Analysis

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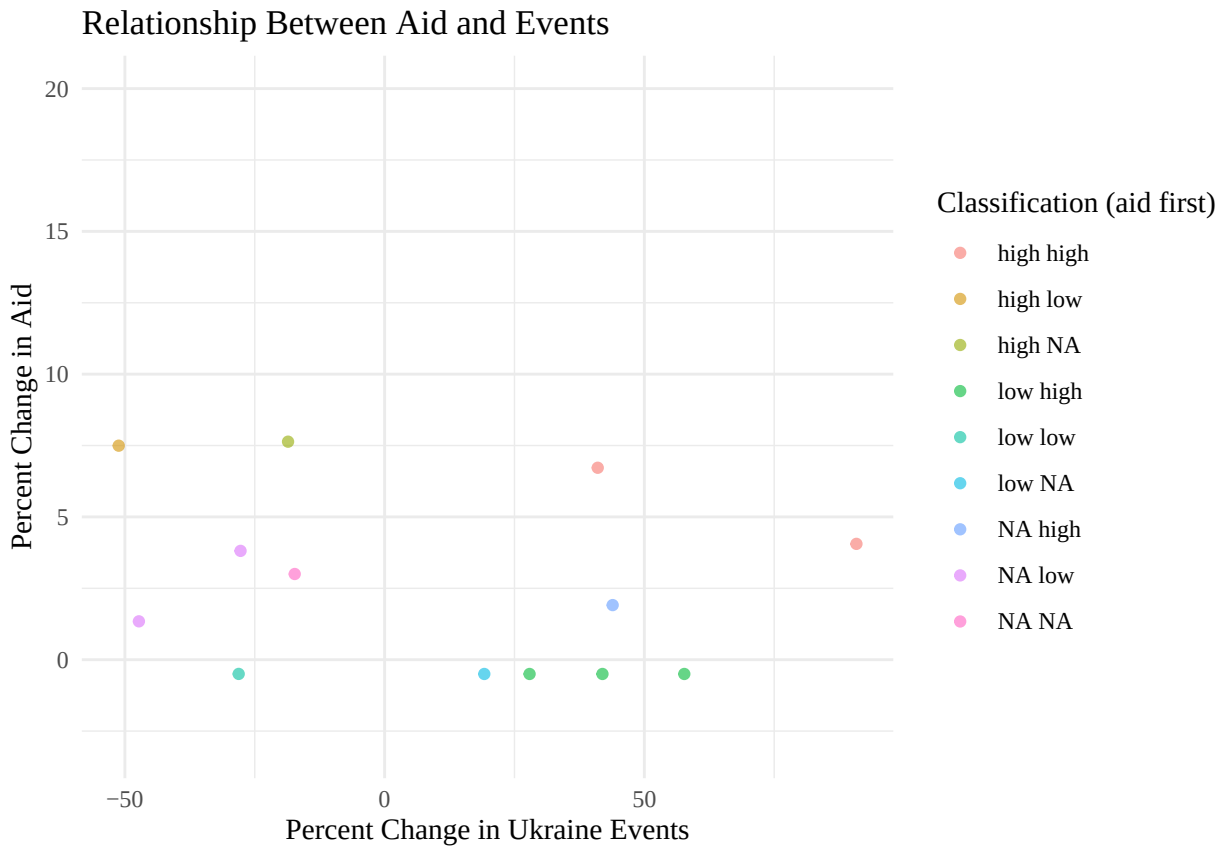
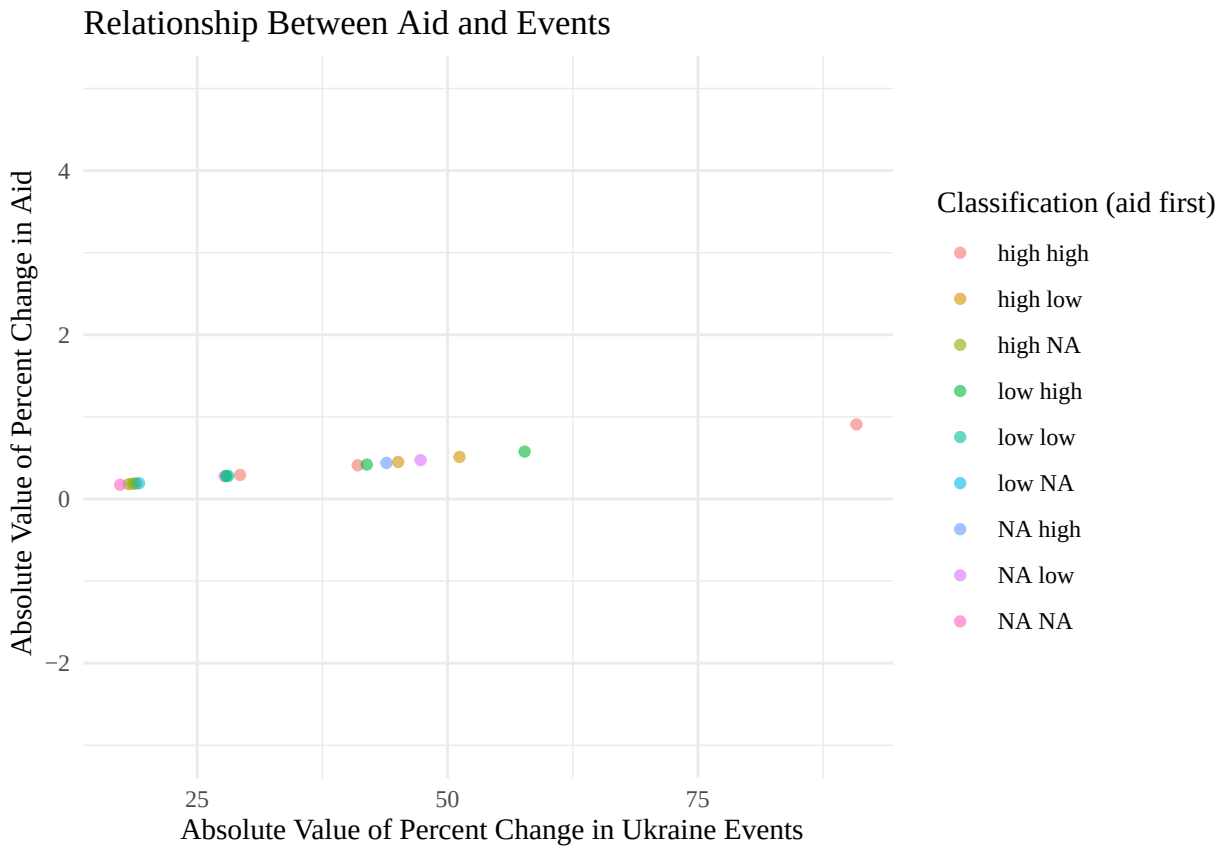
Data structuring

```
## Warning in full_join(drones_dataset[, c(1, 13, 14, 24)], antidrone_aid_df, : Detected an unexpected m
## i Row 1 of `x` matches multiple rows in `y`.
## i Row 1619 of `y` matches multiple rows in `x`.
## i If a many-to-many relationship is expected, set `relationship =
##   "many-to-many"` to silence this warning.
```

