EVALUATING THE IMPACT OF THE ATAL BHUJAL YOJANA ON GROUNDWATER QUALITY IN HARYANA: A DIFFERENCE-IN-DIFFERENCES APPROACH

Author: Jia Lin
Supervisor: Sebastián Daza
Master Degree in Computational Social Science
Madrid, 2nd July 2025

OVERVIEW

INTRODUCTION

- Groundwater quality problem in Haryana, India.
- The Atal Bhujal Yojana (ABY) policy was launched in 2019 to promote sustainable groundwater use.
- This study evaluates its impact on electrical conductivity (EC).
- Methods: Difference-in-Differences (DiD); plus Synthetic Difference-in-Differences (SDiD) & Bayesian Structural Time Series (BSTS).

INTRODUCTION

RESEARCH QUESTIONS

(1) Has Haryana's groundwater conductivity improved as a result of the ABY policy?

(2) Do the outcomes hold true for the various modeling techniques (DiD, SDiD, and BSTS)?

LITERATURE REVIEW

01

Groundwater Stress in Haryana, India

-Quality & quantity declining due to:

- Over-extraction
- Intensive agriculture
- Population growth

02

Research on the ABY Policy

-Covers 7 high-stress states, including Haryana

-Focus: behavioral change, irrigation efficiency, community monitoring

03

Why Use Electrical Conductivity (EC)?

-EC = key indicator of groundwater salinity and mineral content

-Hypothesis: If ABY works → EC should decline after implementation

DATA DESCRIPTION

1 Source: National Ground Water Monitoring Network (NGWMN), by CGWB

2 Time Period: 2017-2022 (pre- & post-policy)

3
- Haryana (ABY pilot) – 436 sites across 20 districts
- Punjab (control) – 317 sites across 17 districts

4 Variables:
- Geographic information
- Physical parameters
- Chemical indicators

METHODOLOGY

DATA PROCESSING AND PANEL CONSTRUCTION

Variable filtering:

- Removed variables with >60% missing data
- Selected 18 variables available in both states

Panel construction:

- Unit of analysis: District-level panel (2017-2022)
- Aggregated site-level data into annual district averages
- Final sample: 213 observations
  - Haryana: 119
  - Punjab: 94

Outcome variable and covariates:

- Key outcome variable: Electrical Conductivity
- Covariates included: Chloride, Sodium, pH

