Payments for Ecosystem Services Programs and Climate Change Adaptation in Agriculture

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Nature-based solutions for climate change mitigation/adaptation

- **Nature-Based Solutions Roadmap** at COP 27 (Biden-Harris Admin., 2022)
  - "... Bipartisan Infrastructure Law and Inflation Reduction Act made unprecedented investments in **nature-based solutions**, placing forests, agricultural lands and coastal wetlands front and center in the climate fight."

- **Climate Change Action Plan 2021-2025** (The World Bank Group)
  - "... **conservation and restoration to improve resilience** to climate change and mitigation potential."

- Deploying **Nature-Based Solutions** to Tackle Climate Change and Enhance Resilience (Executive Order 14072, 2022)

✓ **Land use adjustments** to existing agricultural land

Payments for ecosystem services (PES) programs build nature-based infrastructure

- **Payments** for establishing conservation practices on agricultural land
  - CRP and EQIP in the US; Agri-environmental schemes in the EU
- **Objective:** environmental benefits/amenities
  - Reduction of agricultural nonpoint source water pollution
  - Carbon sequestration benefits
  - Preservation of wildlife habitat
  - **Co-benefits:** soil and crop resilience to extreme weather events

✓ Limited research on the **loss mitigation benefits** of PES programs

Research Objective: Loss mitigation benefits of PES programs

- **Research Question.** Does the **introduction** of a new PES program reduce crop loss under extreme weather events?

- **Empirical Analysis**
  - **Policy**: Conservation Reserve Enhancement Program (CREP) (USDA-FSA)
  - **Outcome**: Flooded crop loss (USDA-RMA)
  - **Method**: Synthetic DID
  - **Data**: County-by-year panel, 384 counties during 1989-2022

✓ **Findings**
  - Number of flooded crop acres ↘ by 39%
  - Extent of damage on flooded crop acres ↘ by 27%
  - Spatial and temporal heterogeneity of the loss mitigation benefits

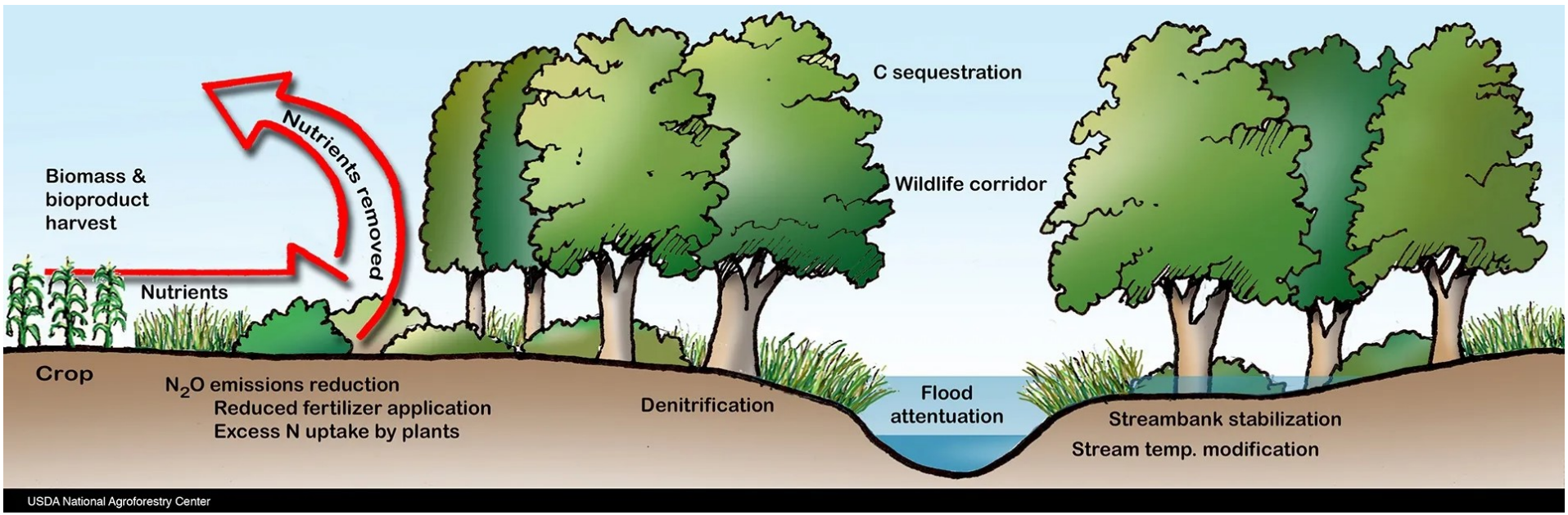
Why is it important?