Top/bottom analysis

Top/bottom 25 aid and events percent changes (only rows with data in both columns)





Summary stats

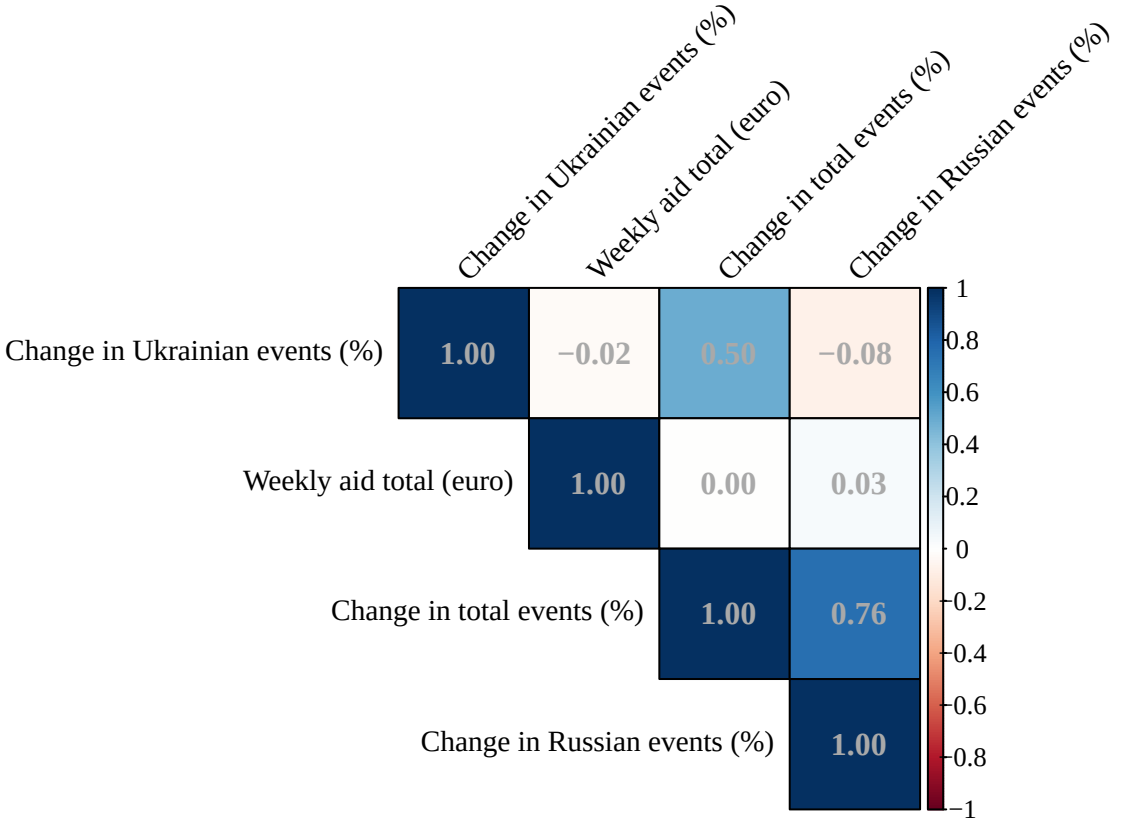
Summary Statistics

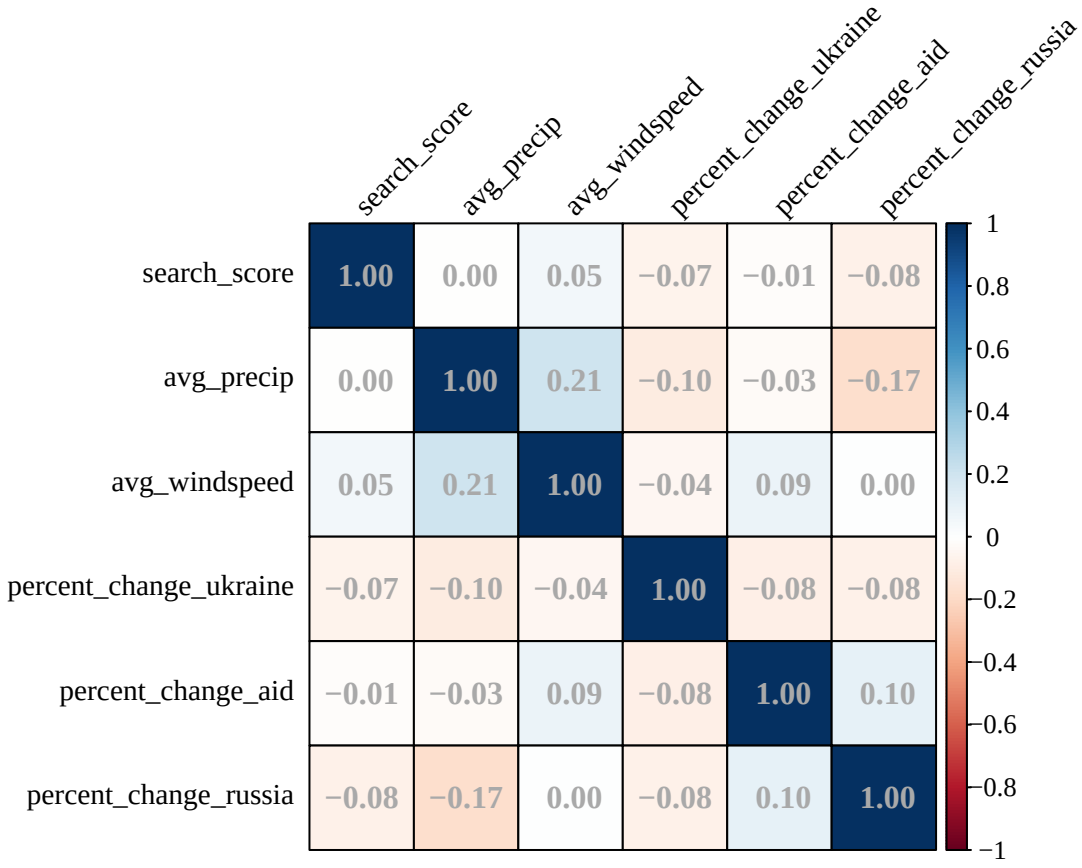
% Table created by stargazer v.5.2.3 by Marek Hlavac, Social Policy Institute. E-mail: marek.hlavac at gmail.com % Date and time: Sun, Apr 13, 2025 - 14:57:38

Summary Statistics

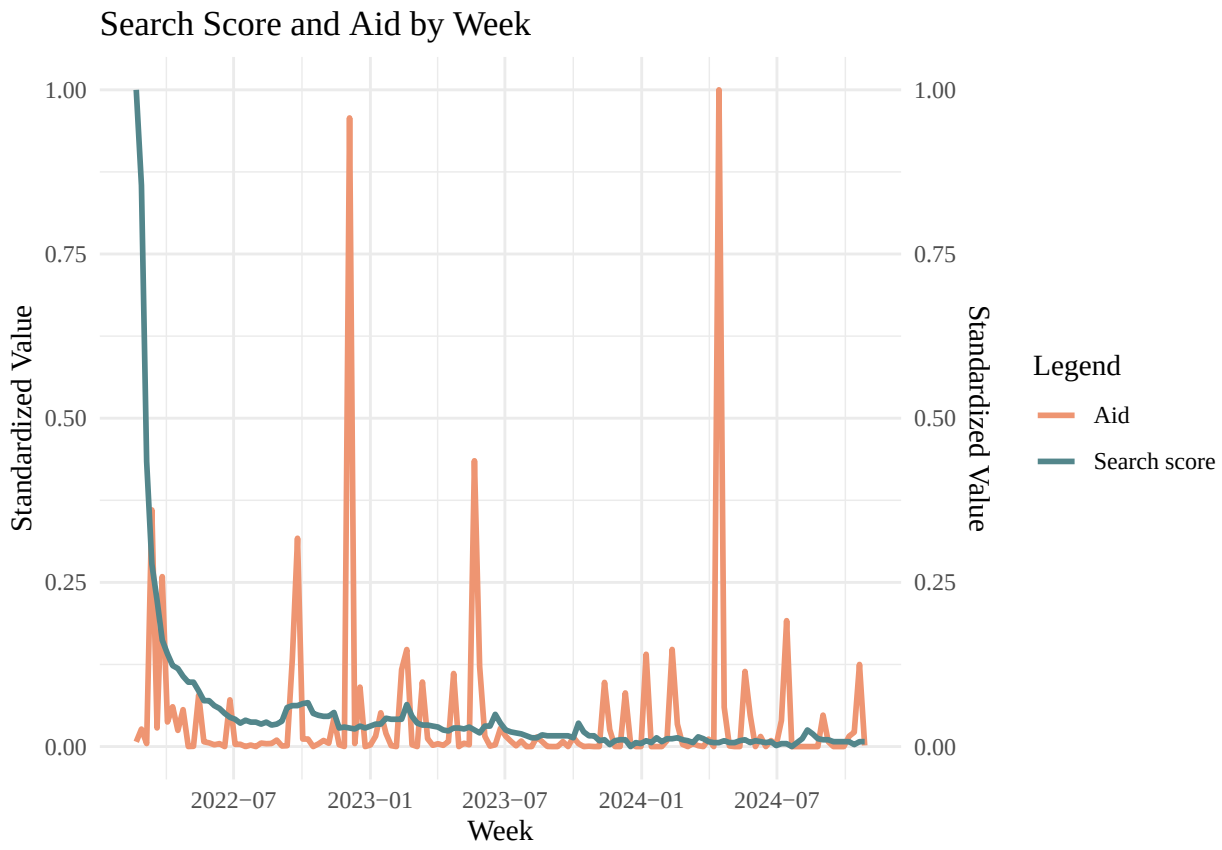
Statistic	N	Mean	St. Dev.	Min	Max
Weekly aid total (euro)	141	834,605,790.00	2,474,692,804.00	0	18,926,299,908
Change in aid (%)	141	5,636.10	47,871.48	−100.00	546,163.60
Weekly event total	141	466.04	76.73	268	638
Russian missile use	141	12.63	10.92	1	58
Russian drone use	141	39.21	16.71	1	75
Change in total events (%)	141	0.44	11.95	−28.87	64.18
Change in Ukrainian events (%)	141	1.07	22.57	−51.19	90.83
Change in Russian events (%)	141	1.30	15.82	−32.14	67.57
Search score	141	7.38	11.33	2.71	98.86

