

Heterogeneous DID with first-switch designs

StataCorp LLC

October 1, 2026

The plan

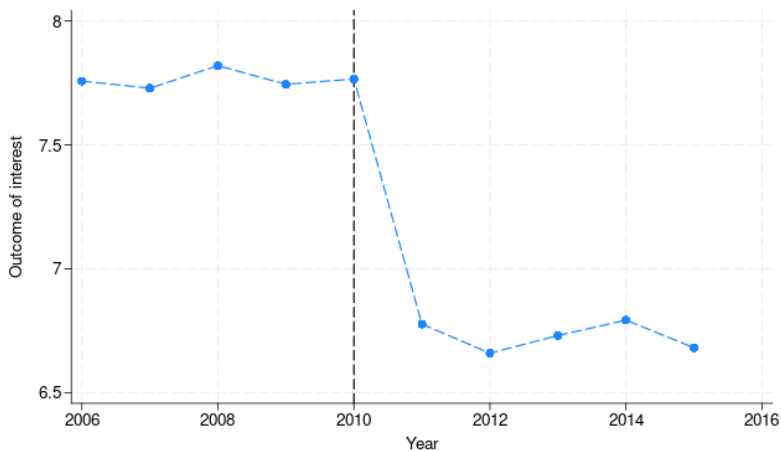
- Present the command `xtswitchdid`
- Acknowledgements and caveats

The plan

- Present the command `xtswitchdid`
- Acknowledgements and caveats
- Provide historical background
- Provide some Stata background
- Present some theory
- A plausible workflow

- We are interested in the effect of a treatment on an outcome for those that were subject to the treatment (ATET)
- We are interested in how that effect evolves over time
- We are interested in ascertaining causality of our estimates
- Repeated measures (panel data or repeated cross-sectional data)