1. **Contribution of PES programs to climate change adaptation**
   - Lack of adaptation to climate risks in agriculture (Annan & Schlenker, 2015; Burke & Emerick, 2016; Falco et al., 2014; Ortiz-Bobea, 2021)
   - "Green" (wetlands and forests) and "Grey" (levee and dams) infrastructures to manage flood risk (Bradt & Aldy, 2022; Karwowski, 2022; Kelly & Molina, 2023; Kousky & Walls, 2014; Taylor & Druckenmiller, 2022)
   - Benefit-cost analysis of PES programs: environmental benefits and payments (Alix-Garcia & Wolff, 2014; Baylis et al., 2022; Claassen et al., 2018; Ferraro & Simpson, 2002; Fleming, 2017; Lichtenberg, 2021; Mezzatesta et al., 2013)

2. **Financial spillover effects to existing risk management programs**
   - Crop insurance impact on land use and environmental outcomes (Claassen et al., 2017; Connor et al., 2021; DeLay, 2019; Feng et al., 2013; Horowitz & Lichtenberg, 1993; Miao et al., 2016; Wu, 1999; Yu et al., 2022)

Conservation Reserve Enhancement Program (CREP)

- Aims to address **national environmental concerns** since 1998
  - Water pollution in the Gulf of Mexico
  - Declining wildlife habitat
- Offers payments to restore vegetative buffers and wetlands for 10-20 years
  - Co-benefits: **regional flood risk mitigation** (Karwowski, 2022; Kousky & Walls, 2014; Taylor & Druckenmiller, 2022)



Opportunity to evaluate the loss mitigation benefits of PES programs

1. **National environmental concerns** rather than trend in historical crop losses
   - Reverse causality

2. **Staggered program roll-out** across counties within the same state
   - Neighboring untreated counties

3. Little incentive to **manipulate** crop damage
   - Anticipation effects

4. Long-term **landscape changes** that mitigate flood risk
   - Strong first stage impact

Data

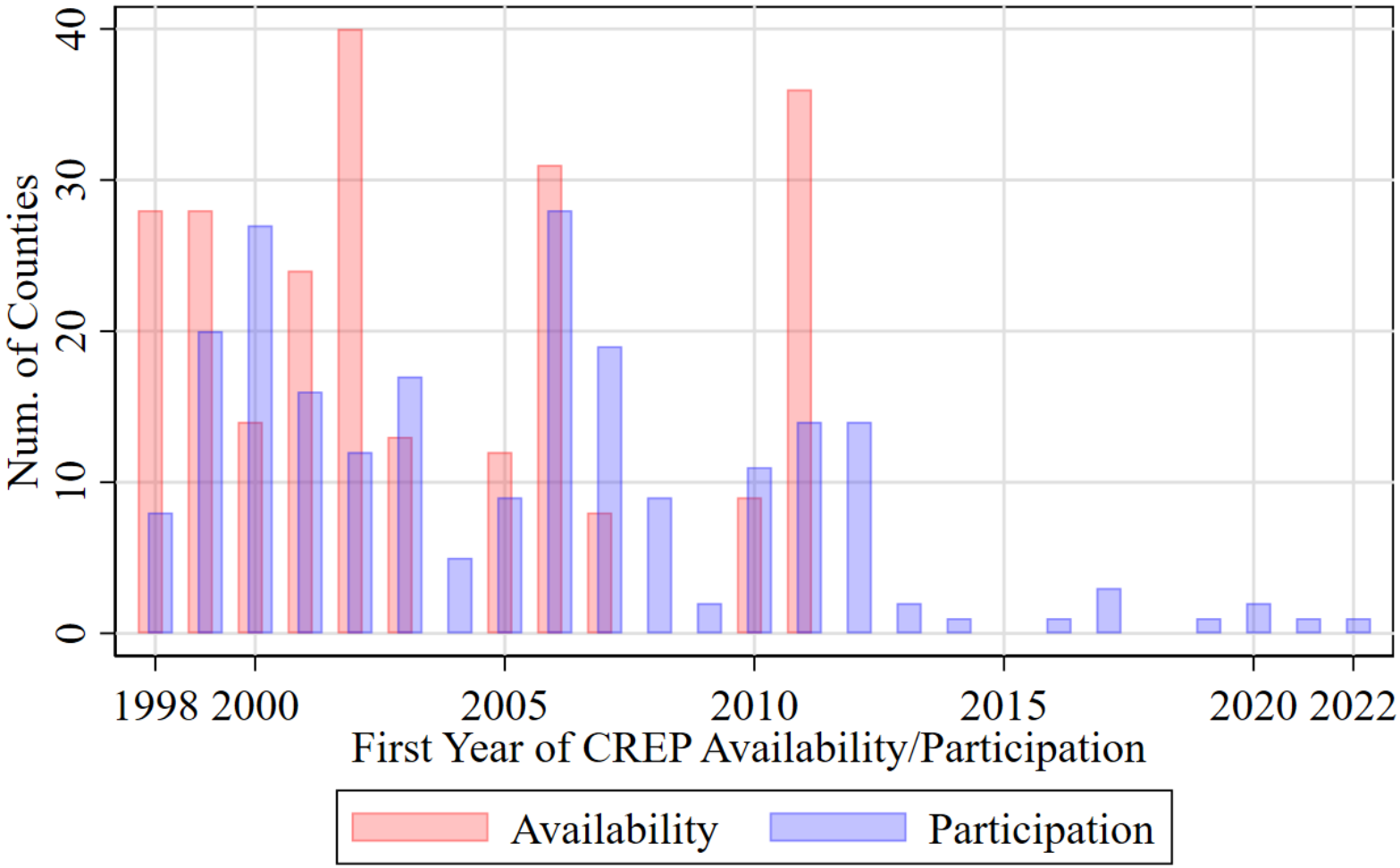
- **Population:** Major crop production region with flood risk in the U.S.
- **Sample:** Balanced county-by-year panel data; 384 counties 1989-2022
  - Heartland and Mississippi River Portal regions; 13 states
- **Policy:** Staggered introduction of CREP 1998-2011; 243 counties in 11 states

