (hhabit), group(district) time(year) aggregate(dlang, varying)

Difference-in-differences regression                        Number of obs = 120
Data type:   Repeated cross-sectional
Aggregation: Donald–Lang, varying coefficients

------------------------------------------------------------------------------
         bmi | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
ATET         |
      hhabit |
(Yes vs No)  |  -1.569087   .9738948    -1.61   0.110    -3.498185    .3600115
------------------------------------------------------------------------------
Note: ATET estimate adjusted for covariates, group effects, and time effects.
```

Aggregation method

```
. didregress (bmi i.girl i.sports) (hhabit), group(district) time(year) aggregate(dlang)

Difference-in-differences regression                    Number of obs = 120
Data type:   Repeated cross-sectional
Aggregation: Donald–Lang
```

bmi	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
ATET						
hhabit (Yes vs No)	-1.971313	.4335124	-4.55	0.000	-2.830018	-1.112609

Note: ATET estimate adjusted for covariates, group effects, and time effects.

Wild cluster bootstrap

1. Fit unrestricted model to estimate t-statistic for ATET, t
2. Fit restricted model (assume ATET=0) and predict outcome, $\hat{y}_{igt}$, and residuals, $\hat{\epsilon}_{igt}$
3. Repeat the following steps B times
    1. Multiply residual by randomly sampled weight function at the group level, i.e. from normal distribution, $\tilde{\epsilon}_{igt,b} = \hat{\epsilon}_{igt} \times w_{g,b}$
    2. Use weighted residual to update predicted outcome, $\tilde{y}_{igt,b} = \hat{y}_{igt} + \tilde{\epsilon}_{igt}$
    3. Fit unrestricted model to $\tilde{y}_{igt,b}$ to estimate t-statistic for ATET, $\tilde{t}_b$
4. Compare the observed t to the B bootstrap sampled $\tilde{t}_b$'s to compute p-values and 95% confidence intervals

Wild cluster bootstrap

```
. didregress (bmi i.girl i.sports) (hhabit), group(district) time(year) wildbootstrap(rseed(273))

Performing 1,000 replications for p-value for constraint
  hhabit = 0 ...

DID with wild-cluster bootstrap inference              Number of obs = 5,649
                                                       Replications  = 1,000
Data type:    Repeated cross-sectional
Error weight: rademacher
```

bmi	Coefficient	t	P>|t|	[95% conf.	interval]
ATET					
hhabit (Yes vs No)	-2.00429	-8.98	0.018	-3.297128	-1.101595

Note: ATET estimate adjusted for covariates, group effects, and time effects.

Wild cluster bootstrap

- Change error weight with option `errorweight()`

Error weight	Formula
`rademacher`	$\{-1 \;\; 1\}$ with probability 1/2
`mammen`	$\{1-\phi\}$ with probability $\frac{\phi}{\sqrt{5}}$, $\{\phi\}$ otherwise where $\phi = \frac{1+\sqrt{5}}{2}$
`webb`	$\left\{\frac{-\sqrt{3}}{2} \;\; \frac{-\sqrt{2}}{2} \;\; \frac{-\sqrt{1}}{2} \;\; \frac{\sqrt{1}}{2} \;\; \frac{\sqrt{2}}{2} \;\; \frac{\sqrt{3}}{2}\right\}$ with probability 1/6
`normal`	$\sim N(0,1)$
`gamma`	$\sim \Gamma\left(4, \frac{1}{2}\right)$

Wild cluster bootstrap

```
. didregress (bmi i.sports i.girl) (hhabit) if district<11, group(district) time(year) wildbootstrap(rseed(432))

Performing 1,000 replications for p-value for constraint
  hhabit = 0 ...
Computing confidence interval for hhabit
  Lower bound: .........10 done (10)
  Upper bound: .........10.........20... done (23)
note: upper-bound CI achieved 1-F(-1.39) = 0.0240, but target is 1-F(x) = .025.
note: at least one bootstrap t statistic matches the t statistic under the null; this prevents the CI bound
      from converging to the target.

DID with wild-cluster bootstrap inference                Number of obs = 1,880
                                                         Replications  = 1,000
Data type:    Repeated cross-sectional
Error weight: rademacher
```

bmi	Coefficient	t	P>|t|	[95.10% conf. interval]	
ATET					
hhabit (Yes vs No)	-2.106906	-8.16	0.002	-2.80338	-1.386673

```
Note: 95.10% confidence interval is wider than requested.
Note: ATET estimate adjusted for covariates, group effects, and time effects.
```

Wild cluster bootstrap

```
. didregress (bmi i.sports i.girl) (hhabit) if district<11, group(district) time(year) wildbootstrap(rseed(432)
  errorweight(normal))

Performing 1,000 replications for p-value for constraint
  hhabit = 0 ...

DID with wild-cluster bootstrap inference                Number of obs = 1,880
                                                         Replications  = 1,000
Data type:    Repeated cross-sectional
Error weight: normal
```

bmi	Coefficient	t	P>|t|	[95% conf.	interval]
ATET					
hhabit (Yes vs No)	-2.106906	-8.16	0.000	-2.676421	-1.448629

Note: ATET estimate adjusted for covariates, group effects, and time effects.

Assumptions

- Conditional-mean independence (CMI) assumption
  - there are no unmeasured confounders
- Overlap assumption
  - each treated individual has a positive probability of not receiving the treatment
- Stable unit treatment value assumption (SUTVA)
  - composition of intervention and comparison groups is stable for repeated cross-sectional design
- Parallel trends
  - treatment and control groups have parallel trends in outcome prior to treatment

Assessing SUTVA

```
. dtable parksd medu i.girl i.sports if treatment, by(year, nototal test) novarlabel
note: using test regress across levels of year for parksd and medu.
note: using test pearson across levels of year for girl and sports.
```

	Year				
	2016	2017	2018	2019	Test
N	137 (24.7%)	149 (26.9%)	145 (26.2%)	123 (22.2%)	
parksd	5.686 (0.466)	5.658 (0.476)	5.614 (0.489)	5.691 (0.464)	0.509
medu	10.036 (2.922)	9.852 (2.820)	9.469 (2.438)	10.008 (2.757)	0.281
girl					
No	58 (42.3%)	74 (49.7%)	78 (53.8%)	67 (54.5%)	0.169
Yes	79 (57.7%)	75 (50.3%)	67 (46.2%)	56 (45.5%)	
sports					
No	41 (29.9%)	39 (26.2%)	49 (33.8%)	33 (26.8%)	0.474
Yes	96 (70.1%)	110 (73.8%)	96 (66.2%)	90 (73.2%)	

Assessing SUTVA