Correlation matrix

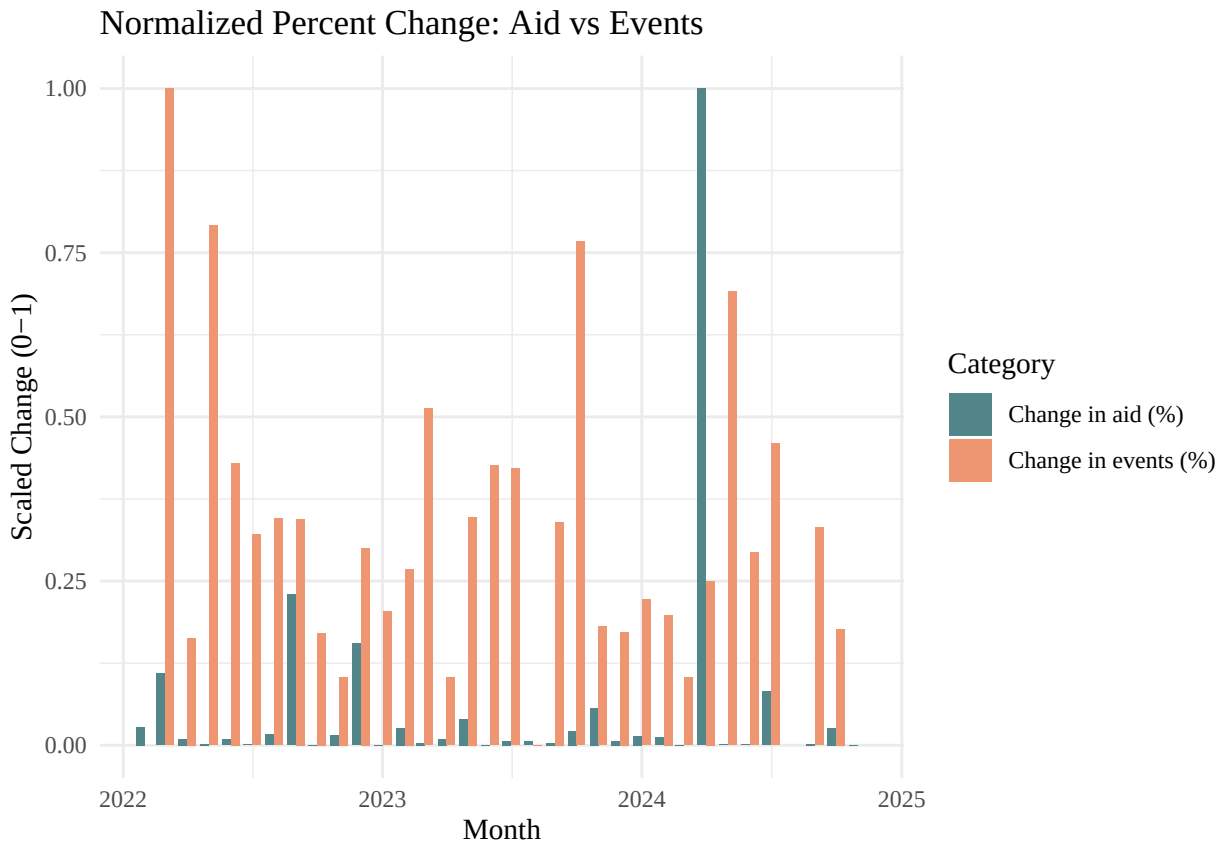


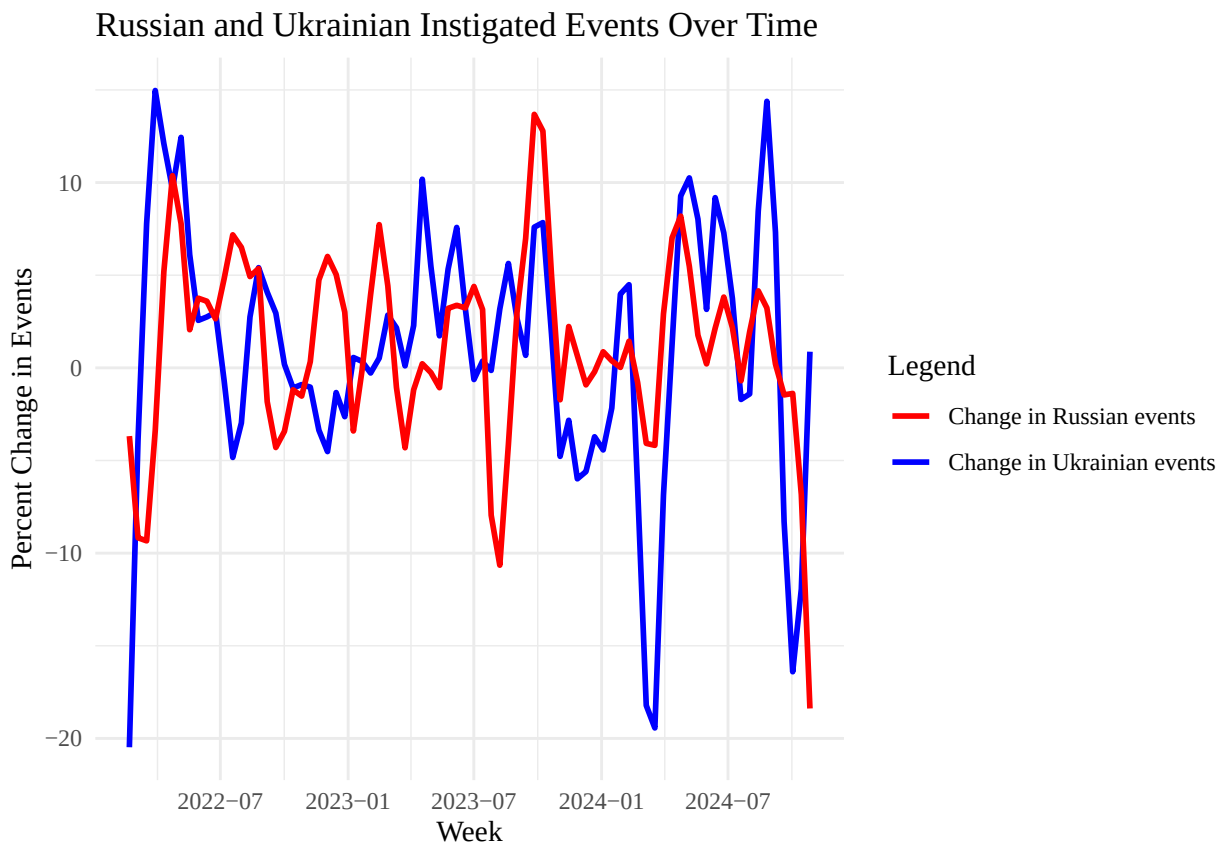


Visualizations




```
## Warning: Removed 2 rows containing missing values or values outside the scale range
## (`geom_bar()`).
```


Normalized Percent Change: Aid vs Events
Scaled Change (0–1)
1.00
0.75
0.50
0.25
0.00
2022
2023
2024
2025
Month
Category
Change in aid (%)
Change in events (%)



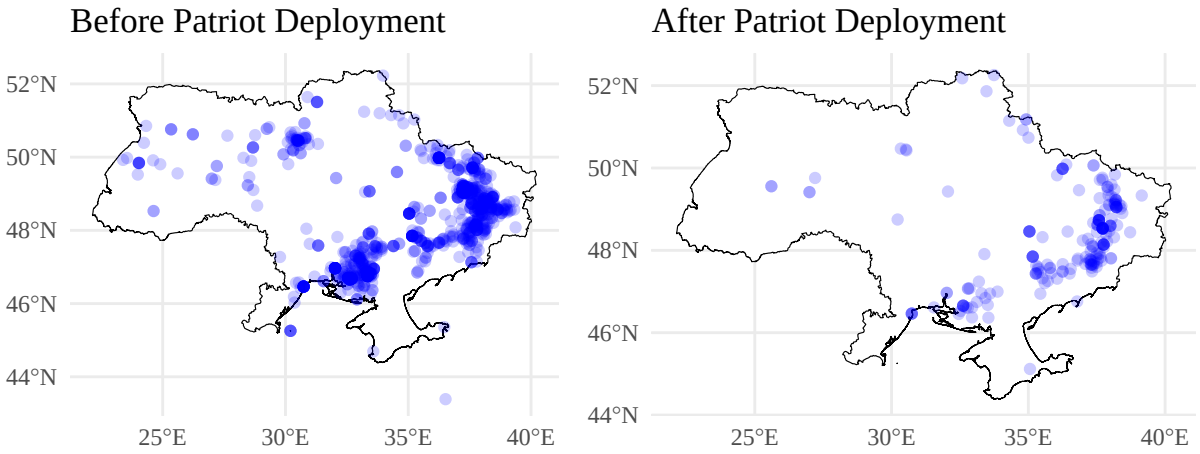

```
# Map of missile attacks

ukraine <- st_read("/Users/briannapenkala/Downloads/Capstone/gadm41_UKR_shp")
```

```
## Multiple layers are present in data source /Users/briannapenkala/Downloads/Capstone/gadm41_UKR_shp, r
## Use `st_layers' to list all layer names and their type in a data source.
## Set the `layer' argument in `st_read' to read a particular layer.

## Warning in CPL_read_ogr(dsn, layer, query, as.character(options), quiet, :
## automatically selected the first layer in a data source containing more than
## one.

## Reading layer `gadm41_UKR_0' from data source
##   `/Users/briannapenkala/Downloads/Capstone/gadm41_UKR_shp' using driver `ESRI Shapefile'
## Simple feature collection with 1 feature and 2 fields
## Geometry type: MULTIPOLYGON
## Dimension:     XY
## Bounding box:  xmin: 22.14045 ymin: 44.38597 xmax: 40.21807 ymax: 52.37503
## Geodetic CRS:  WGS 84
```

```
missiles_sf <- st_as_sf(missile_events, coords = c("longitude", "latitude"), crs = 4326)

missile_before1 <- missiles_sf %>% filter(date < as.Date("2022-12-21"))