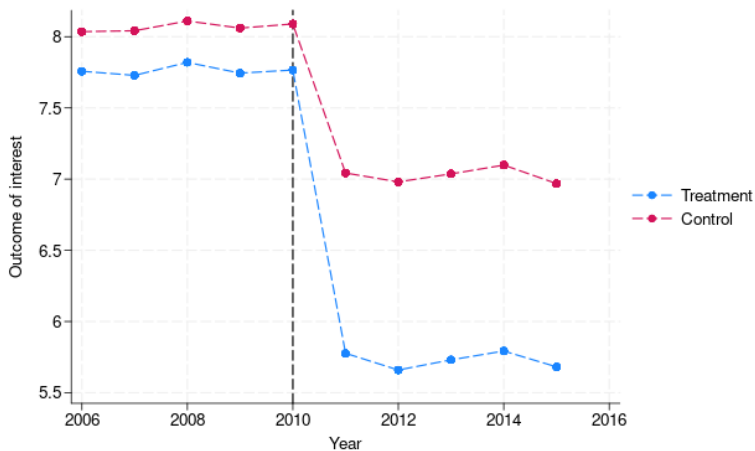
Antebellum DID



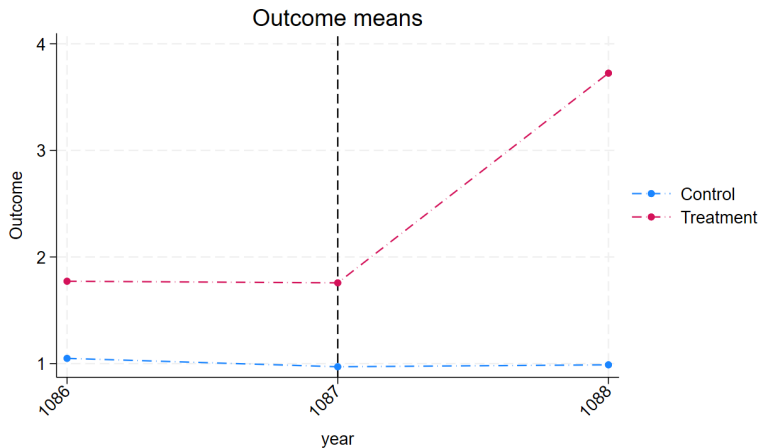
Antebellum DID



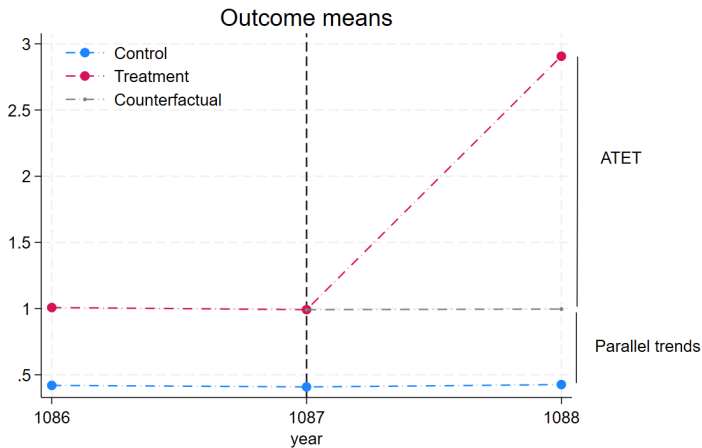
Antebellum DID



Antebellum DID



Antebellum DID



Antebellum DID

- DID was obtained via

$$y_{it} = \beta_0 + D_{it}\beta_1 + \gamma_t + \gamma_g + e_{it}$$

- β_1 is the ATET
- A generalization of the well understood 2 by 2 model.

Antebellum DID

- DID was obtained via

$$y_{it} = \beta_0 + D_{it}\beta_1 + \gamma_t + \gamma_g + e_{it}$$

- β_1 is the ATET
- A generalization of the well understood 2 by 2 model.
- Two-way fixed-effects (TWFE) was criticized in the last 10 years
- Why:
 - 1 Homogeneity (well understood)
 - 2 Hidden cost of generalizing of 2 by 2

What happens when we go beyond the 2 by 2 model?

- ATET might be different for groups treated at different times
- Within groups, ATET might change over time
- If this is the case:

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- Weighted average
 - Borusyak, Jaravel, and Spiess (2024)
 - de Chaisemartin and D'Haultfoeuille (2020)
 - Goodman-Bacon (2021) (estat bdecomp)

Some heterogeneous treatment effects approaches

- Solution 1: Callaway and Sant'Anna (2021)
 - Use valid comparison groups
 - Split the problem into 2 by 2 comparisons
 - Compute $ATET(g, t)$, where g is the cohort and t is the time
- Solution 2: Wooldridge (2021)
 - (Do not blame the messenger) Include heterogeneity in your regression
 - Add the adequate interactions with cohort and time
 - Compute $ATET(g, t)$, where g is the cohort and t is the time
 - Computing $ATET(g)$ or $ATET(t)$ is also possible

What the solutions need

- Staggered
- In the first period everyone is untreated
- Treatment is binary

de Chaisemartin and D'Haultfoeuille (2020 and 2024)

- Units can switch treatment status
- First treatment level does not need to be baseline (0)
- Treatment may be multivalued
- Lagged treatment may affect outcome (2024)

Setup I

- Group level panel data $Y_{g,t}$, $g = 1, \dots, G$ and $t = 1, \dots, T$
- Treatments are a sequence $(0, 0, \dots, 0)$, $(0, 2, \dots, 0)$
 - Initial treatment level $D_{g,1}$
 - $D_g = (D_{g,1}, \dots, D_{g,T}) = (d_1, \dots, d_T) = (2, 1, \dots, 0)$
 - $D_g = (D_{g,1}, \dots, D_{g,T}) = (d_1, \dots, d_T) = (3, 4, \dots, 3)$
 - $D_g = (D_{g,1}, \dots, D_{g,T}) = (d_1, \dots, d_T) = (3, 4, \dots, 2)$
- F_g First period at which a group's treatment changes
- Inference is conditional on the observed treatment sequence **D**