```
. dtable parksd medu i.girl i.sports if !treatment, by(year, nototal test) novarlabel
note: using test regress across levels of year for parksd and medu.
note: using test pearson across levels of year for girl and sports.
```

	Year				
	2016	2017	2018	2019	Test
N	1,289 (25.3%)	1,213 (23.8%)	1,308 (25.7%)	1,285 (25.2%)	
parksd	4.648 (1.192)	4.613 (1.212)	4.622 (1.177)	4.591 (1.202)	0.689
medu	10.049 (2.714)	9.967 (2.738)	9.997 (2.871)	9.886 (2.694)	0.503
girl					
No	650 (50.4%)	587 (48.4%)	691 (52.8%)	652 (50.7%)	0.173
Yes	639 (49.6%)	626 (51.6%)	617 (47.2%)	633 (49.3%)	
sports					
No	428 (33.2%)	420 (34.6%)	438 (33.5%)	439 (34.2%)	0.873
Yes	861 (66.8%)	793 (65.4%)	870 (66.5%)	846 (65.8%)	

Assessing parallel trends

- Parallel-trends assumption: Both groups had mean outcomes that evolved similarly to each other over time prior to treatment
  - `estat ptrends`
  - `estat trendplots`

- Anticipatory treatment assumption: Neither group changed their behavior in anticipation of the treatment
  - `estat granger`
  - `estat grangerplot`

Linear trend model

$$y_{igt} = \gamma_g + \gamma_t + \boldsymbol{z_{igt}}\beta + D_{gt}\delta + T_g pre_t t\theta + \epsilon_{igt}$$

i observation
g group
t time

- Need two new variables:

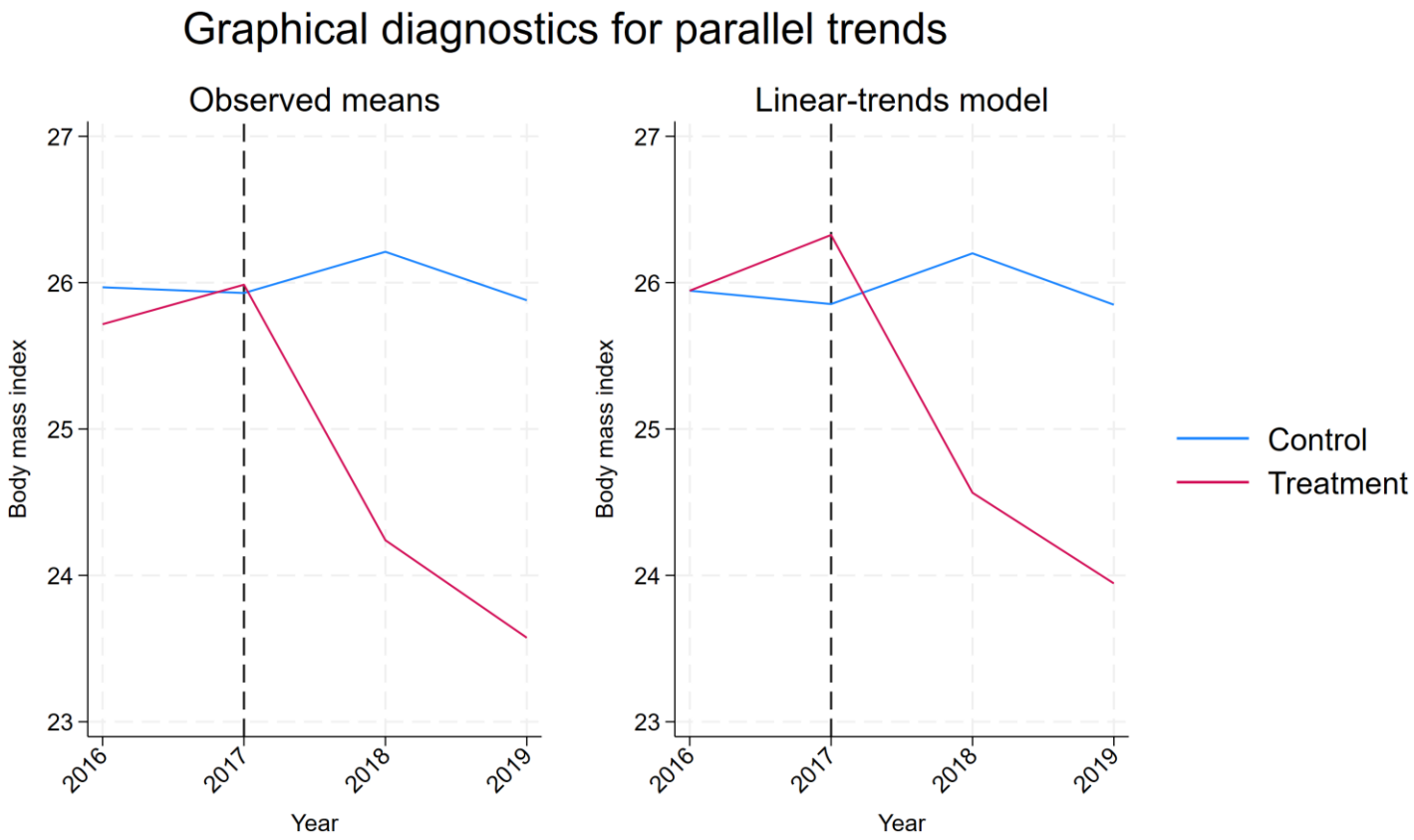
```
. bysort district: egen treatment = max(hhabit)
. generate pre = year<2018
```

- And include their three-way interaction with continuous time variable

```
. regress bmi i.hhabit i.district i.year treatment#pre#c.year, vce(cluster district)
```

Linear trend model

```
. estat trendplot
```




```
. estat ptrend

Parallel-trends test (pretreatment time period)
H0: Linear trends are parallel

F(1, 29) =    0.52
Prob > F = 0.4749
```

Granger causality model

$$y_{igt} = \gamma_g + \gamma_t + \boldsymbol{z_{igt}}\beta + D_{gt}\delta + T_g pre_t \gamma_t \theta + \epsilon_{igt}$$

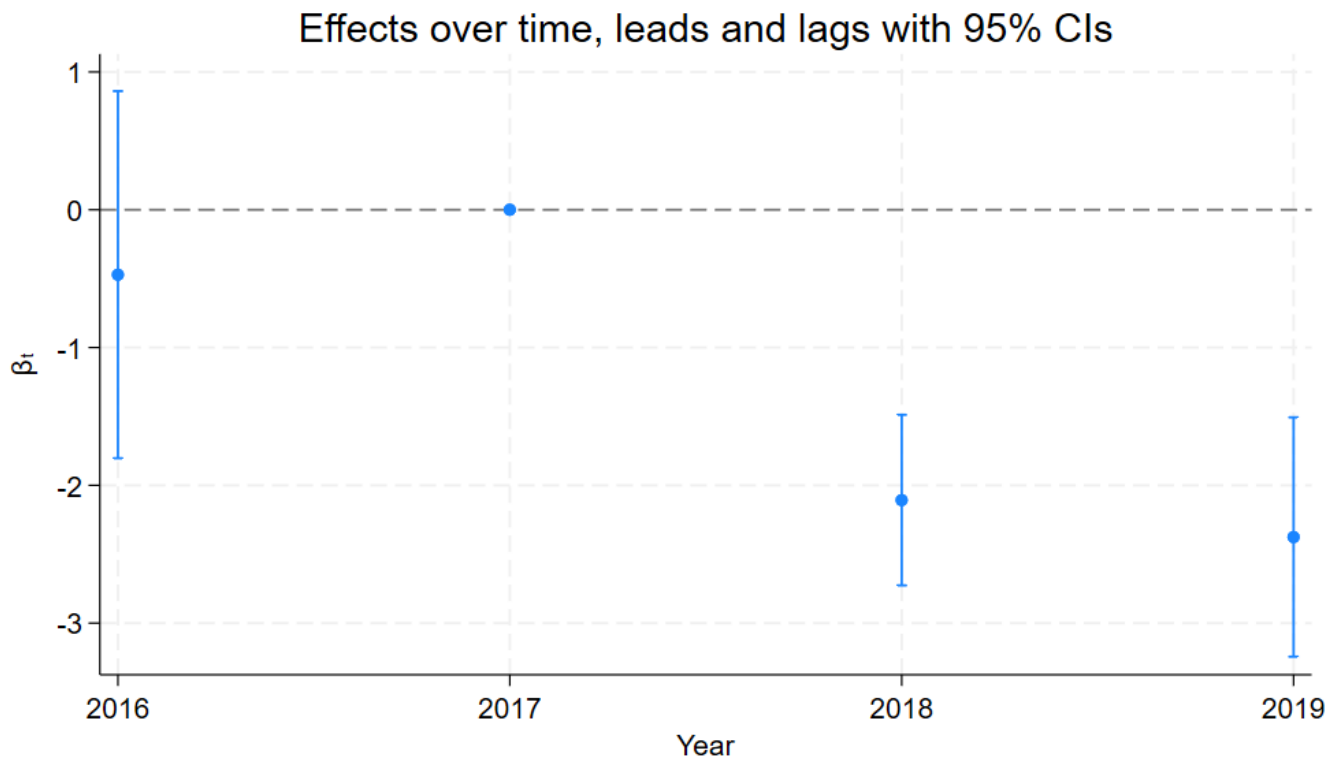
i observation
g group
t time

- Include the three-way interaction with *discrete* time variable