METHODOLOGY

DATA PROCESSING AND PANEL CONSTRUCTION

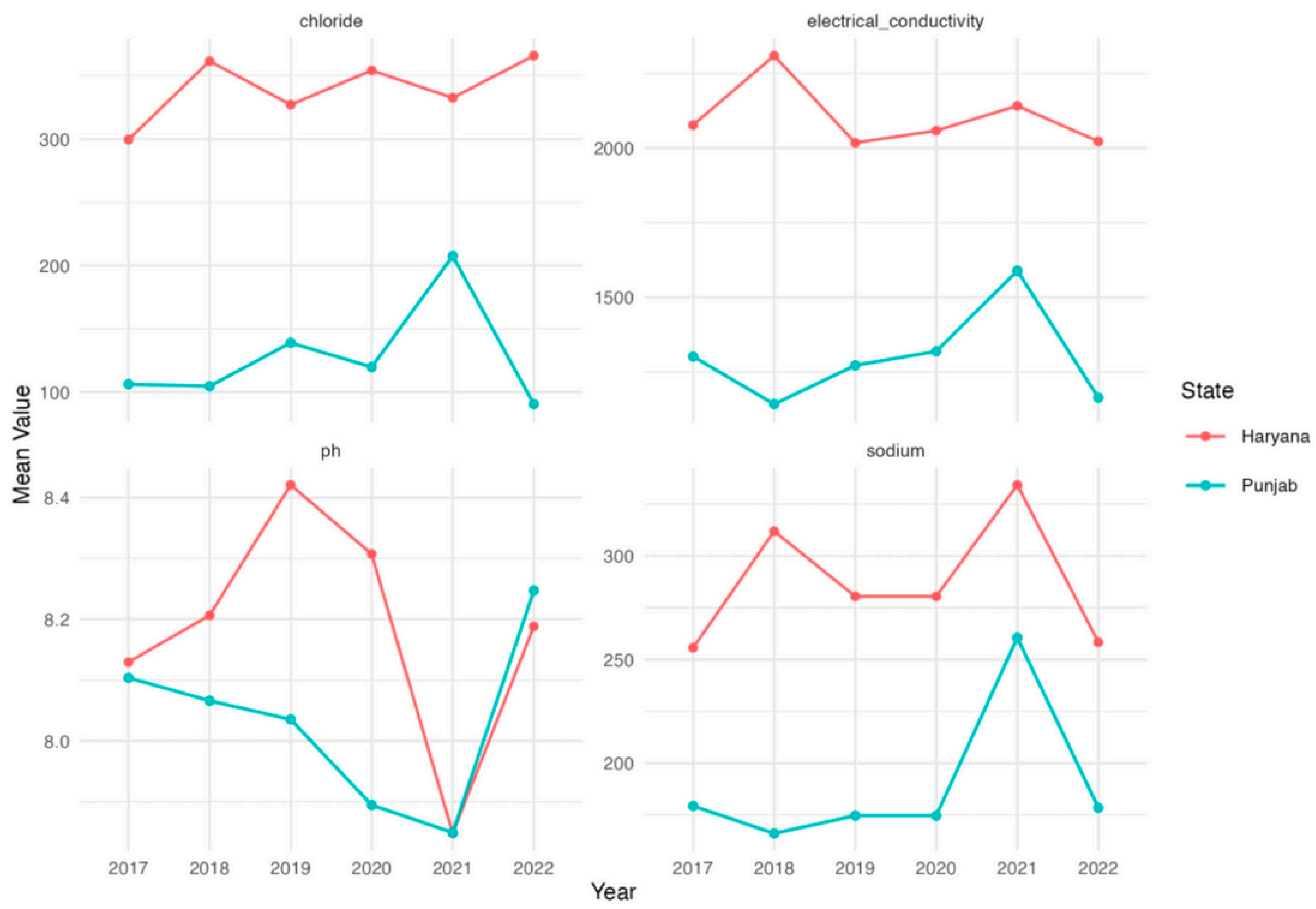


Figure 1. Trends of groundwater indicators by state (2017–2022)

METHODOLOGY

DIFFERENCE-IN-DIFFERENCES MODEL

Baseline DiD Model:

$EC_{it} = \beta_0 + \beta_1 \cdot treated_i + \beta_2 \cdot post_t + \beta_3 \cdot (treated_i \times post_t) + \varepsilon_{it}$

Extended Model with Fixed Effects (district and year):

$EC_{it} = \alpha_i + \delta_t + \beta_3 \cdot (treated_i \times post_t) + \varepsilon_{it}$

With Covariates (chloride, sodium, pH):

$EC_{it} = \alpha_i + \delta_t + \beta_3 \cdot (treated_i \times post_t) + \gamma_1 \cdot chloride_{it} + \gamma_2 \cdot sodium_{it} + \gamma_3 \cdot ph_{it} + \varepsilon_{it}$

Parallel Trend Assumption & Placebo Test (2017–2019):

Introduced fake policy period (fake_post)

$EC_{it} = \beta_0 + \beta_1 \cdot treated_i + \beta_2 \cdot fake\_post_t + \beta_3 \cdot (treated_i \times fake\_post_t) + \varepsilon_{it}$

If β_3 not significant → supports parallel trend assumption

METHODOLOGY

COMPLEMENTARY MODELS: SDID & BSTS

Synthetic Difference-in-Differences (SDiD):

-Combines features of Synthetic Control and DiD

-Introduces unit weights (ω_i) and time weights

$$\hat{\tau}^{\text{sdid}} = \sum_{i \in \text{treated}} \omega_i \left(\frac{1}{T_1} \sum_{t \in \text{post}} Y_{it} - \frac{1}{T_0} \sum_{t \in \text{pre}} Y_{it} \right) - \sum_{i \in \text{control}} \omega_i \left(\frac{1}{T_1} \sum_{t \in \text{post}} Y_{it} - \frac{1}{T_0} \sum_{t \in \text{pre}} Y_{it} \right)$$

Bayesian Structural Time Series (BSTS):

