

# Exploratory Analysis of Synthetic Policy Evaluation Data

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## 1 Exploratory Analysis of Synthetic Panel Data

This notebook provides a brief exploratory analysis of the synthetic panel dataset generated in this repository.

The goals are to:

- Inspect the structure and summary statistics of the data
- Visualize outcomes over time for treated vs. control units
- Build intuition for the difference in differences (DiD) setup

The dataset was generated by `generate_data.py` and saved to `data/processed/sim_panel.csv`. Each row corresponds to a unit-time observation with:

- `unit_id`: unit identifier (e.g., firm or region)
- `time`: time period (integer)
- `treated`: 1 if the unit is ever treated, 0 otherwise
- `post`: 1 if the period is after the policy starts, 0 otherwise
- `treat_post`: interaction of `treated * post` (the DiD term)
- `x1`, `x2`: additional covariates
- `y`: outcome variable

### 1.1 Imports & Settings

```
[1]: import os

import pandas as pd
import matplotlib.pyplot as plt
import numpy as np

# Make plots a bit bigger by default
plt.rcParams["figure.figsize"] = (8, 5)
```

```
# Show pandas floats with fewer decimals for readability
pd.options.display.float_format = "{:.3f}".format
```

## 1.2 Load Data

```
[2]: # Construct path to the processed data
notebook_dir = os.path.dirname(os.getcwd()) # parent of notebooks/
data_path = os.path.join(notebook_dir, "data", "processed", "sim_panel.csv")

print("Loading data from:", data_path)
df = pd.read_csv(data_path)

df.head()
```

Loading data from: d:\GitHub\coding-sample\data\processed\sim\_panel.csv

```
[2]:
```

	unit_id	time	treated	post	treat_post	x1	x2	y
0	1	1	0	0	0	1.191	0.263	3.922
1	1	2	0	0	0	-1.745	0.927	2.529
2	1	3	0	0	0	-1.110	-0.472	3.376
3	1	4	0	0	0	0.052	-0.292	3.836
4	1	5	0	0	0	-0.252	0.153	5.425

## 1.3 Quick Data Description

### 1.4 Basic Structure and Summary

We start by checking:

- The number of units and time periods
- The balance of treated vs. control units
- Basic summary statistics for the main variables

### 1.5 Shape, Unique Counts, Summary Stats

```
[3]: n_rows, n_cols = df.shape
n_units = df["unit_id"].nunique()
n_periods = df["time"].nunique()

print(f"Rows: {n_rows}, Columns: {n_cols}")
print(f"Unique units: {n_units}")
print(f"Unique time periods: {n_periods}")

print("\nTreated vs. control units (count):")
print(df.groupby("treated")["unit_id"].nunique())
```

```
print("\nSummary statistics:")
df[["y", "treated", "post", "treat_post", "x1", "x2"]].describe()
```

```
Rows: 2000, Columns: 8
Unique units: 200
Unique time periods: 10
```

```
Treated vs. control units (count):
treated
0      120
1       80
Name: unit_id, dtype: int64
```

```
Summary statistics:
```

```
[3]:
```

	y	treated	post	treat_post	x1	x2
count	2000.000	2000.000	2000.000	2000.000	2000.000	2000.000
mean	3.811	0.400	0.500	0.200	-0.023	0.020
std	1.886	0.490	0.500	0.400	1.023	0.983
min	-2.407	0.000	0.000	0.000	-4.389	-3.110
25%	2.492	0.000	0.000	0.000	-0.714	-0.635
50%	3.772	0.000	0.500	0.000	0.010	0.008
75%	5.158	1.000	1.000	0.000	0.645	0.703
max	10.257	1.000	1.000	1.000	3.241	3.208

## 1.6 Average Outcome Over Time by Treatment Status

To build intuition for the DiD setting, we plot average outcomes over time separately for:

- Units that are **ever treated** (`treated = 1`)
- Units that are **never treated** (`treated = 0`)

In a typical DiD setup, we are interested in whether the treated units experience a differential change in outcomes after the policy starts, relative to the control units.