```
. regress bmi i.hhabit i.district i.year treatment#pre#year, vce(cluster district)
```

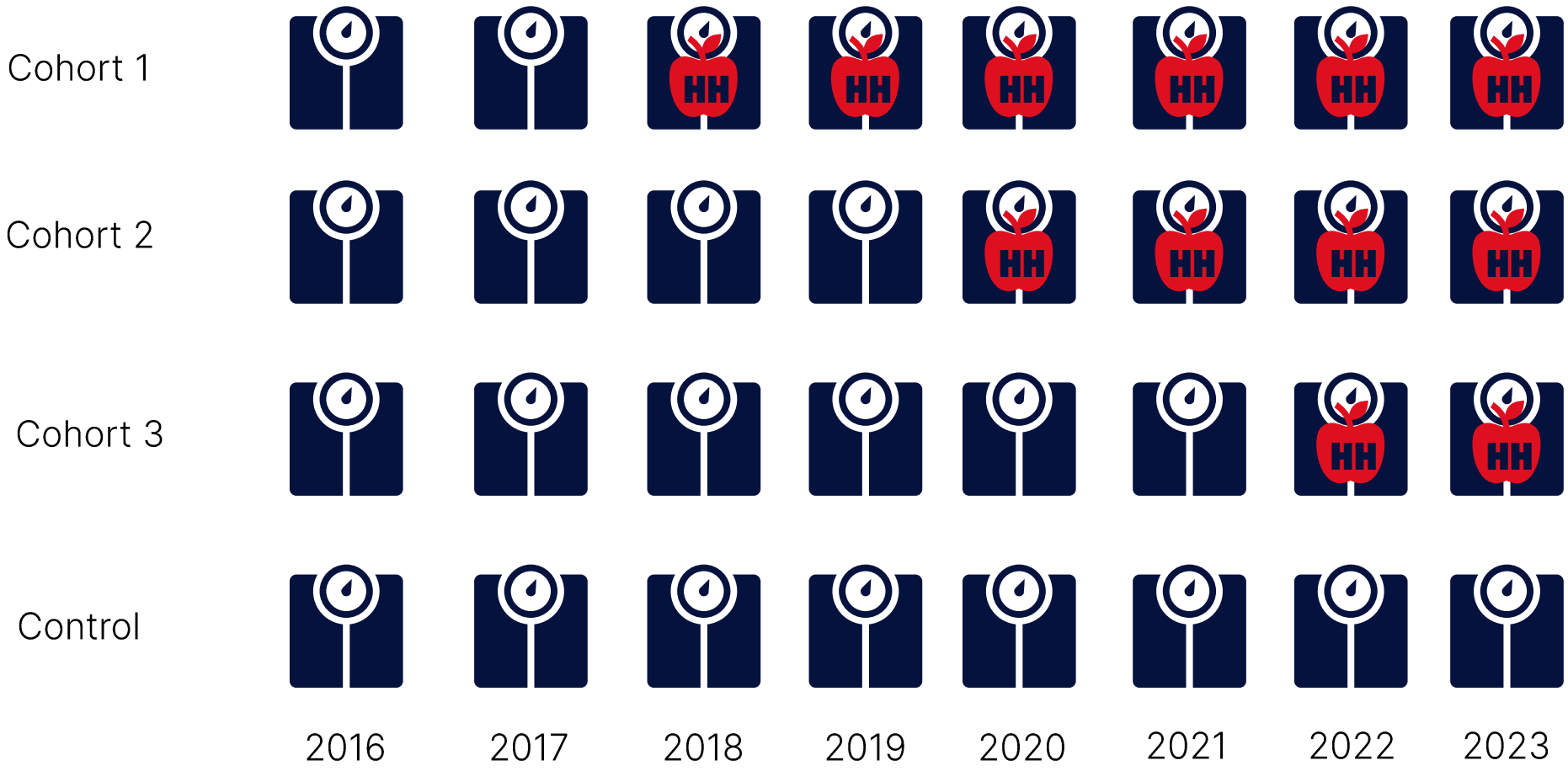
Granger causality model

```
. estat grangerplot
```




```
. estat granger

Granger causality test
H0: No effect in anticipation of treatment

F(1, 29) =   0.52
Prob > F = 0.4754
```

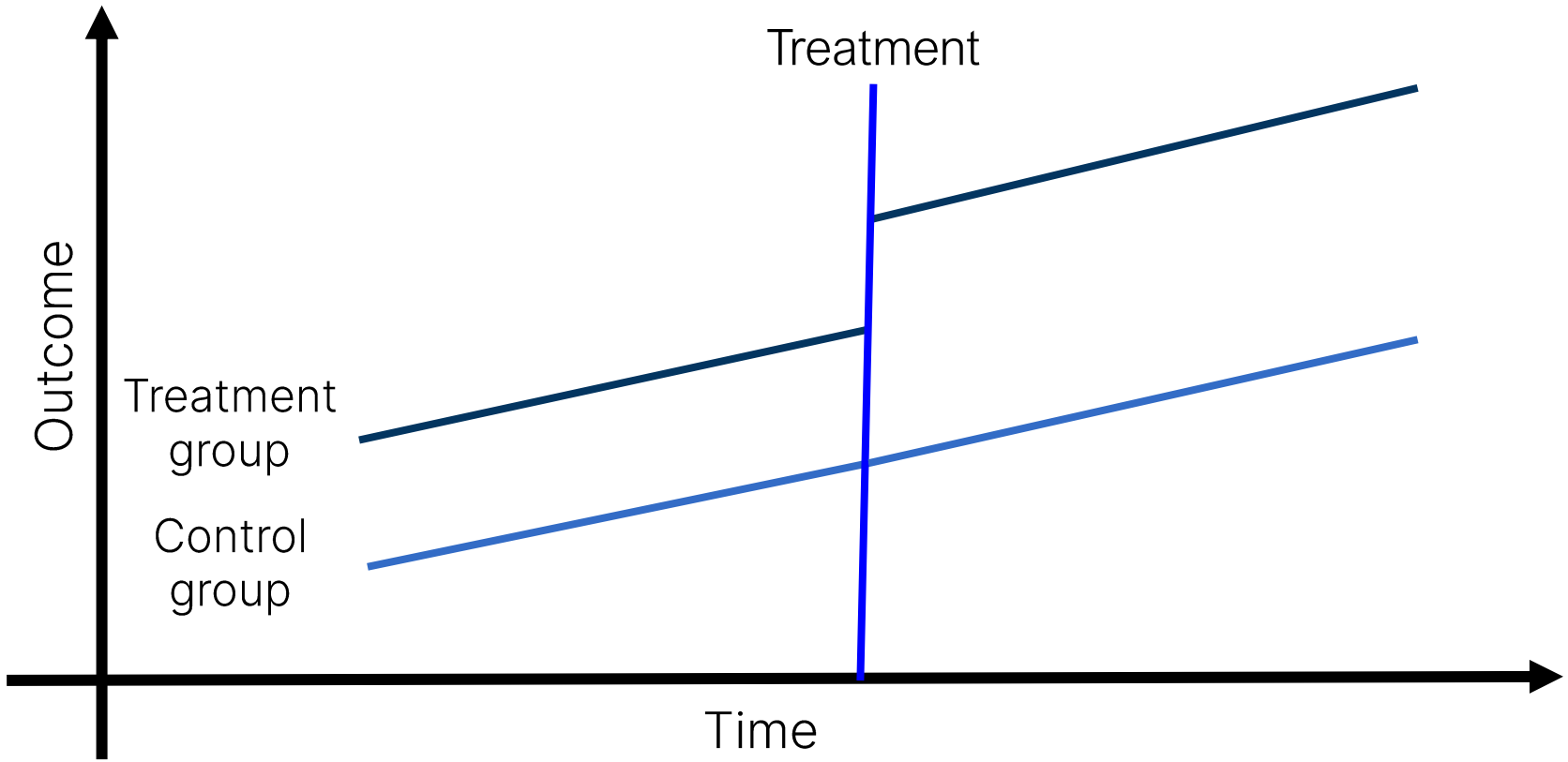
The saga continues...



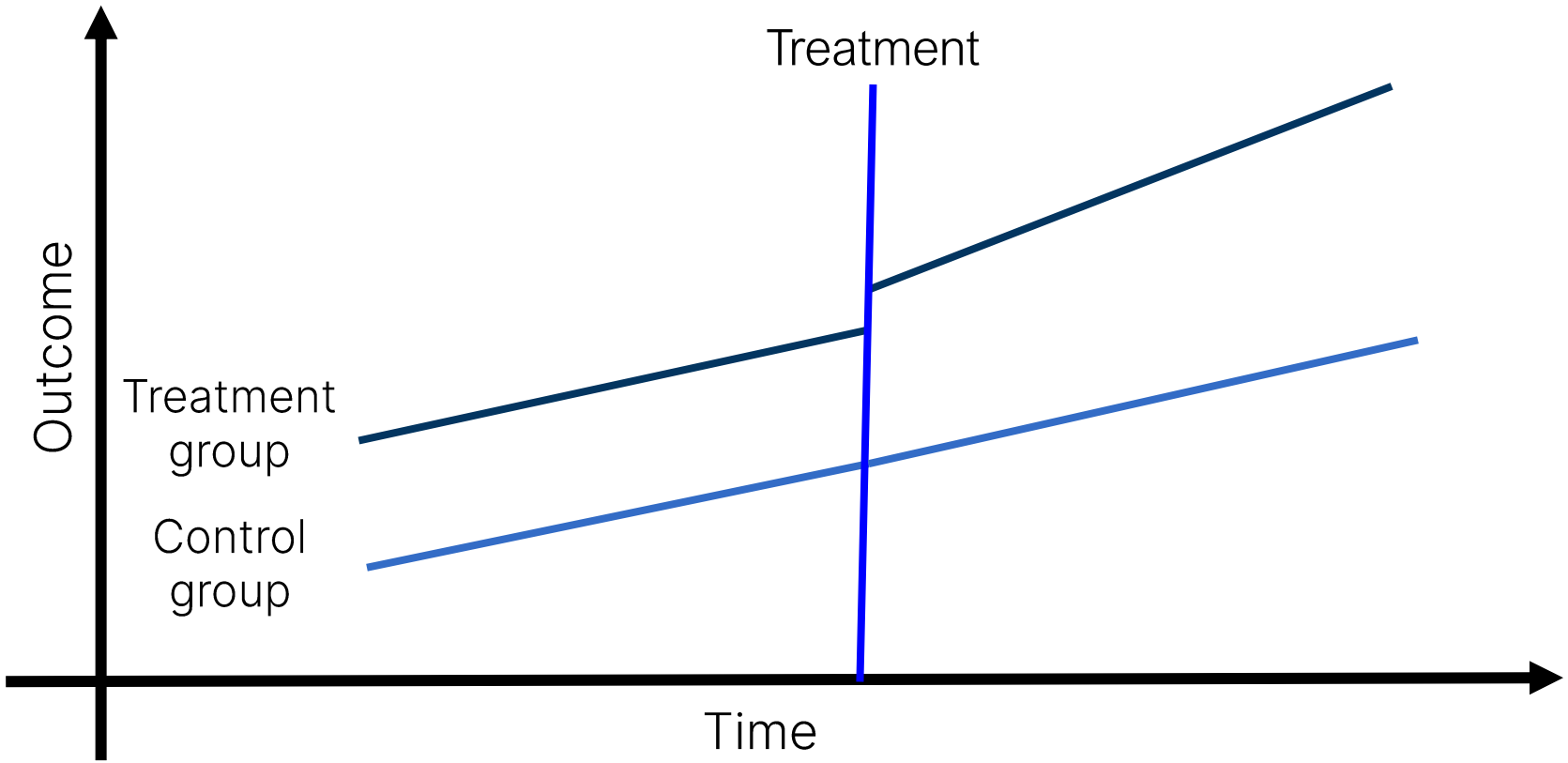
DID regression