Setup II

- Potential outcomes are $Y_{g,t} = Y(d_1, \dots, d_t, \dots, d_T)$
- Comparison group: Those that have the same initial treatment level but have not changed their treatment status.
 - $T_g = \max_{g': D_{g',1} = D_{g,1}} F_{g'} - 1$
- No anticipation: $Y_{g,t}(d_1, \dots, d_T) = Y_{g,t}(d_1, \dots, d_t)$
- Parallel trends: $E[Y_{g,t}(\mathbf{D}_{g,1,t}) - Y_{g,t-1}(\mathbf{D}_{g,1,t-1}) | \mathbf{D}] = E[Y_{g',t}(\mathbf{D}_{g',1,t}) - Y_{g',t-1}(\mathbf{D}_{g',1,t-1}) | \mathbf{D}]$

Population parameters

$$E \left[Y_{g,F_g} - Y_{g,F_g}(D_{g,1}, \dots, D_{g,1}) \mid \mathbf{D} \right]$$

- Suppose there are two periods $t = 1, 2$, $F_g = 2$, and $D_{g,1} = 0$

Population parameters

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- Suppose there are two periods $t = 1, 2$, $F_g = 2$, and $D_{g,1} = 0$
- The population parameter is then $E[Y_{g,2} - Y_{g,2}(0, 0) | \mathbf{D}]$

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- The population parameter is then $E \left[Y_{g,2} - Y_{g,2} (0, 0) \mid \mathbf{D} \right]$
- But we can also think about population parameters of the form:
 - $E \left[Y_{g,F_{g+1}} - Y_{g,F_{g+1}} (D_{g,1}, \dots, D_{g,1}) \mid \mathbf{D} \right]$
 - $E \left[Y_{g,F_{g+2}} - Y_{g,F_{g+2}} (D_{g,1}, \dots, D_{g,1}) \mid \mathbf{D} \right]$

Population parameters

$$E \left[Y_{g,F_g} - Y_{g,F_g} (D_{g,1}, \dots, D_{g,1}) \mid \mathbf{D} \right]$$

- Suppose there are two periods $t = 1, 2$, $F_g = 2$, and $D_{g,1} = 0$
- The population parameter is then $E \left[Y_{g,2} - Y_{g,2} (0, 0) \mid \mathbf{D} \right]$
- But we can also think about population parameters of the form:
 - $E \left[Y_{g,F_{g+1}} - Y_{g,F_{g+1}} (D_{g,1}, \dots, D_{g,1}) \mid \mathbf{D} \right]$
 - $E \left[Y_{g,F_{g+2}} - Y_{g,F_{g+2}} (D_{g,1}, \dots, D_{g,1}) \mid \mathbf{D} \right]$
- And so forth for a set of parameters indexed by l periods away from the initial intervention, F_{g-1+l} for $l = 1, \dots, T_g - F_g - 1$, i.e. as long as we have comparison groups

Estimator

- So the population parameter is given by
$$\delta_{g,l} = E \left[Y_{g,F_{g-1+l}} - Y_{g,F_{g-1+l}} (D_{g,1}, \dots, D_{g,1}) | \mathbf{D} \right]$$
- $E \left[Y_{g,F_{g-1+l}} - Y_{g,F_{g-1+l}} (D_{g,1}, \dots, D_{g,1}) | \mathbf{D} \right]$
- The estimator is given by
$$DID_{g,l} = Y_{g,F_{g-1+l}} - Y_{g,F_{g-1}} - \frac{1}{N_g''} \sum_{g''} (Y_{g'',F_{g-1+l}} - Y_{g'',F_{g-1}})$$
- DID estimators that compares outcome evolution relative to the status quo.

Event study effects

- We need to think of representing $DID_{g,l}$ over all groups g and exposure to treatment for l periods.
- By construction sequences of treatments could be increasing or decreasing. Letting $S_g = 1 \{D_{F_g} > D_{g,1}\} - 1 \{D_{F_g} < D_{g,1}\}$ we can aggregate effects in such way that:
 - $\delta_l = \frac{1}{N_l} \sum_g S_g \delta_{g,l}$
- It is an average effect of being exposed to a weakly higher treatment for l periods

Normalized event-study effects

- We can think of dosage evolving over time
- $\delta_{g,l}^D = \sum_{k=1}^l (D_{g,F_g-1+k} - D_{g,1})$