-Models counterfactual trend using pre-policy time series + Bayesian inference

-Effective for single-unit evaluation (Haryana) or

With external control (Punjab) or

With external control (Punjab) plus covariates: chloride and sodium

RESULTS

DIFFERENCE-IN-DIFFERENCES MODEL

Baseline Model

INTERACTION TERM (TREATED × POST): -173.0 (SE = 129.78, P = 0.192); ADJ. R^2 = 0.155

NOT STATISTICALLY SIGNIFICANT → WEAK EXPLANATORY POWER

Placebo Test (2017–2019)

INTERACTION (TREATED × FAKE_POST): 187.3 (P = 0.331)

NO SIGNIFICANT DIFFERENCE → SUPPORTS PARALLEL TRENDS ASSUMPTION

Two-Way Fixed Effects

INTERACTION (TREATED × POST): -170.33 (P = 0.19); ADJ. R^2 = -0.213

STILL NOT STATISTICALLY SIGNIFICANT

Two-Way Fixed Effects with Covariates

INTERACTION (TREATED × POST): -142.81 (P = 0.006); ADJ. R^2 = 0.823

- CHLORIDE: 2.640 (P < 0.001)
- SODIUM: 2.051 (P < 0.001)
- PH: -222.506 (P < 0.001)

RESULTS

SYNTHETIC DIFFERENCE-IN-DIFFERENCES

ATT ESTIMATE: -180.16 MS/CM (SE = 137.36)
95% CI: [-445.72, 85.40] → NOT STATISTICALLY SIGNIFICANT

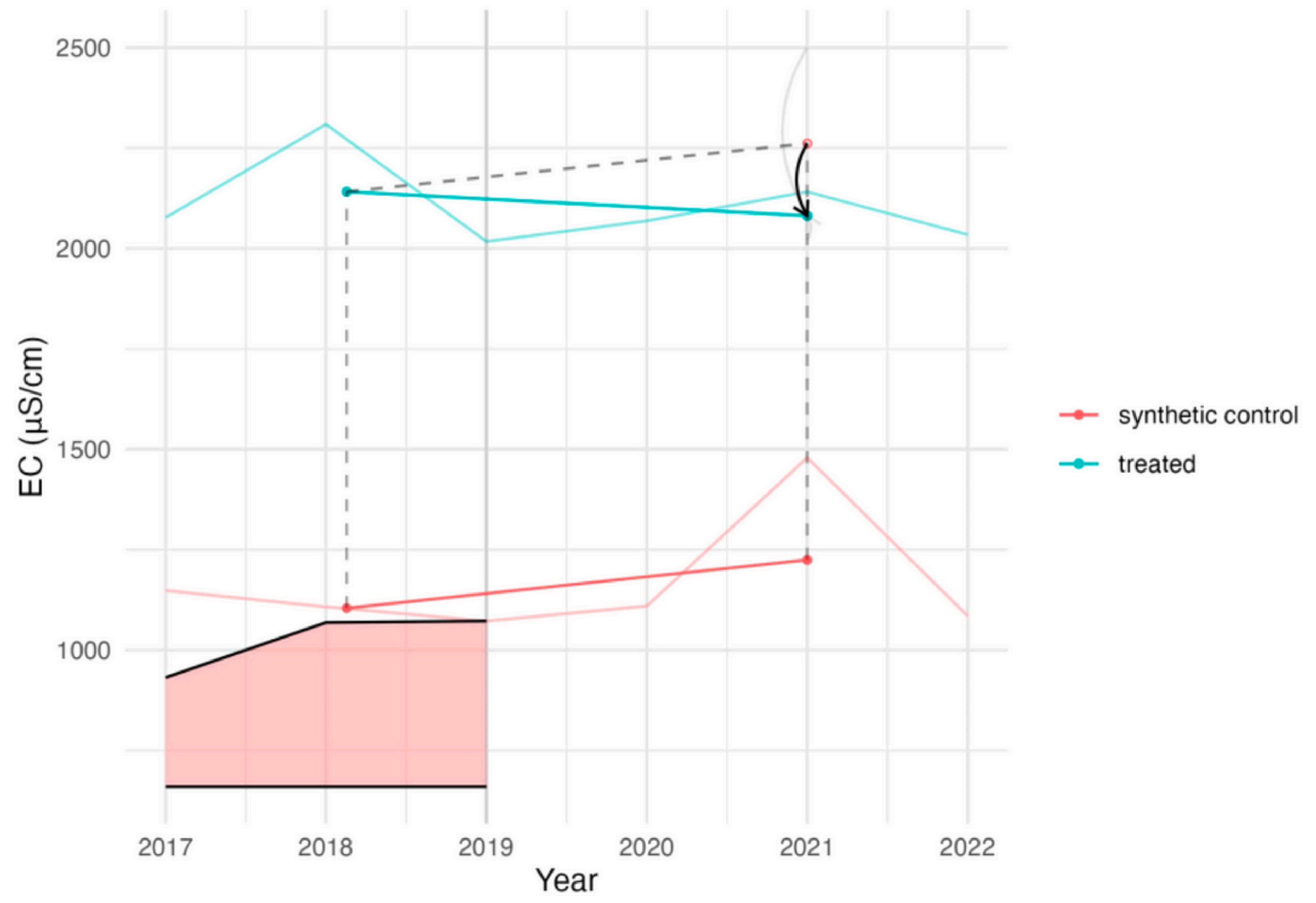
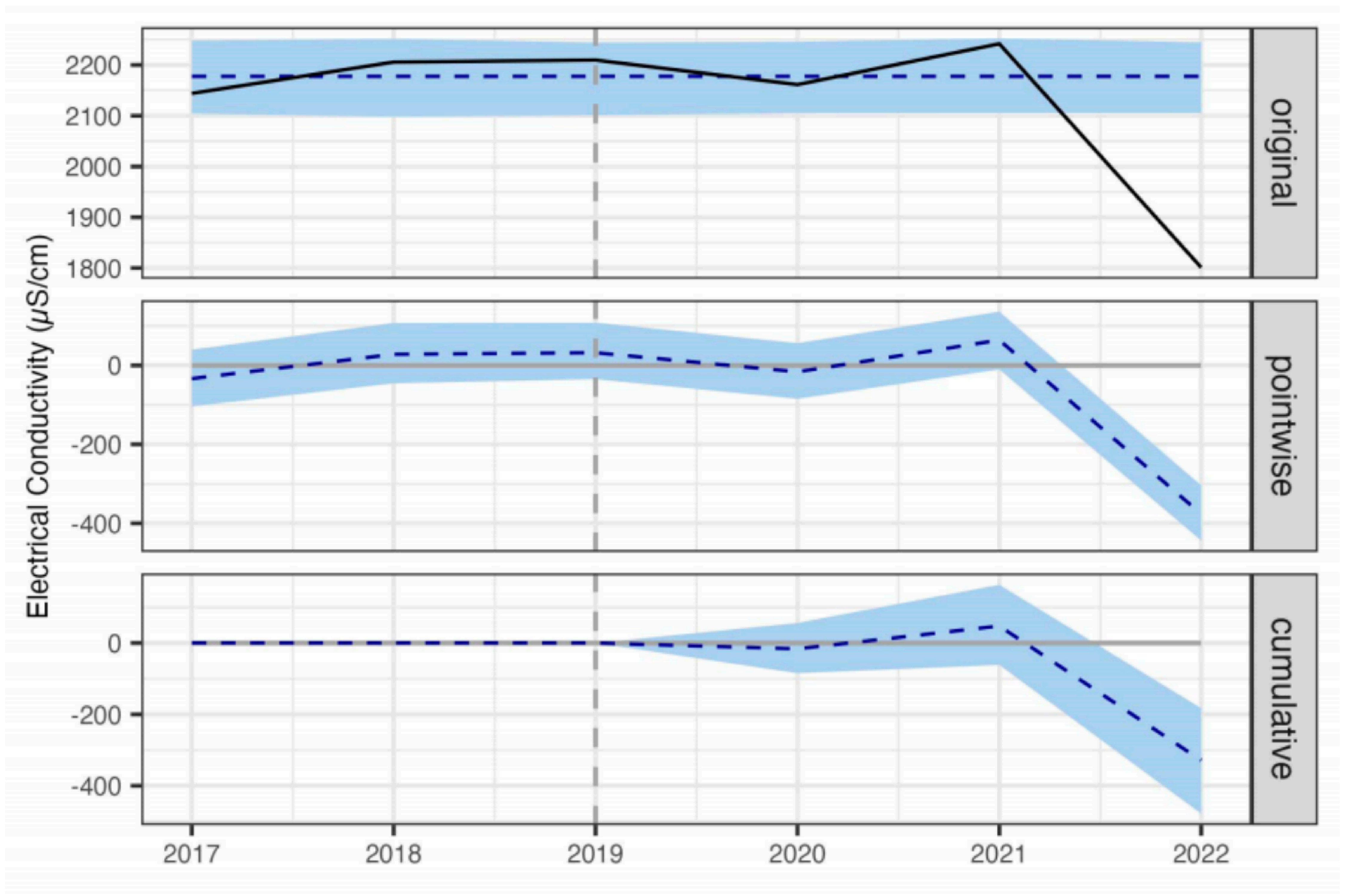