```
. use hhabit3

. didregress (bmi i.girl i.sports) (hhabit), group(district) time(year)

Difference-in-differences regression                    Number of obs = 16,725
Data type: Repeated cross-sectional

                                (Std. err. adjusted for 40 clusters in district)
------------------------------------------------------------------------------
             |               Robust
         bmi | Coefficient  std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
ATET         |
      hhabit |
(Yes vs No)  |  -2.340611   .1951221   -12.00   0.000    -2.735282   -1.945939
------------------------------------------------------------------------------
Note: ATET estimate adjusted for covariates, group effects, and time effects.
Note: Treatment occurs at different times.
```

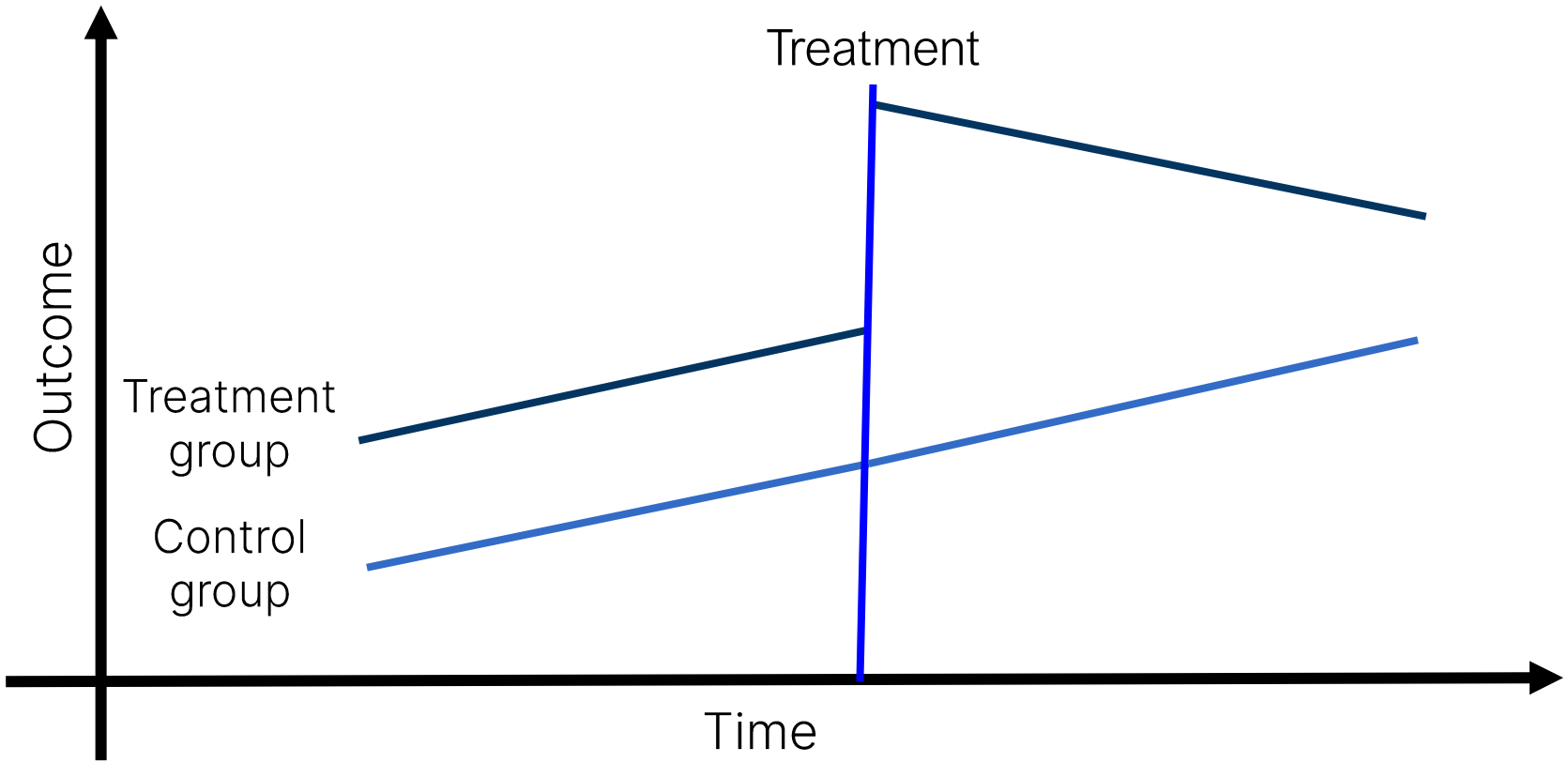
DID



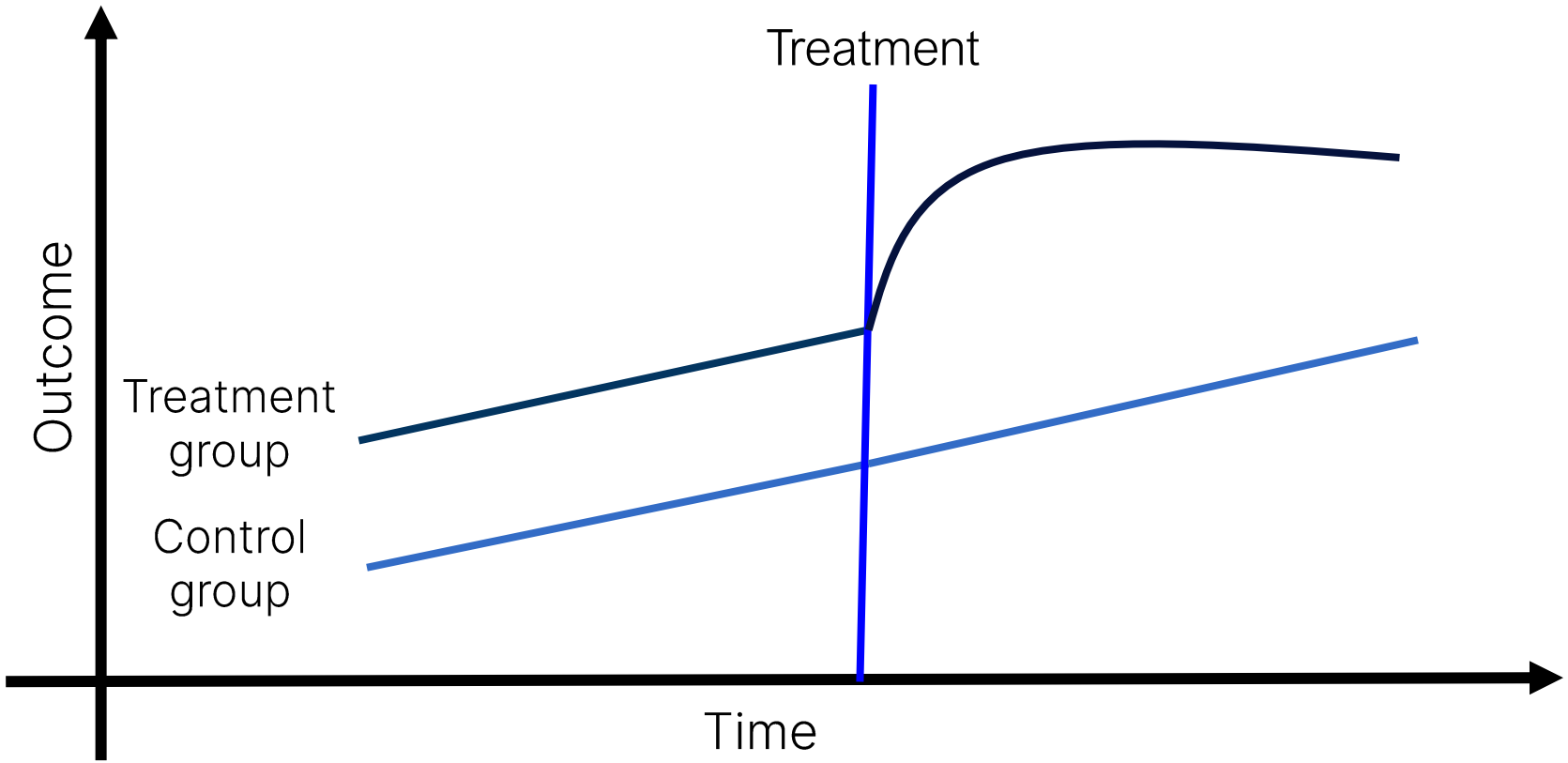
Heterogeneous DID



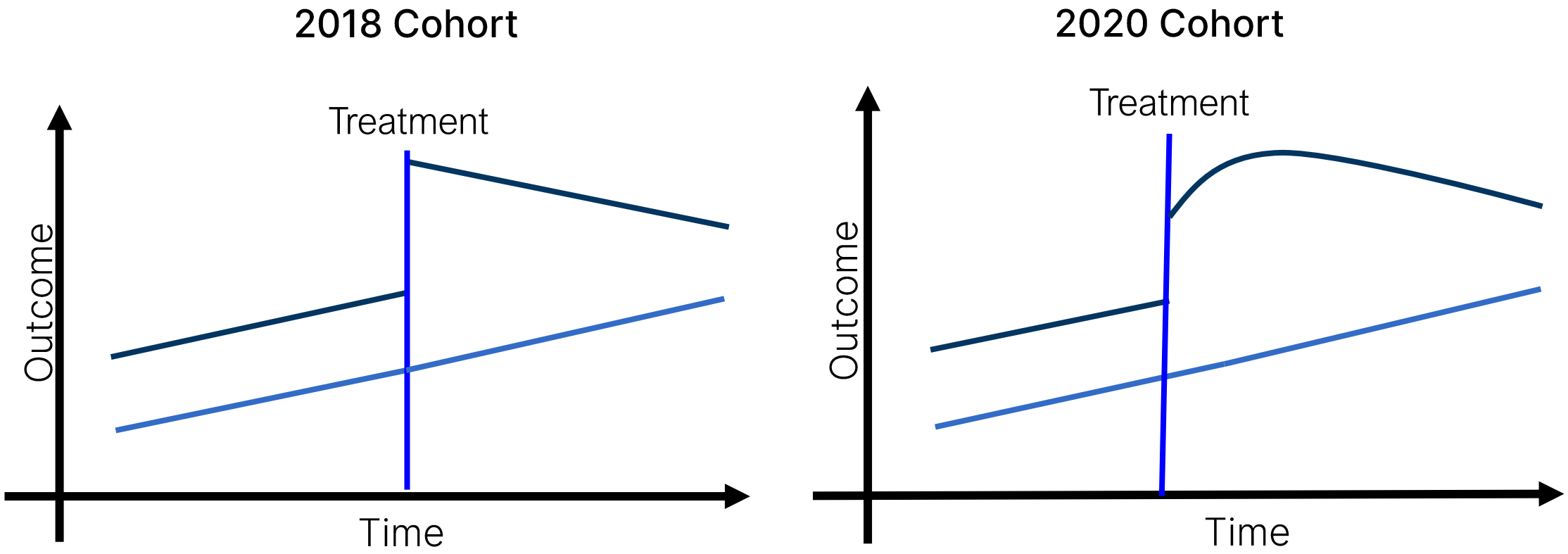
Heterogeneous DID



Heterogeneous DID



Heterogeneous DID



Heterogeneous TWFE

- First, create a cohort variable:

```
. bysort district hhabit: egen firstyear = min(year)
. bysort district: egen cohort = max(firstyear)
. replace cohort = 0 if !treatment
. egen tagme = tag(district year)

. list district year hhabit firstyear cohort if district==1 & tagme
```

	district	year	hhabit	firsty~r	cohort
1.	1	2017	No	2016	2018
2.	1	2016	No	2016	2018
102.	1	2022	Yes	2018	2018
103.	1	2024	Yes	2018	2018
104.	1	2020	Yes	2018	2018
106.	1	2023	Yes	2018	2018
107.	1	2018	Yes	2018	2018
110.	1	2019	Yes	2018	2018
119.	1	2021	Yes	2018	2018

Heterogeneous TWFE

$$y_{igCt} = \gamma_g + \gamma_t + \boldsymbol{z_{igt}}\beta + \gamma_{t|post}\gamma_C D_{Ct}\delta_{Ct} + \epsilon_{igCt}$$

i observation
g group
t time
C cohort

- Include the three-way interaction with post time and cohort

```
. regress bmi i.district i.year treatment#0.pre#year#cohort, vce(cluster district)
```

- Or use command **`hdidregress`**

```
. hdidregress twfe (bmi) (hhabit), group(district) time(year)
```

Heterogeneous TWFE

```
. hdidregress twfe (bmi i.girl i.sports) (hhabit), group(district) time(year)