missile_after1 <- missiles_sf %>% filter(date >= as.Date("2022-12-21") & date < as.Date("2023-06-01"))
```

```r
missile_map_before1 <- ggplot() +
  geom_sf(data = ukraine, fill = "white", color = "black") +
  geom_sf(data = missile_before1 , color = "blue", alpha = 0.2) +
  ggtitle("Before Patriot Deployment") +
  theme(plot.title = element_text(size = 9)) +
  theme_minimal(base_family = "Times New Roman") +
  theme(
    text = element_text(family = "Times New Roman"),
    axis.title = element_text(family = "Times New Roman"),
    axis.text = element_text(family = "Times New Roman"),
    plot.title = element_text(family = "Times New Roman"))

missile_map_after1 <- ggplot() +
  geom_sf(data = ukraine, fill = "white", color = "black") +
  geom_sf(data = missile_after1 , color = "blue", alpha = 0.2) +
  ggtitle("After Patriot Deployment") +
  theme_minimal(base_family = "Times New Roman") +
  theme(
    text = element_text(family = "Times New Roman"),
    axis.title = element_text(family = "Times New Roman"),
    axis.text = element_text(family = "Times New Roman"),
    plot.title = element_text(family = "Times New Roman"))

(missile_map_before1 + missile_map_after1) +
   plot_annotation(
    title = "Missile Attacks in Ukraine Before and After Patriot Deployment",
    caption = "Before = 02/22/2022 - 12/21/2022; After = 12/21/2022 - 06/21/2023",
    theme = theme(plot.title = element_text(family = "Times New Roman"),
                  plot.caption = element_text(family = "Times New Roman")))
```