Normalized event-study effects

- We can think of dosage evolving over time
- $\delta_{g,l}^D = \sum_{k=1}^l (D_{g,F_g-1+k} - D_{g,1})$
- We can think of a weighted average of current and l treatment lags
- $\delta_{g,l}^n = \frac{\delta_{g,l}}{\delta_{g,l}^D}$
- $\delta_l^D = \sum_g |\delta_{g,l}^D|$
- $\delta_l^n = \sum_g \frac{\delta_{g,l}^n |\delta_{g,l}^D|}{\delta_l^D}$ which in turn gives $\delta_l^n = \frac{\delta_l}{\delta_l^D}$
- Effect of the current and $l - 1$ treatment on the outcome

Let's see it work

```
. describe
Contains data from hockey.dta
Observations:      6,877              Fictional minor hockey team
                                      injury data
Variables:          8                25 Apr 2026 15:43
```

Variable name	Storage type	Display format	Value label	Variable label
league	byte	%8.0g	region	League
team	int	%9.0g		Team
year	int	%9.0g		Year
region	byte	%8.0g		Region
injrate	int	%10.0g		Player injury days
safety	byte	%8.0g		Number of safety measures
lwinpct	double	%10.0g		Team win percentage
schedule	double	%10.0g		Schedule intensity

Sorted by: team year

Inspecting the data I

```
. xtset team year
Panel variable: team (unbalanced)
Time variable: year, 2010 to 2025
Delta: 1 unit
```

Inspecting the data I

```
. xtset team year
Panel variable: team (unbalanced)
Time variable: year, 2010 to 2025
Delta: 1 unit
```

```
. xttrans safety
```

Number of safety measures	Number of safety measures				Total
	0	1	2	3	
0	90.36	0.71	8.02	0.91	100.00
1	0.00	82.73	17.27	0.00	100.00
2	1.77	0.00	93.20	5.03	100.00
3	0.00	0.00	0.00	100.00	100.00
Total	28.64	9.18	50.29	11.89	100.00

Inspecting your data II

```
. tabulate year safety
```

Year	Number of safety measures				Total
	0	1	2	3	
2010	213	121	41	0	375
2011	215	122	42	0	379
2012	43	30	306	0	379
2013	96	48	314	0	458
2014	100	34	328	0	462
2015	100	34	328	0	462
2016	100	34	328	0	462
2017	156	34	261	11	462
2018	156	34	261	11	462
2019	156	34	261	11	462
2020	141	34	233	11	419
2021	141	34	233	11	419
2022	123	34	85	177	419
2023	123	34	85	177	419
2024	123	34	85	177	419
2025	123	34	85	177	419
Total	2,109	729	3,276	763	6,877

syntax

```
xtswitchdid (yvar xvars) (tvar), group(groupvar) [opts]
```

Output table I

```
. xtswitchdid (injrate lwinpct schedule) (safety), group(team)
```

Treatment and time information

Panel variable: team

Time variable: year

Time interval: 2010 thru 2025

Treatment level: team

Control: safety maintaining baseline

Treatment: safety changing from baseline

Initial treatment	Groups	Obs	Switch out	Switch in	Absorbing
0	272	3749		1 2 3	No
1	140	1956		2 3	No
2	50	723		3	Yes

(output omitted)

Output table II

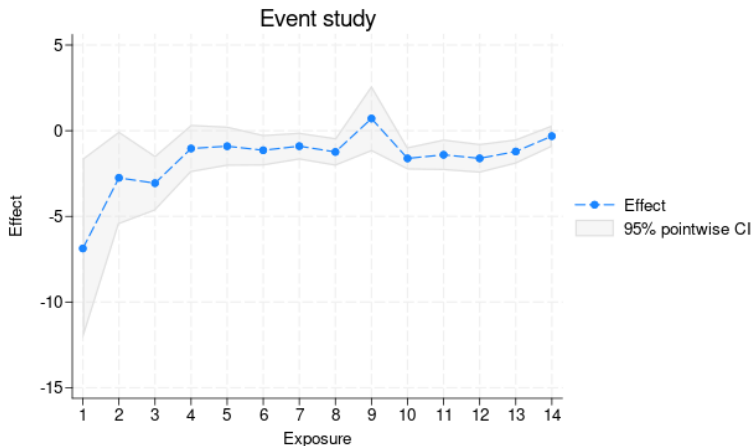
```
. xtswitchdid (injrate lwinpct schedule) (safety), group(team)
      (output omitted)
DID with switching treatments                                Number of obs   = 6,428
                                                            Number of panels = 462
                                                            Number of groups = 462
                                                            (Std. err. adjusted for 462 clusters in team)
```