Figure 3. Synthetic control vs. actual treatment group: comparison of conductivity changes before and after intervention (2017-2022)

RESULTS

BAYESIAN STRUCTURAL TIME SERIES



ESTIMATED EFFECT: -110 MS/CM (-5%, P = 0.002)

POSTERIOR P: 99.8%

RESULTS

BAYESIAN STRUCTURAL TIME SERIES

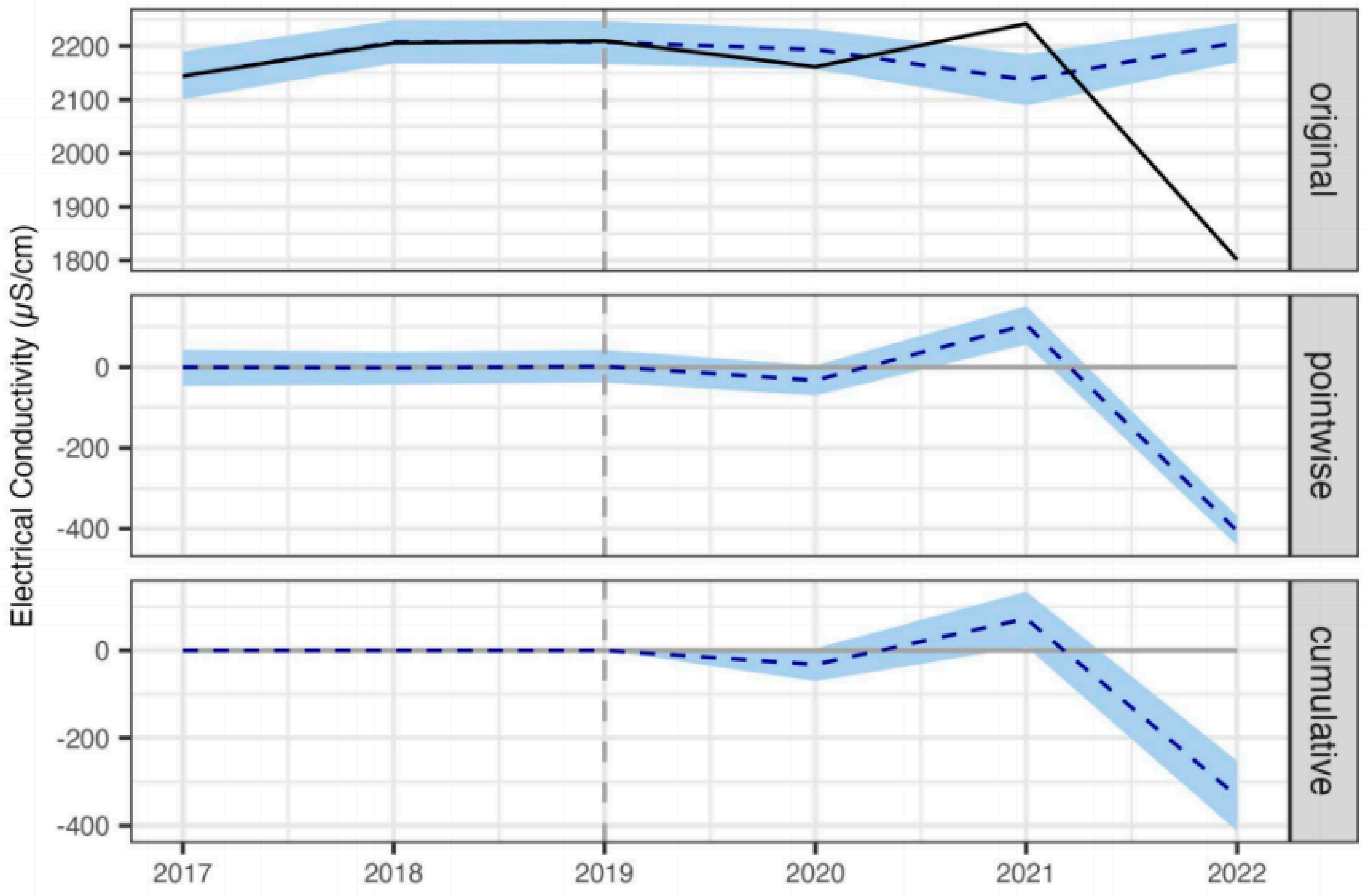


Figure 5. BSTS Two-Series Model: Haryana vs. Punjab (Control Group)