Missile Attacks in Ukraine Before and After Patriot Deployment



Before = 02/22/2022 − 12/21/2022; After = 12/21/2022 − 06/21/2023

T-tests

T-statistic	Degrees of Freedom	P-value	95% Confidence Interval
-28.3	218	< 2.2e-16	-294.746 - (-221.623)

Comparison of Mean Ukrainian and Russian-Instigated Events

T-statistic	Degrees of Freedom	P-value	95% Confidence Interval
-28.3	218	< 2.2e-16	-294.746 - (-221.623)

T-statistic	Degrees of Freedom	P-value	95% Confidence Interval
-0.351	4	0.743	-45.597 - 35.363

Regressions on Ukraine

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Comparison of Mean Ukrainian Event Percent Changes in High and Low Aid Periods

T-statistic	Degrees of Freedom	P-value	95% Confidence Interval
-0.351	4	0.743	-45.597 - 35.363

First stage (using SearchScore as instrument):

$$AidGiven_W = \beta_0 + \beta_1 \text{SearchScore}_W + u_W$$

Second stage:

$$UVE_W = \beta_0 + \beta_1 \hat{AidGiven}_{W-lag} + \beta_2 \text{RVE}_W + \beta_3 \text{AveragePrecipitation}_W + \beta_4 \text{AverageWindSpeed}_W + u_W$$

Where UVE shows Ukrainian-instigated events; RVE shows Russian-instigated events

Regressions on Russia

```
# Russia regressions no lag
basic_reg_russia <- lm(percent_change_russia ~ percent_change_aid + percent_change_ukraine, data = bywe

# Regressions one week lag
basic_reg_lag1_russia <- lm(percent_change_russia ~ week_lag_percent_aid + percent_change_ukraine, data

# Regressions two week lag
basic_reg_lag2_russia <- lm(percent_change_russia ~ twoweek_lag_percent_aid + percent_change_ukraine, da

# Instrument
inst_basic_russia <- ivreg(formula = percent_change_russia ~ percent_change_aid + percent_change_ukraine

output_russia <- huxreg(basic_reg_russia,
                basic_reg_lag1_russia,
                basic_reg_lag2_russia,
                inst_basic_russia,
                 coefs = c("Aid" = "percent_change_aid",
                           "Ukrainian-instigated events change (%)" = "percent_change_ukraine",
                           "Aid lagged one week" = "week_lag_percent_aid",
                           "Aid lagged two weeks" = "twoweek_lag_percent_aid")) %>%
  set_caption("Percent Change Aid Russia") %>%
  set_markdown_contents(1, 2, "OLS") %>%
  set_markdown_contents(1, 3, "OLS") %>%
  set_markdown_contents(1, 4, "OLS") %>%
  set_markdown_contents(1, 5, "2SLS")
output_russia
```

```
# Russia dummy variable regressions

# Regressions dummy no lag
basic_dummy_russia <- lm(percent_change_russia ~ aidgiven + percent_change_ukraine, data = byweek_data)
```

Ukrainian-Instigated Events on an Aid Dummy Variable

	OLS	OLS	OLS	2SLS	2SLS	2SLS
Constant	6.870	4.308	2.952	23.974	123.610	-24.768
	(10.569)	(10.958)	(10.759)	(23.566)	(139.127)	(37.574)
Aid (dummy)	-1.456			-24.152		
	(4.573)			(28.477)		
Aid lagged one week (dummy)		1.752			-155.673	
		(4.506)			(183.547)	
Aid lagged two weeks (dummy)			3.606			40.228
			(4.430)			(47.431)
Russian-instigated events change (%)	-0.135	-0.140	-0.136	-0.144	-0.144	-0.144
	(0.123)	(0.123)	(0.123)	(0.123)	(0.123)	(0.123)
Average precipitation	-1.557	-1.671	-1.715	-1.650	-1.650	-1.650
	(1.258)	(1.249)	(1.245)	(1.240)	(1.240)	(1.240)
Average wind speed	-0.127	-0.111	-0.109	-0.103	-0.103	-0.103
	(0.573)	(0.575)	(0.572)	(0.572)	(0.572)	(0.572)
N	141	141	141	141	141	141
R2	0.021	0.021	0.025	0.025	0.025	0.025