Exposure	Normalized effect	Robust std. err.	z	P> z	[95% conf. interval]	
1	-6.871766	2.679854	-2.56	0.010	-12.12418	-1.619348
2	-2.75066	1.380428	-1.99	0.046	-5.45625	-.0450695
3	-3.061524	.8162018	-3.75	0.000	-4.66125	-1.461798
4	-1.038777	.7065305	-1.47	0.141	-2.423551	.3459975
5	-.9033563	.5854862	-1.54	0.123	-2.050888	.2441756
6	-1.140814	.4573033	-2.49	0.013	-2.037112	-.2445157
7	-.9005077	.4021147	-2.24	0.025	-1.688638	-.1123773
8	-1.239846	.4123365	-3.01	0.003	-2.048011	-.4316814
9	.7121286	.9774432	0.73	0.466	-1.203625	2.627882
10	-1.615785	.3346074	-4.83	0.000	-2.271603	-.9599661
11	-1.405509	.457877	-3.07	0.002	-2.302931	-.5080862
12	-1.613272	.430911	-3.74	0.000	-2.457842	-.7687025
13	-1.213585	.3641668	-3.33	0.001	-1.927339	-.4998312
14	-.3144064	.3203691	-0.98	0.326	-.9423183	.3135055

Note: effects computed using covariates.

Event study plot

```
. estat eventplot
```



Aggregating

```
. estat total
Average total effect per unit of treatment      Number of obs   = 6,428
                                                Number of panels =  462
                                                Number of groups =  462
                                                (Std. err. adjusted for 462 clusters in team)
```

	Effect	Robust std. err.	z	P> z	[95% conf. interval]	
injrate						
safety	-8.65764	2.281467	-3.79	0.000	-13.12923	-4.186046

Switching dynamics and paths

```
. estat paths
note: pathlen() not specified; using path length 14.
note: variable _did_paths, which encodes a unique value for each treatment
      path, was added to the dataset.
```

Distribution of treatment paths

Path length: 14, not counting initial treatment

Treatment: team changing initial treatment level

Paths	Freq.	Percent	Cum.
0 1 1 2 2 2 2 2 2 . 2 2 2 2 2	14	4.56	4.56
0 2 . 2 2 2 2 2 2	1	0.33	4.89
0 2 2 2 . 2 2 2 2 . 2 3 3 3 3	3	0.98	5.86
0 2 2 2 2 2 0 0 . . 0 0 0 0 0	1	0.33	6.19
0 2 2 2 2 2 0 0 0 . 0 0 0 0 0	55	17.92	24.10
0 2 2 2 2 2 2 2 . . 2 3 3 3 3	1	0.33	24.43
0 2 2 2 2 2 2 2 . 2 3 3 3 3 .	1	0.33	24.76
0 2 2 2 2 2 2 2 2	11	3.58	28.34
0 2 2 2 2 2 2 2 2 . . 3 3 3 3	2	0.65	28.99
0 2 2 2 2 2 2 2 2 . 2 3 3 3 .	1	0.33	29.32
0 2 2 2 2 2 2 2 2 . 2 3 3 3 3	82	26.71	56.03
0 3 3 3 3	18	5.86	61.89
1 2 . 2 2 2 2 2 2 . 2 2 2 2 2	1	0.33	62.21
1 2 2 2 2 2 2 . 2 . 2 2 2 2 2	1	0.33	62.54
1 2 2 2 2 2 2 2 2	16	5.21	67.75
1 2 2 2 2 2 2 2 2 . 2 . 3 3 3	1	0.33	68.08
1 2 2 2 2 2 2 2 2 . 2 2 2 2 2	30	9.77	77.85
1 2 2 2 2 2 2 2 2 . 2 3 3 3 3	57	18.57	96.42
2 3 3 3 . 3 3 3 3 3	11	3.58	100.00