Treatment and time information

Time variable: year
Time interval: 2016 to 2024
Control:       _did_cohort = 0
Treatment:     _did_cohort > 0
```

	_did_cohort
Number of cohorts	4
Number of obs	
Never treated	11355
2018	1231
2020	2097
2022	2042

```
Heterogeneous treatment-effects regression            Number of obs = 16,725
Data type:       Repeated cross-sectional
Estimator:       Two-way fixed effects
Treatment level: district
Control group:   Never treated
Heterogeneity:   Cohort and time
```

Heterogeneous treatment-effects regression Number of obs = 16,725
Data type: Repeated cross-sectional
Estimator: Two-way fixed effects
Treatment level: district
Control group: Never treated
Heterogeneity: Cohort and time

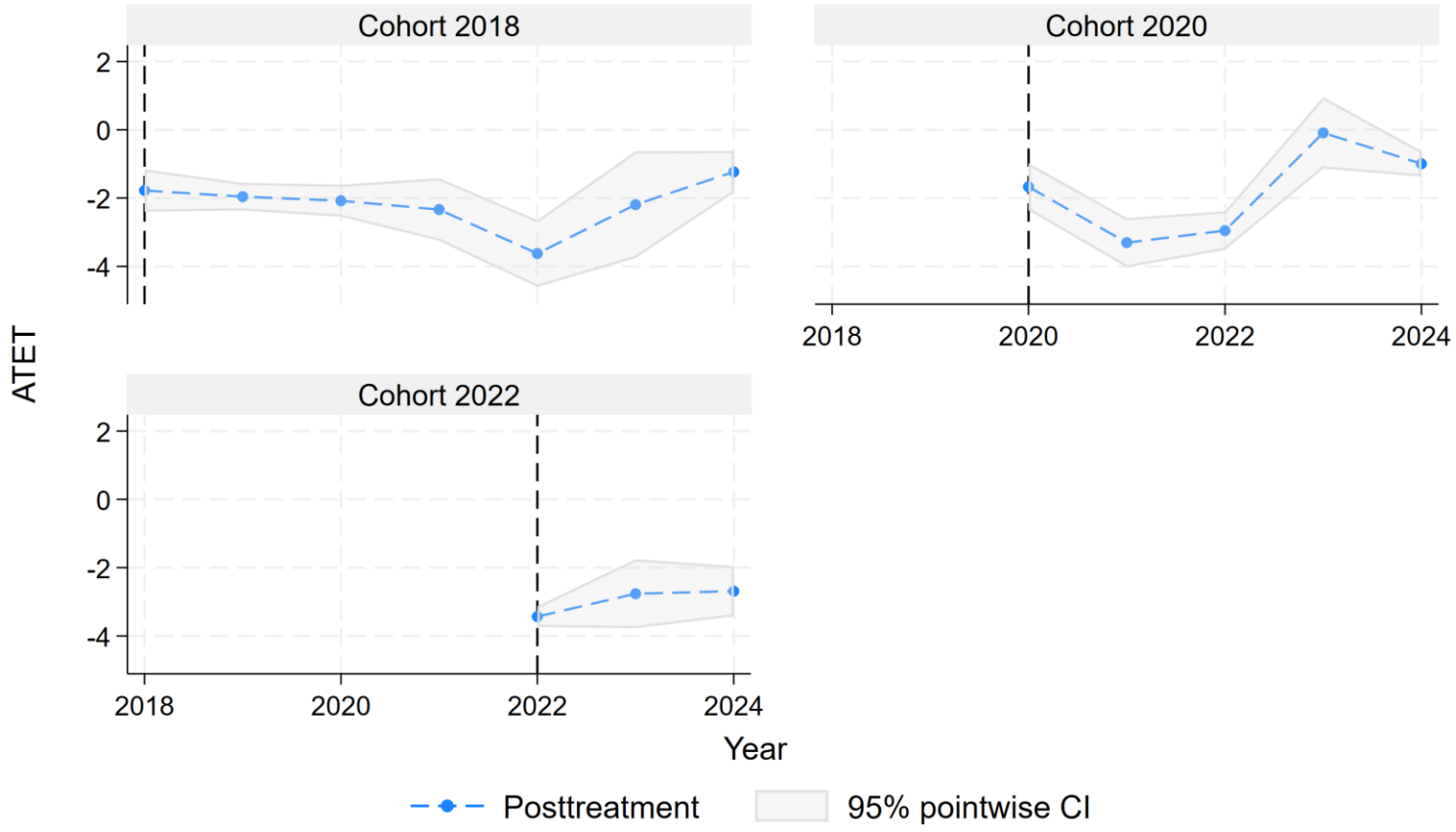
(Std. err. adjusted for 40 clusters in district)

Cohort	ATET	Robust std. err.	t	P>|t|	[95% conf.	interval]
2018						
year						
2018	-1.778337	.3072316	-5.79	0.000	-2.399771	-1.156902
2019	-1.958607	.2017833	-9.71	0.000	-2.366752	-1.550461
2020	-2.078508	.2329257	-8.92	0.000	-2.549645	-1.607371
2021	-2.335608	.4538528	-5.15	0.000	-3.253612	-1.417604
2022	-3.623921	.484945	-7.47	0.000	-4.604815	-2.643027
2023	-2.191493	.7730937	-2.83	0.007	-3.755223	-.6277634
2024	-1.233747	.3058222	-4.03	0.000	-1.852331	-.6151629
2020						
year						
2020	-1.66891	.3419441	-4.88	0.000	-2.360557	-.9772632
2021	-3.306659	.3584147	-9.23	0.000	-4.031621	-2.581697
2022	-2.952263	.2806694	-10.52	0.000	-3.51997	-2.384556
2023	-.0899332	.518215	-0.17	0.863	-1.138122	.9582555
2024	-.9960773	.1854916	-5.37	0.000	-1.37127	-.6208851
2022						
year						
2022	-3.43286	.1509675	-22.74	0.000	-3.738221	-3.127499
2023	-2.762743	.4995317	-5.53	0.000	-3.773141	-1.752344
2024	-2.688314	.3648448	-7.37	0.000	-3.426282	-1.950346

Note: ATET computed using covariates.

Visualize ATETs by cohort and time

```
. estat atetplot
```



Aggregations

`estat aggregation,`	`overall`	aggregate ATETs within cohorts and time periods; the default
	`dynamic`	aggregate ATETs within exposures to the treatment
	`time`	aggregate ATETs within time periods
	`cohort`	aggregate ATETs within cohorts
	`graph`	display the aggregation plot

Aggregations