*** p < 0.001; ** p < 0.01; * p < 0.05.

```
# Regressions one week lag
basic_dummy_lag1_russia <- lm(percent_change_russia ~ aidgiven_week_lag + percent_change_ukraine, data =

# Regressions two week lag
basic_dummy_lag2_russia <- lm(percent_change_russia ~ aidgiven_twoweek_lag + percent_change_ukraine, da

# Instrument
inst_dummy_russia <- ivreg(formula = percent_change_russia ~ aidgiven + percent_change_ukraine | search_

output_dummy_russia <- huxreg(basic_dummy_russia,
                        basic_dummy_lag1_russia,
                        basic_dummy_lag2_russia,
                        inst_dummy_russia,
                  coefs = c("Aid" = "aidgiven",
                            "Ukrainian-instigated events change (%)" = "percent_change_ukraine",
                            "Aid lagged one week" = "aidgiven_week_lag",
                            "Aid lagged two weeks" = "aidgiven_twoweek_lag")) %>%
```

Percent Change Aid Russia

	OLS	OLS	OLS	2SLS
Aid	0.000			0.001
	(0.000)			(0.006)
Ukrainian-instigated events change (%)	-0.047	-0.053	-0.051	0.188
	(0.059)	(0.059)	(0.059)	(1.107)
Aid lagged one week		0.000		
		(0.000)		
Aid lagged two weeks			0.000	
			(0.000)	
N	141	141	141	141
R2	0.015	0.006	0.018	-17.080
logLik	-587.836	-588.494	-587.655	
AIC	1183.673	1184.987	1183.310	

*** p < 0.001; ** p < 0.01; * p < 0.05.

```
  set_caption("Aid as a Dummy Variable Russia") %>%
  set_markdown_contents(1, 2, "OLS") %>%
  set_markdown_contents(1, 3, "OLS") %>%
  set_markdown_contents(1, 4, "OLS") %>%
  set_markdown_contents(1, 5, "2SLS")
output_dummy_russia
```

Regressions on missiles

```
# Missiles regressions

# Patriot aid on missile use (expect to decrease)
missile_reg <- lm(russian_missiles ~ patriot_aid, data = byweek_data)

missile_reg_controlled <- lm(russian_missiles ~ patriot_aid + russian_drones + avg_precip + avg_windspe

output_missile <- huxreg(missile_reg,
                missile_reg_controlled,
                coefs = c("Constant" = "(Intercept)",
                          "Patriot aid" = "patriot_aid",
                          "Russian drone use" = "russian_drones",
```

Aid as a Dummy Variable Russia

	OLS	OLS	OLS	2SLS
Aid	-0.591			-19.304
	(3.164)			(22.677)
Ukrainian-instigated events change (%)	-0.053	-0.054	-0.052	-0.069
	(0.060)	(0.059)	(0.060)	(0.069)
Aid lagged one week		2.525		
		(3.122)		
Aid lagged two weeks			-0.195	
			(3.104)	
N	141	141	141	141
R2	0.006	0.010	0.006	-0.246
logLik	-588.506	-588.190	-588.522	
AIC	1185.012	1184.380	1185.044	

*** p < 0.001; ** p < 0.01; * p < 0.05.

```
                          "Average precipitation" = "avg_precip",
                          "Average wind speed" = "avg_windspeed")) %>%
  set_caption("Russian Missile Use on Patriot Aid") %>%
  set_markdown_contents(1, 2, "OLS") %>%
  set_markdown_contents(1, 3, "OLS")
output_missile <- output_missile[-c(14,15),]
output_missile
```

$$RMU_W = \beta_0 + \beta_1 \text{PatriotAid}_W + \beta_2 \text{RDU}_W + \beta_3 \text{AveragePrecipitation}_W + \beta_4 \text{AverageWindSpeed}_W + u_W$$

Where RMU shows Russian missile use; RDU shows Russian drone use

```
# Patriot aid on drone use (expect to increase)
missile_reg_drone <- lm(russian_drones ~ patriot_aid , data = byweek_data)
summary(missile_reg_drone)
```

```
##
## Call:
## lm(formula = russian_drones ~ patriot_aid, data = byweek_data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
```

Russian Missile Use on Patriot Aid

	OLS	OLS
Constant	13.611 ***	14.620 *
	(0.979)	(5.753)
Patriot aid	-4.603 *	-4.663 *
	(1.794)	(1.824)
Russian drone use		0.002
		(0.056)
Average precipitation		-0.345
		(0.585)
Average wind speed		-0.032
		(0.278)
N	141	141
R2	0.045	0.048

*** p < 0.001; ** p < 0.01; * p < 0.05.

```
## -38.848 -10.848   2.152  12.139  35.152
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)   39.848      1.527  26.088   <2e-16 ***
## patriot_aid   -2.987      2.799  -1.067    0.288
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 16.7 on 139 degrees of freedom
## Multiple R-squared:  0.008128,   Adjusted R-squared:  0.0009918
## F-statistic: 1.139 on 1 and 139 DF,  p-value: 0.2877
```

```
ex <- lm(russian_missiles ~ russian_drones, data = byweek_data)
summary(ex)
```

```
##
## Call:
## lm(formula = russian_missiles ~ russian_drones, data = byweek_data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -11.742  -7.685  -3.500   3.514  44.988
##
## Coefficients:
```