Switching dynamics and paths

```
. list team year safety _did_paths in 1/16, sepby(team) noobs
```

team	year	safety	_did_paths																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
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Switching dynamics and paths

```
. quietly estat paths, generate(safetypath)
. describe safetypath*
```

Variable name	Storage type	Display format	Value label	Variable label
safetypath1	byte	%8.0g		_did_paths==0 1 1 2 2 2 2 2 2 . 2 2 2 2 2
safetypath2	byte	%8.0g		_did_paths==0 2 . 2 2 2 2 2 2
safetypath3	byte	%8.0g		_did_paths==0 2 2 2 . 2 2 2 2 . 2 3 3 3 3
safetypath4	byte	%8.0g		_did_paths==0 2 2 2 2 2 0 0 . . 0 0 0 0 0
safetypath5	byte	%8.0g		_did_paths==0 2 2 2 2 2 0 0 0 . 0 0 0 0 0
safetypath6	byte	%8.0g		_did_paths==0 2 2 2 2 2 2 2 . . 2 3 3 3 3
safetypath7	byte	%8.0g		_did_paths==0 2 2 2 2 2 2 2 . 2 3 3 3 3 .
safetypath8	byte	%8.0g		_did_paths==0 2 2 2 2 2 2 2 2
safetypath9	byte	%8.0g		_did_paths==0 2 2 2 2 2 2 2 2 . . 3 3 3 3
safetypath10	byte	%8.0g		_did_paths==0 2 2 2 2 2 2 2 2 . 2 3 3 3 .
safetypath11	byte	%8.0g		_did_paths==0 2 2 2 2 2 2 2 2 . 2 3 3 3 3
<i>(output omitted)</i>				
safetypath18	byte	%8.0g		_did_paths==1 2 2 2 2 2 2 2 2 . 2 3 3 3 3
safetypath19	byte	%8.0g		_did_paths==2 3 3 3 . 3 3 3 3 3

Switching dynamics and paths

```
. xtswitchdid (injrate lwinpct schedule) (safety), group(team) path(safetypath5
> )
```

note: 4 groups with only a single available time period were dropped.

note: effect of exposure 9 cannot be estimated because of missing data.

DID with switching treatments

Number of obs = 2,222

Number of panels = 268

Number of groups = 268

Treatment path: (0 2 2 2 2 2 0 0 0 . 0 0 0 0 0)

Treatment type: Switcher-in, nonabsorbing

(Std. err. adjusted for 268 clusters in team)

	Normalized effect	Robust std. err.	z	P> z	[95% conf. interval]	
Exposure						
1	-8.803413	3.036455	-2.90	0.004	-14.75476	-2.85207
2	-3.423294	1.351155	-2.53	0.011	-6.071509	-.7750789
3	-2.574106	.9883007	-2.60	0.009	-4.51114	-.6370724
4	-1.090292	.8124545	-1.34	0.180	-2.682673	.50209
5	-.3275366	.6412151	-0.51	0.609	-1.584295	.9292218
6	-1.138047	.5870595	-1.94	0.053	-2.288663	.0125683
7	-1.17035	.5815419	-2.01	0.044	-2.310152	-.0305493
8	-1.320975	.5834758	-2.26	0.024	-2.464567	-.1773839
9	0	(omitted)				
10	-.9877028	.5803887	-1.70	0.089	-2.125244	.1498381
11	-.9415612	.927531	-1.02	0.310	-2.759489	.8763662
12	-1.390374	.9659295	-1.44	0.150	-3.283561	.5028133
13	-.3080592	.9232056	-0.33	0.739	-2.117509	1.501391
14	-.8733448	.8459017	-1.03	0.302	-2.531282	.7845921

Testing parallel trends and anticipation

```
. quietly xtswitchdid (injrate lwinpct schedule) (safety), group(team)
. estat ptrends
Placebo estimates
```

Number of obs = 6,428

Number of panels = 462

Number of groups = 462

(Std. err. adjusted for 462 clusters in team)