ESTIMATED EFFECT:
-111 MS/CM
(-5.1%, P = 0.001)
POSTERIOR P: 99.9%

RESULTS

BAYESIAN STRUCTURAL TIME SERIES

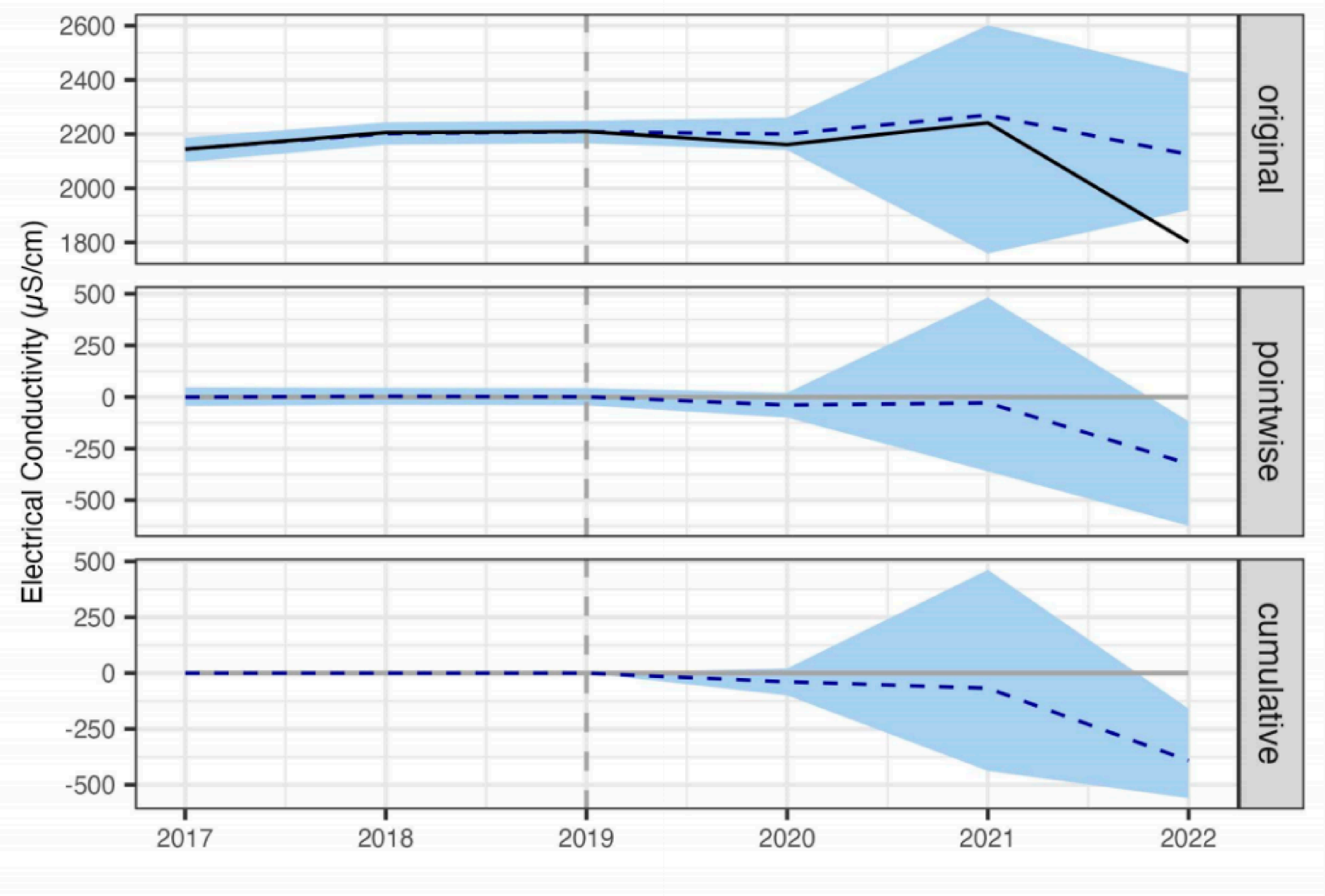


Figure 6. BSTS Two-Series Model: Haryana vs. Punjab (Control Group) with Chloride & Sodium Covariates

ESTIMATED EFFECT:
-130 MS/CM
(-5.9%, P = 0.003)
POSTERIOR P:
99.7%

DISCUSSION

Main Findings

- DiD (with FE & covariates): Significant reduction in conductivity post-ABY
- SDiD: Similar negative effect, not statistically significant
- BSTS: Strongest decline in 2022, indicating lagged effect

Mechanisms

Likely behavioral: irrigation & water-use changes
Not explained by natural ion variation

DISCUSSION

Limitations

Conductivity ≠ full water quality (e.g., heavy metals not included)

Short post-treatment period (only 3 years)

Only Haryana and Punjab → limited geographic & statistical scope

Future Directions

Include more contaminants & years

Expand to all Indian states

Link with behavioral & remote sensing data

CONCLUSIONS

1. ABY likely improved groundwater quality in Haryana
2. DiD shows significant reduction in conductivity
3. SDiD support similar direction
4. All three BSTS models identify a consistent decrease in conductivity
5. Triangulated approach adds robustness under data limits

REFERENCES

GitHub Repository:https://github.com/JacklynLin/TFM.git

Ali, S., Shekhar, S., Bhattacharya, P., Verma, G., Chandrasekhar, T., & Chandrashekhar, A. K. (2018). Elevated fluoride in groundwater of Siwani Block, Western Haryana, India: A potential concern for sustainable water supplies for drinking and irrigation. Groundwater for Sustainable Development, 7, 410–420. https://doi.org/10.1016/j.gsd.2018.05.008

Angrist, J. D., & Pischke, J.-S. (2008). Mostly harmless econometrics: An empiricist's companion. Princeton University Press.