```
. estat aggregation

Overall ATET                                    Number of obs = 16,725

                                (Std. err. adjusted for 40 clusters in district)
```

bmi	ATET	Robust std. err.	t	P>|t|	[95% conf.	interval]
hhabit (Yes vs No)	-2.226743	.18228	-12.22	0.000	-2.595439	-1.858047

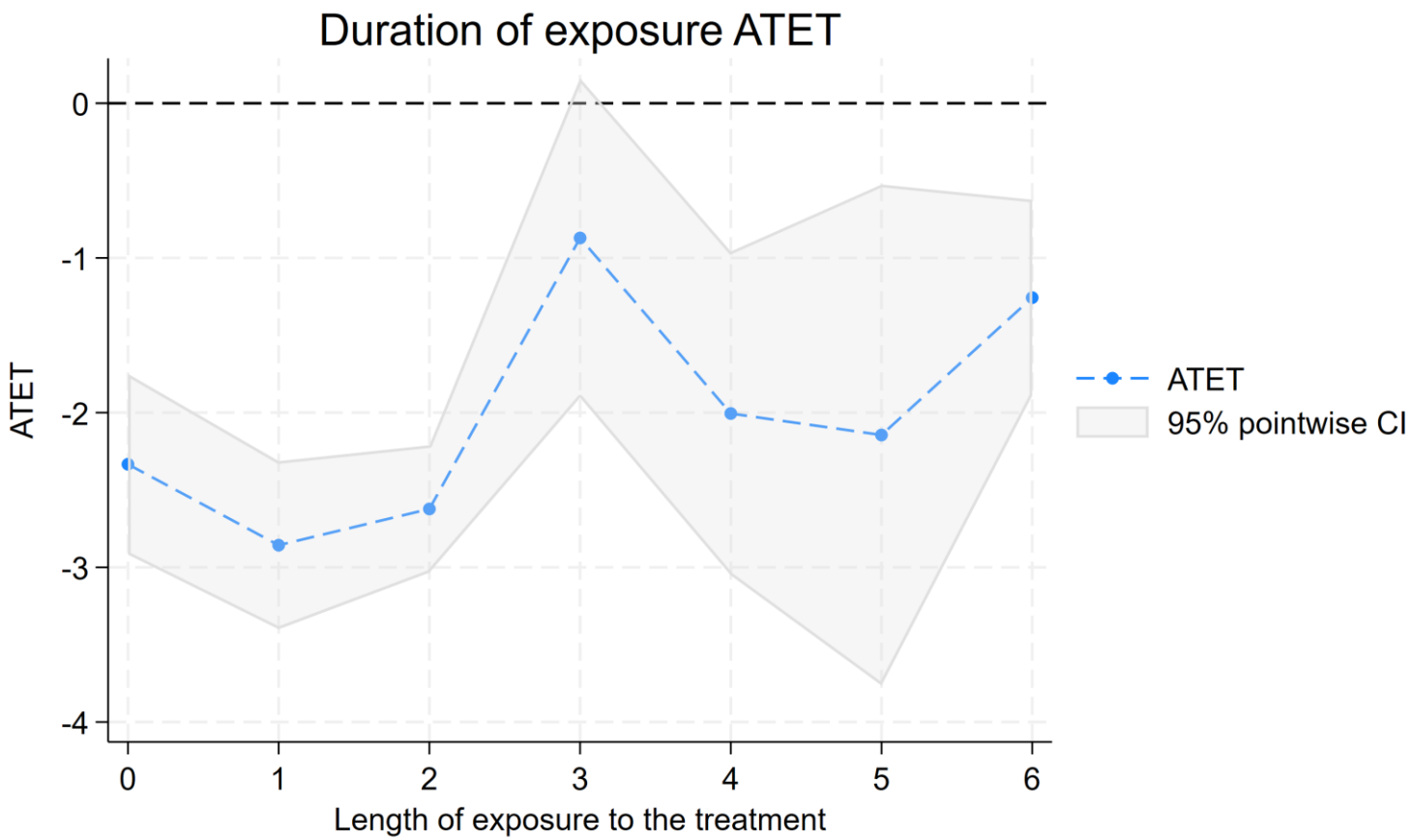
Aggregations

```
. estat aggregation, dynamic graph

Duration of exposure ATET                          Number of obs = 16,725

                                   (Std. err. adjusted for 40 clusters in district)
```

Exposure	ATET	Robust std. err.	t	P>|t|	[95% conf.	interval]
0	-2.333457	.288695	-8.08	0.000	-2.917398	-1.749516
1	-2.856789	.2685596	-10.64	0.000	-3.400002	-2.313576
2	-2.622523	.2035392	-12.88	0.000	-3.03422	-2.210826
3	-.8707736	.5103908	-1.71	0.096	-1.903136	.1615892
4	-2.005368	.5174664	-3.88	0.000	-3.052043	-.9586937
5	-2.144589	.8003042	-2.68	0.011	-3.763357	-.5258206
6	-1.256447	.3128612	-4.02	0.000	-1.889268	-.6236253

```
Note: Exposure is the number of periods since the first treatment time.
```

Aggregations

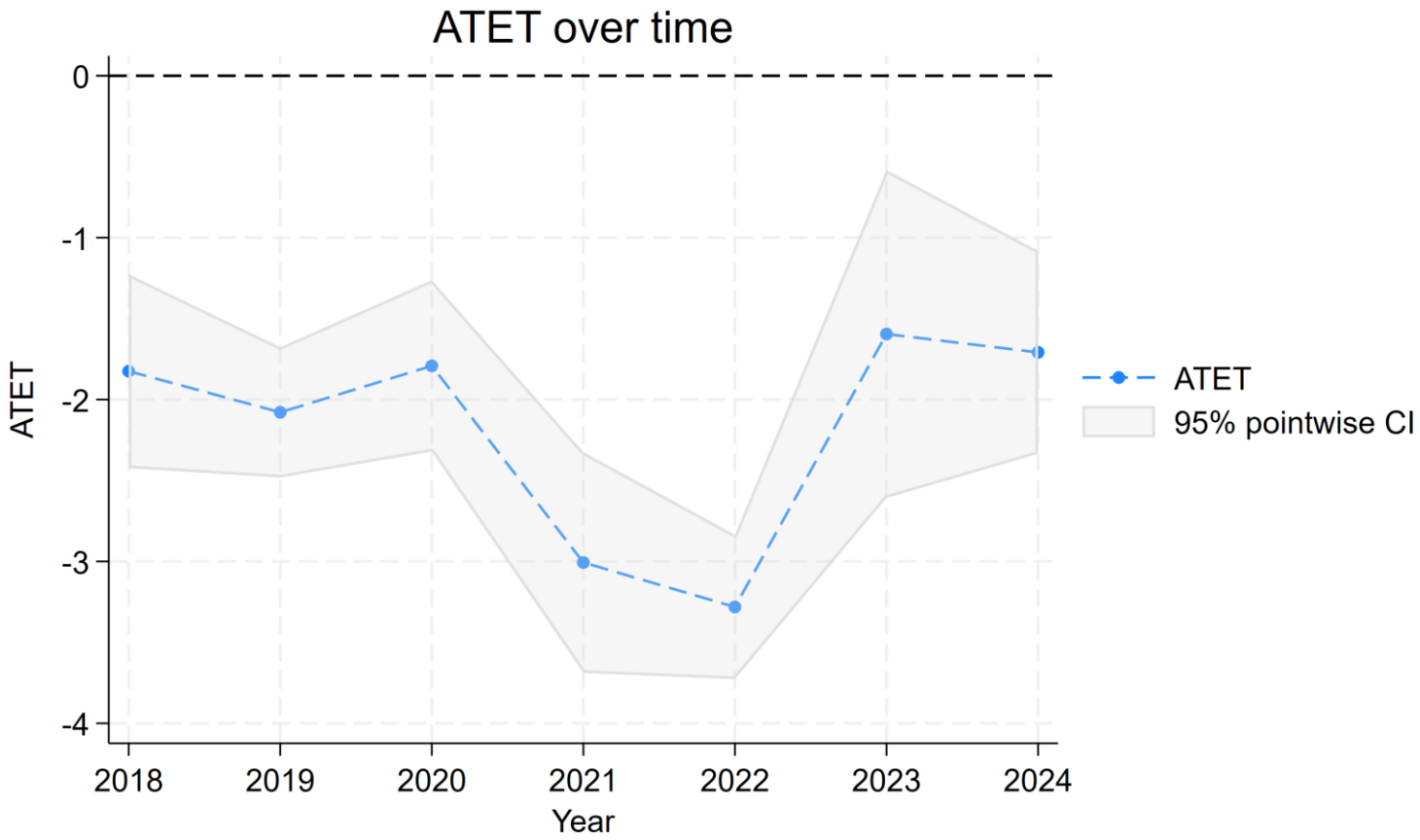


Aggregations

```
. estat aggregation, time graph

ATET over time                                  Number of obs = 16,725

                                  (Std. err. adjusted for 40 clusters in district)
```

Time	ATET	Robust std. err.	t	P>|t|	[95% conf.	interval]
2018	-1.82485	.296194	-6.16	0.000	-2.423959	-1.225741
2019	-2.078951	.1990162	-10.45	0.000	-2.4815	-1.676403
2020	-1.791954	.2616474	-6.85	0.000	-2.321186	-1.262722
2021	-3.006472	.3371145	-8.92	0.000	-3.68835	-2.324593
2022	-3.281085	.220464	-14.88	0.000	-3.727016	-2.835155
2023	-1.595299	.5005498	-3.19	0.003	-2.607757	-.5828419
2024	-1.708546	.309853	-5.51	0.000	-2.335283	-1.081809

Aggregations



Aggregations