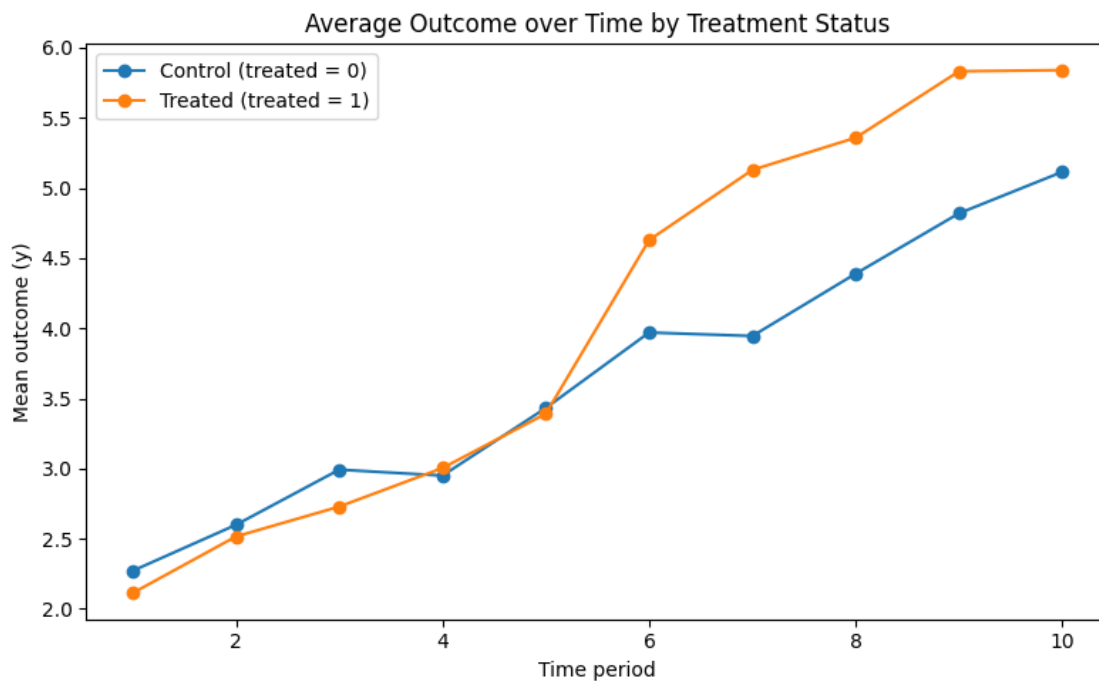
## 1.7 Compute Group Means and Plot

```
[4]: # Compute mean outcome by time and treatment status
mean_y = (
    df.groupby(["time", "treated"])["y"]
      .mean()
      .reset_index()
      .pivot(index="time", columns="treated", values="y")
)

mean_y.columns = ["control_mean_y", "treated_mean_y"]
mean_y
```

```
[4]:      control_mean_y  treated_mean_y
time
1          2.271          2.112
2          2.599          2.516
3          2.992          2.729
4          2.950          3.004
5          3.432          3.391
6          3.970          4.629
7          3.945          5.129
8          4.390          5.359
9          4.820          5.832
10         5.115          5.841
```

```
[5]: # Line plot of average outcome over time for treated vs control
ax = mean_y.plot(marker="o")
ax.set_title("Average Outcome over Time by Treatment Status")
ax.set_xlabel("Time period")
ax.set_ylabel("Mean outcome (y)")
ax.legend(["Control (treated = 0)", "Treated (treated = 1)"])
plt.tight_layout()
plt.show()
```



## 1.8 Pre vs Post Policy Comparison

Next, we look at how average outcomes change **before** and **after** the policy:

- For treated units
- For control units

This connects directly to the DiD intuition.

```
[6]: # Average outcome by treated x post
pre_post_summary = (
    df.groupby(["treated", "post"])["y"]
      .mean()
      .reset_index()
      .pivot(index="treated", columns="post", values="y")
)

pre_post_summary.columns = ["pre_policy_mean_y", "post_policy_mean_y"]
pre_post_summary.index = ["control (0)", "treated (1)"]

pre_post_summary
```

```
[6]:
```

	pre_policy_mean_y	post_policy_mean_y
control (0)	2.849	4.448
treated (1)	2.750	5.358

```
[7]: # Compute simple differences
pre_post_summary["change"] = (
    pre_post_summary["post_policy_mean_y"] -
    pre_post_summary["pre_policy_mean_y"]
)

pre_post_summary
```

```
[7]:
```

	pre_policy_mean_y	post_policy_mean_y	change
control (0)	2.849	4.448	1.599
treated (1)	2.750	5.358	2.608

## 1.9 Connecting to Difference in Differences

From the table above:

- The change for control units captures background trends over time
- The change for treated units reflects both background trends and the policy effect

The difference-in-differences estimate is computed as:

(change in average outcome for treated units) minus (change in average outcome for control units).

Below we compute this quantity directly from the summary table.

```
[8]: delta_control = pre_post_summary.loc["control (0)", "change"]
      delta_treated = pre_post_summary.loc["treated (1)", "change"]
```

```
did_estimate = float(delta_treated - delta_control)

print(f"Change (control): {delta_control:.3f}")
print(f"Change (treated): {delta_treated:.3f}")
print(f"Difference in differences estimate: {did_estimate:.3f}")
```

Change (control): 1.599

Change (treated): 2.608

Difference in differences estimate: 1.008

## 1.10 Optional: Compare to Regression-Based DiD Estimate

The script `analysis_diff_in_diff.py` fits a regression model of the form:

Outcome = unit fixed effects

+ time fixed effects

+ (treated  $\times$  post)

+ controls (x1, x2)

+ error

The coefficient on `treated:post` is the regression-based DiD estimate.

In the synthetic data generation process, the true policy effect was set to be around 1.0.

You can:

- Run the script from the command line to see the full regression table, or
- Replicate the regression here in the notebook if you would like to explore specification choices.