Arkhangelsky, D., Athey, S., Hirshberg, D. A., Imbens, G. W., & Wager, S. (2021). Synthetic difference-in-differences. American Economic Review, 111(12), 4088–4118.

Bertrand, M., Duflo, E., & Mullainathan, S. (2010). How much should we trust differences-in differences estimates? The Quarterly Journal of Economics, 119(1), 249–275.

Brodersen, K. H., Gallusser, F., Koehler, J., Remy, N., & Scott, S. L. (2015). Inferring causal impact using Bayesian structural time-series models. The Annals of Applied Statistics, 9(1), 247–274. https://doi.org/10.1214/14-AOAS788

Central Ground Water Board. (2022). National Ground Water Monitoring Network: Ground-water quality observations for Haryana, 2017–2022 [Data set]. Ministry of Jal Shakti, Government of India. Retrieved June 10, 2025.

Central Ground Water Board. (2022). National Ground Water Monitoring Network: Ground-water quality observations for Punjab, 2017–2022 [Data set]. Ministry of Jal Shakti, Government of India. Retrieved June 10, 2025.

Central Ground Water Board. (2021). Ground Water Quality Data – 2021. Ministry of Jal Shakti, Government of India. Retrieved from Central Ground Water Board website.

Central Ground Water Board. (2021). National compilation on dynamic ground water resources of India, 2020. Ministry of Jal Shakti, Department of Water Resources, River Development & Ganga Rejuvenation, Government of India. https://cgwb.gov.in/cgwbpnm/public/uploads/documents/16872615581345047562file.pdf

REFERENCES

Choudhary, K., Choudhary, D., Choudhary, L., & Nitharwal, P. K. (2023, May). Atal Bhujal Yojana: Agriculture (Vol. 2, Issue 7). [E-ISSN 2583-1755]. https://www.researchgate.net/publication/371173355_Atal_Bhujal_Yojana_Agriculture

Central Ground Water Board. (2021). Ground Water Quality Data – 2021. Ministry of Jal Shakti, Government of India. Retrieved from Central Ground Water Board website.