Placebo	Normalized effect	Robust std. err.	z	P> z	[95% conf. interval]	
-6	1.181488	2.081433	0.57	0.570	-2.898045	5.261022
-5	.4904605	2.581445	0.19	0.849	-4.569079	5.55
-4	-.4558745	.6090937	-0.75	0.454	-1.649676	.7379272
-3	1.016594	.7035227	1.45	0.148	-.3622855	2.395473
-2	-.3029398	1.40519	-0.22	0.829	-3.057062	2.451182
-1	-4.016654	3.185429	-1.26	0.207	-10.25998	2.226673

Test of parallel-trends and no-anticipation assumptions

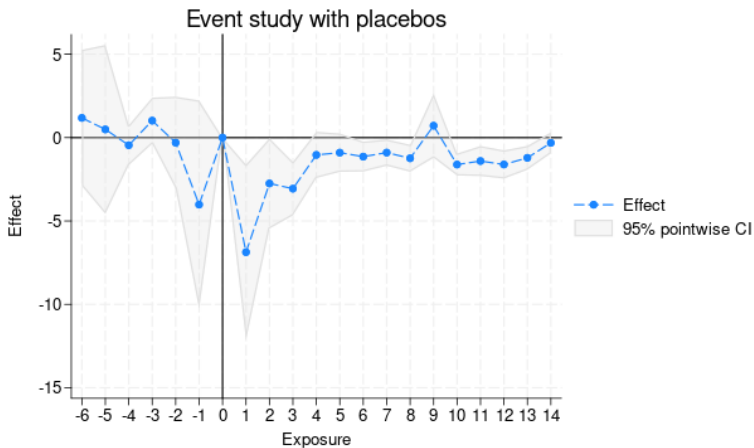
H0: Placebos are zero for all exposures

chi2(6) = 6.55

Prob > chi2 = 0.3647

Placebos

. estat ptrends, graph alleffects



Controlling your controls

```
. xtswitchdid (injrate lwinpct schedule) (safety), group(team) supergroup(regio  
> n)  
note: 4 initial treatment/supergroup combinations were dropped; no switchers.  
note: 3 initial treatment/supergroup combinations were dropped; no controls.  
note: 1 initial treatment/supergroup combination was dropped; insufficient data  
> .  
note: effect of exposure 9 cannot be estimated because of missing data.  
Treatment and time information  
Panel variable:  team  
Time variable:   year  
Time interval:   2010 thru 2025  
Treatment level: team  
Control:         safety maintaining baseline  
Treatment:       safety changing from baseline
```

Initial treatment	Groups	Obs	Switch out	Switch in	Absorbing
0	204	2198		1 2	0

(output omitted)

Controlling your controls

```
. xtswitchdid (injrate lwinpct schedule) (safety), group(team) supergroup(regio  
> n)  
(output omitted)
```

Panel DID with switching treatments

Number of obs	=	2,198
Number of panels	=	204
Number of groups	=	204
Number of supergroups	=	3

(Std. err. adjusted for 204 clusters in team)

Exposure	Normalized effect	Robust std. err.	z	P> z	[95% conf. interval]	
1	-6.155398	2.743241	-2.24	0.025	-11.53205	-.7787444
2	-2.284206	1.505154	-1.52	0.129	-5.234254	.6658426
3	-2.285472	1.047505	-2.18	0.029	-4.338544	-.2323989
4	-.8643861	.8303966	-1.04	0.298	-2.491934	.7631612
5	-1.110083	.6256107	-1.77	0.076	-2.336258	.1160909
6	-1.896084	.5303533	-3.58	0.000	-2.935557	-.8566108
7	-1.172279	.5187632	-2.26	0.024	-2.189036	-.1555216
8	-1.248924	.4757709	-2.63	0.009	-2.181418	-.3164301
9	0	(omitted)				
10	-1.792667	.4404417	-4.07	0.000	-2.655917	-.9294172

Note: effects computed using covariates.

Concluding remarks

- The framework of de Chaisemartin and D'Haultfoeuille (2020/2024)
 - Heterogeneous treatment effects
 - Dynamics
 - Switching
 - Non-binary treatments
- `xtswitchdid`
- Acknowledgements