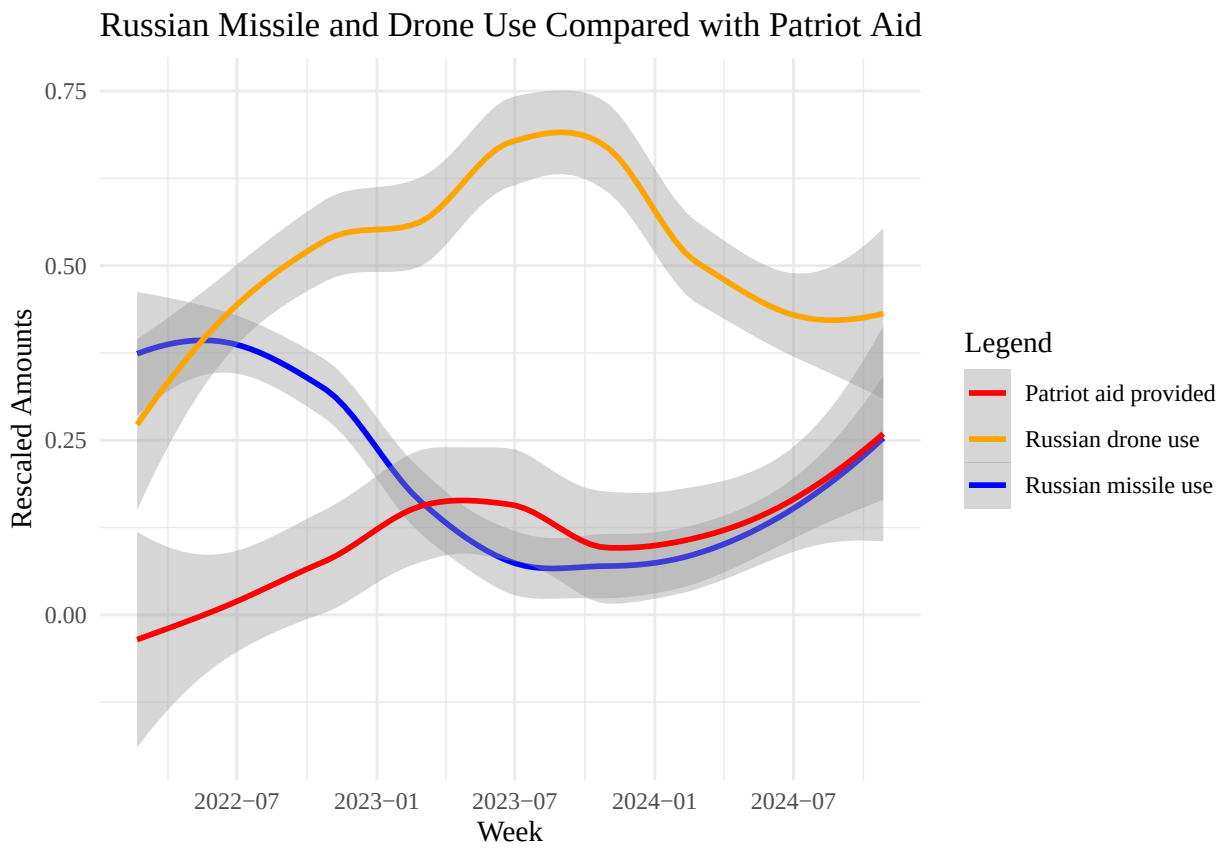
```
##                Estimate Std. Error t value Pr(>|t|)
## (Intercept)    12.07448    2.36086   5.114 1.02e-06 ***
## russian_drones  0.01420    0.05542   0.256    0.798
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 10.96 on 139 degrees of freedom
## Multiple R-squared:  0.000472,   Adjusted R-squared:  -0.006719
## F-statistic: 0.06564 on 1 and 139 DF,  p-value: 0.7982
```

```r
# Drone regressions (russian drone activity on anti drone aid)
antidrone_reg <- lm(russian_drones ~ antidrone_aid, data = drones_dataset)
summary(antidrone_reg)
```

```
##
## Call:
## lm(formula = russian_drones ~ antidrone_aid, data = drones_dataset)
##
## Residuals:
##        Min         1Q     Median         3Q        Max
## -1.900e-15 -1.900e-15 -1.900e-15 -1.900e-15  3.007e-11
##
## Coefficients:
##                 Estimate Std. Error   t value Pr(>|t|)
## (Intercept)    1.000e+00  1.821e-15  5.49e+14   <2e-16 ***
## antidrone_aid -1.876e-15  7.565e-15 -2.48e-01    0.804
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.306e-13 on 17008 degrees of freedom
##   (705 observations deleted due to missingness)
## Multiple R-squared:    0.5,  Adjusted R-squared:    0.5
## F-statistic: 1.701e+04 on 1 and 17008 DF,  p-value: < 2.2e-16
```

```r
ggplot(aes(x = week), data = byweek_data) +
  geom_smooth(aes(y = rescale(russian_missiles), color = "Russian missile use")) +
  geom_smooth(aes(y = rescale(russian_drones), color = "Russian drone use")) +
  geom_smooth(aes(y = rescale(patriot_aid), color = "Patriot aid provided")) +
  scale_color_manual(values = c("Russian missile use" = "blue", "Russian drone use" = "orange", "Patriot
  labs(title = "Russian Missile and Drone Use Compared with Patriot Aid",
       x = "Week",
       y = "Rescaled Amounts",
       color = "Legend") +
  theme_minimal(base_family = "Times New Roman") +
  theme(
    text = element_text(family = "Times New Roman"),
    axis.title = element_text(family = "Times New Roman"),
    axis.text = element_text(family = "Times New Roman"),
    plot.title = element_text(family = "Times New Roman"))
```

```
## `geom_smooth()` using method = 'loess' and formula = 'y ~ x'
## `geom_smooth()` using method = 'loess' and formula = 'y ~ x'
## `geom_smooth()` using method = 'loess' and formula = 'y ~ x'
```


Russian Missile and Drone Use Compared with Patriot Aid
0.75
0.50
0.25
0.00
Rescaled Amounts
2022−07
2023−01
2023−07
2024−01
2024−07
Week
Legend
Patriot aid provided
Russian drone use
Russian missile use