Central Ground Water Board. (2021). National compilation on dynamic ground water resources of India, 2020. Ministry of Jal Shakti, Department of Water Resources, River Development & Ganga Rejuvenation, Government of India. https://cgwb.gov.in/cgwbpnm/public/uploads/documents/16872615581345047562file.pdf

Choudhary, K., Choudhary, D., Choudhary, L., & Nitharwal, P. K. (2023, May). Atal Bhujal Yojana: Agriculture (Vol. 2, Issue 7). [E-ISSN 2583-1755]. https://www.researchgate.net/publication/371173355_Atal_Bhujal_Yojana_Agriculture

Datta, K. K., de Jong, C., & Singh, O. P. (2000). Reclaiming salt-affected land through drainage in Haryana, India: A financial analysis. Agricultural Water Management, 46(1), 55–71. https://doi.org/10.1016/S0378-3774(00)00077-9

Kaur, L., Rishi, M. S., & Siddiqui, A. U. (2020). Deterministic and probabilistic health-risk assessment techniques to evaluate non-carcinogenic human-health risk due to fluoride and nitrate in groundwater of Panipat, Haryana, India. Environmental Pollution, 259, 113711. https://doi.org/10.1016/j.envpol.2019.113711

Khanduja, E., Chaturvedi, K., Jain, A. V., & Bassi, N. (2023). India's participatory groundwater management programme: Learnings from the Atal Bhujal Yojana implementation in Rajasthan. Council on Energy, Environment and Water. https://www.ceew.in/sites/default/files/atal-bhujal-yojana-sustainable-participatory-groundwater-resources-management-india.pdf

Kumar, K. S., Kumar, P. S., Ratnakanth Babu, M. J., & Hanumantharao, C. (2010). Assessment and mapping of ground water quality using geographical information systems. International Journal of Engineering Science and Technology, 2(11), 6035–6046. https://www.researchgate.net/publication/50366238

REFERENCES

Kumari, M., & Rai, S. C. (2020). Hydrogeochemical evaluation of groundwater quality for drinking and irrigation purposes using water quality index in semi-arid region of India. Journal of the Geological Society of India, 95(2), 159–168. https://doi.org/10.1007/s12594-020-1405-4

Mutum, L., Mizan, S. A., Bhatpuria, D., Taneja, G., Mitra, A., Gupta, S. K., & Sikka, A. (2025). Direct seeded rice in Haryana (India) ABY districts: Impact and lessons for scaling. International Water Management Institute (IWMI). https://cgspace.cgiar.org/items/ab07a586-93c6-4fa4-97fd-10120f29a68c

Ministry of Jal Shakti, Department of Water Resources, River Development & Ganga Rejuvenation. (2023). Atal Bhujal Yojana (Atal Jal): Program guidelines (Version 1.2).

Rani, P., & Kumar, S. (2023). The dual nature of pesticides: Assessing agricultural benefits and ecological risks with insights from Haryana. *Educational Administration: Theory and Practice, 29*(4), 5201–5207. https://doi.org/10.7492/7p436w75

Shaikh, M., & Birajdar, F. (2023). Groundwater awareness using various IEC tools in Atal Bhujal Yojana at Solapur District. *International Journal of Research Trends and Innovation, 8*(9), 6–14. https://ijrti.org/viewpaperforall?paper=IJRTI2309002

Sharma, S., Nagpal, A. K., & Kaur, I. (2019). Appraisal of heavy metal contents in groundwater and associated health hazards posed to human population of Ropar wetland, Punjab, India and its environs. Chemosphere, 227, 179–190. https://doi.org/10.1016/j.chemosphere.2019.04.009

Sheikh, M. A., Vishwakarma, C. A., Mukherjee, S., & Kumari, R. (2017). An assessment of groundwater salinization in Haryana state in India using hydrochemical tools in association with GIS. Environmental Earth Sciences, 76(13), 465. https://doi.org/10.1007/s12665-017-6789-0

World Bank. (2012, March 6). India groundwater: A valuable but diminishing resource. World Bank. https://www.worldbank.org/en/news/feature/2012/03/06/india-groundwater-critical
diminishing

THANK YOU FOR YOUR LISTENING!