```
. estat aggregation, cohort

ATET over cohort                                Number of obs = 16,725

                                (Std. err. adjusted for 40 clusters in district)
```

Cohort	ATET	Robust std. err.	t	P>|t|	[95% conf.	interval]
2018	-2.181784	.2444538	-8.93	0.000	-2.676238	-1.687329
2020	-1.851562	.1949819	-9.50	0.000	-2.24595	-1.457174
2022	-2.955739	.2123999	-13.92	0.000	-3.385358	-2.526119

Constrain cohort effects

```
. hdidregress twfe (bmi i.girl i.sports) (hhabit), group(district) time(year) hettype(time)

Heterogeneous treatment-effects regression              Number of obs = 16,725
Data type:       Repeated cross-sectional
Estimator:       Two-way fixed effects
Treatment level: district
Control group:   Never treated
Heterogeneity:   Time

                              (Std. err. adjusted for 40 clusters in district)
```

Cohort	ATET	Robust std. err.	t	P>|t|	[95% conf.	interval]
year						
2018	-1.894845	.3354881	-5.65	0.000	-2.573434	-1.216256
2019	-1.970336	.3191638	-6.17	0.000	-2.615906	-1.324766
2020	-2.084416	.2635516	-7.91	0.000	-2.6175	-1.551333
2021	-3.287492	.3853363	-8.53	0.000	-4.066908	-2.508075
2022	-3.354472	.2075074	-16.17	0.000	-3.774195	-2.934748
2023	-1.65903	.495814	-3.35	0.002	-2.661908	-.6561514
2024	-1.77315	.3215191	-5.51	0.000	-2.423484	-1.122817

```
Note: ATET computed using covariates.

.
```

Constrain time effects

```
. hdidregress twfe (bmi i.girl i.sports) (hhabit), group(district) time(year) hettype(cohort)

Heterogeneous treatment-effects regression              Number of obs = 16,725
Data type:       Repeated cross-sectional
Estimator:       Two-way fixed effects
Treatment level: district
Control group:   Never treated
Heterogeneity:   Cohort

                              (Std. err. adjusted for 40 clusters in district)
```

Cohort	ATET	Robust std. err.	t	P>|t|	[95% conf.	interval]
2018	-2.186048	.2379634	-9.19	0.000	-2.667375	-1.704722
2020	-1.83563	.1947801	-9.42	0.000	-2.22961	-1.44165
2022	-3.027139	.2130329	-14.21	0.000	-3.458038	-2.596239

```
Note: ATET computed using covariates.

.
```

Other estimators

Estimator	Option	Outcome model	Treatment model
Two-way fixed effect	`twfe`	YES	NO
Regression adjustment	`ra`	YES	NO
Inverse-probability weighting	`ipw`	NO	YES
Augmented inverse-probability weighting	`aipw`	YES	YES

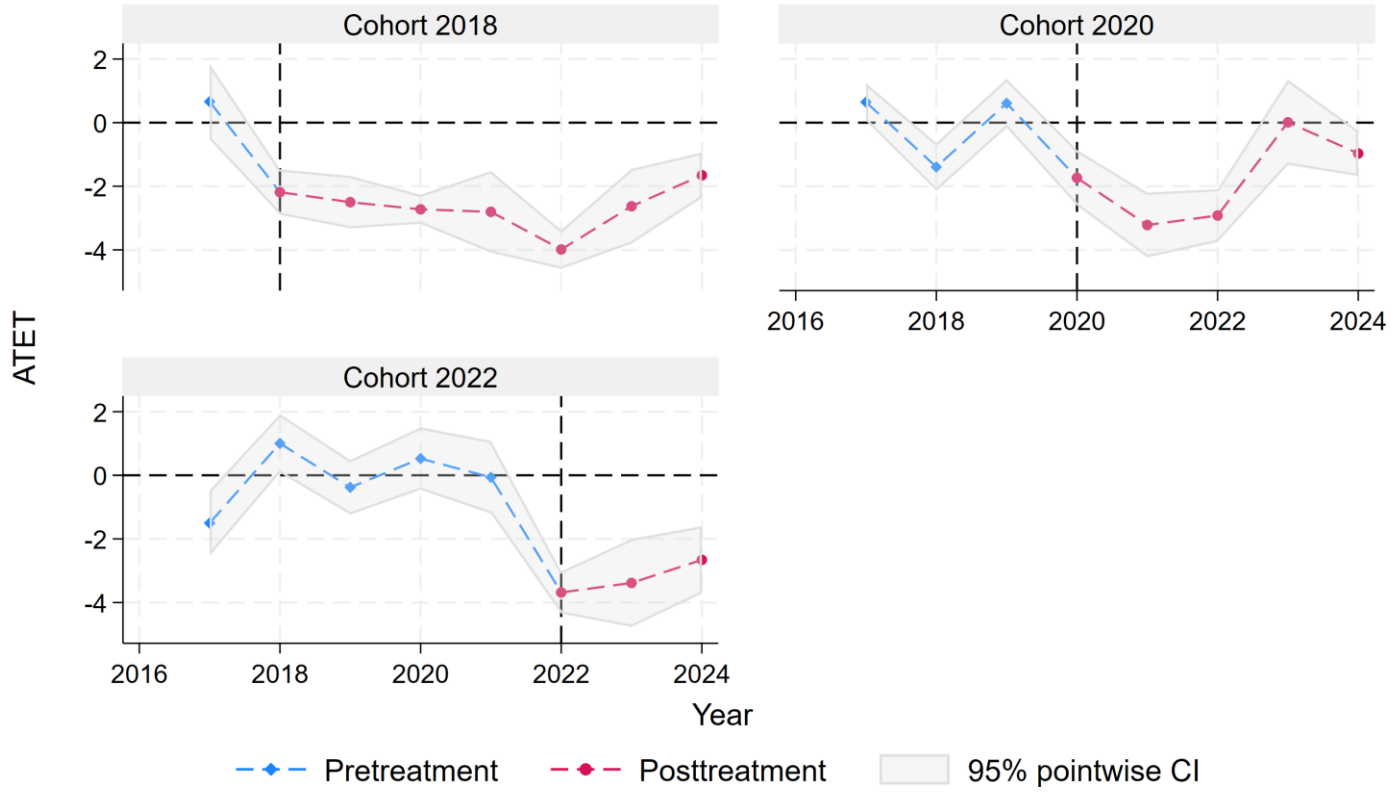
Heterogeneous DID with AIPW

```
. hdidregress aipw (bmi i.girl i.sports) (hhabit parksd medu), group(district) time(year)

Heterogeneous treatment-effects regression              Number of obs = 16,725
Estimator:       Augmented IPW
Treatment level: district
Control group:   Never treated

                                (Std. err. adjusted for 40 clusters in district)
```

Cohort	ATET	Robust std. err.	z	P>|z|	[95% conf.	interval]
2018						
year						
2017	.6610372	.6068607	1.09	0.276	-.5283878	1.850462
2018	-2.184167	.3638684	-6.00	0.000	-2.897336	-1.470998
2019	-2.499109	.4201546	-5.95	0.000	-3.322597	-1.675621
2020	-2.724452	.232414	-11.72	0.000	-3.179975	-2.268929
2021	-2.803982	.6541718	-4.29	0.000	-4.086136	-1.521829
2022	-3.986615	.310742	-12.83	0.000	-4.595658	-3.377572
2023	-2.627951	.59908	-4.39	0.000	-3.802126	-1.453776
2024	-1.653263	.3645688	-4.53	0.000	-2.367805	-.9387212
2020						
year						
2017	.6468236	.3014149	2.15	0.032	.0560614	1.237586
2018	-1.39342	.3832857	-3.64	0.000	-2.144646	-.6421936
2019	.6095265	.3913018	1.56	0.119	-.157411	1.376464
2020	-1.734927	.4457704	-3.89	0.000	-2.608621	-.8612329
2021	-3.21896	.5187638	-6.21	0.000	-4.235718	-2.202201

Heterogeneous DID with AIPW

```
. estat atetplot
```



Test for parallel trends

```
. estat ptrends

Parallel-trends test (pretreatment time period)
H0: Treatment effects in all the pretreatment periods are zero

    chi2(9) =  33.93
Prob > chi2 = 0.0001
```

Meghan K. Cain, Ph.D.
mcain@stata.com