  Source: USDA-Farm Service Agency
- **Outcome:** Extent of flood damage on cropland 1989-2022
  - Disaster/Indemnity payouts per flooded acre for 8 major cash crops

  Source: USDA-Risk Management Agency
- **Covariates:** Precipitation and growing degree days 1989-1997
  - Post-harvest (Oct-Mar) and crop growing (Apr-Sep) seasons

  Source: Schlenker and Roberts (2009)

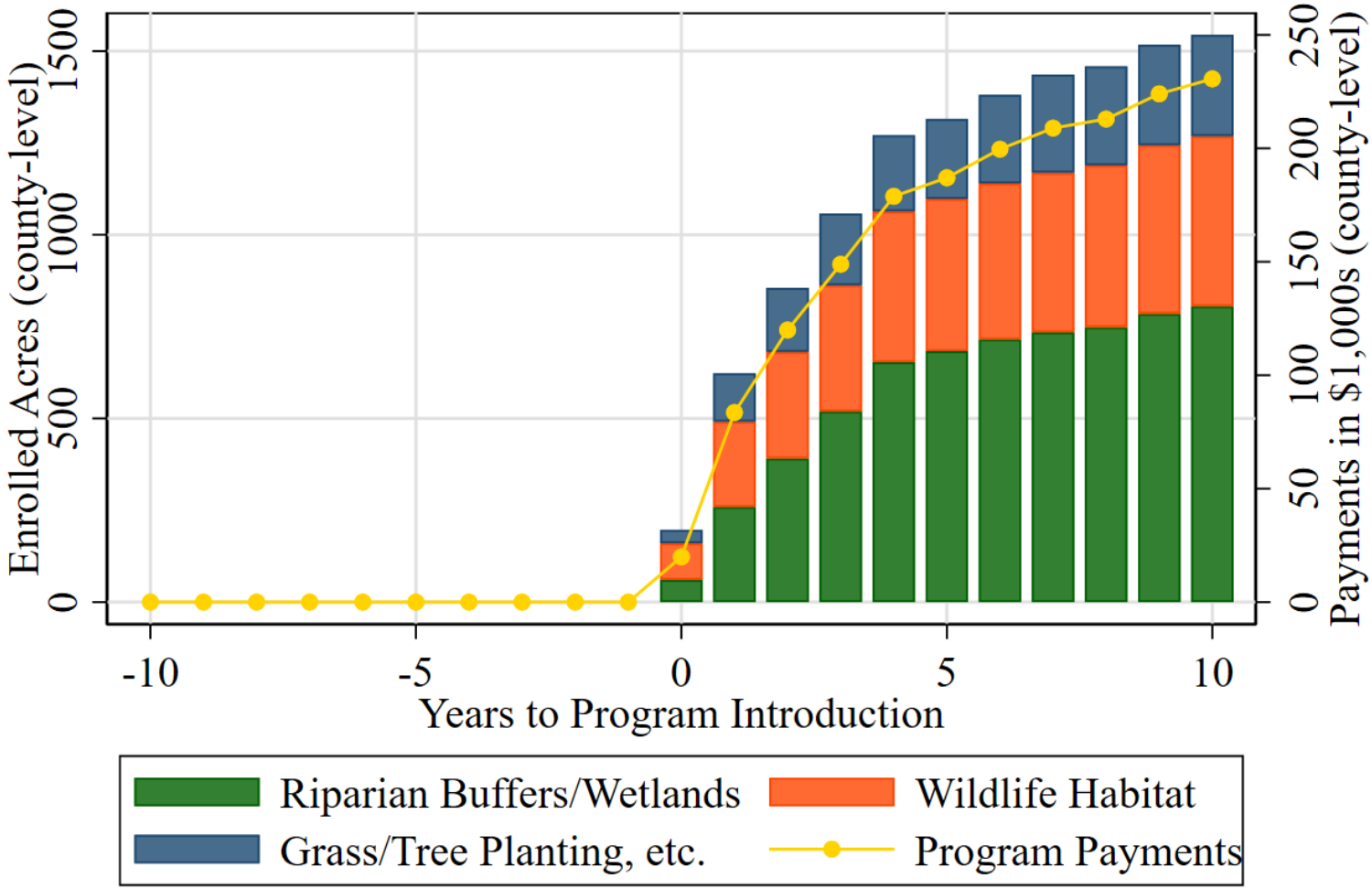
Timing variations of program availability and participation 1998-2022



CREP Availability: 243 counties from 11 states
CREP Participation: 223 counties from 11 states
CREP Not Available: 141 counties from 12 states

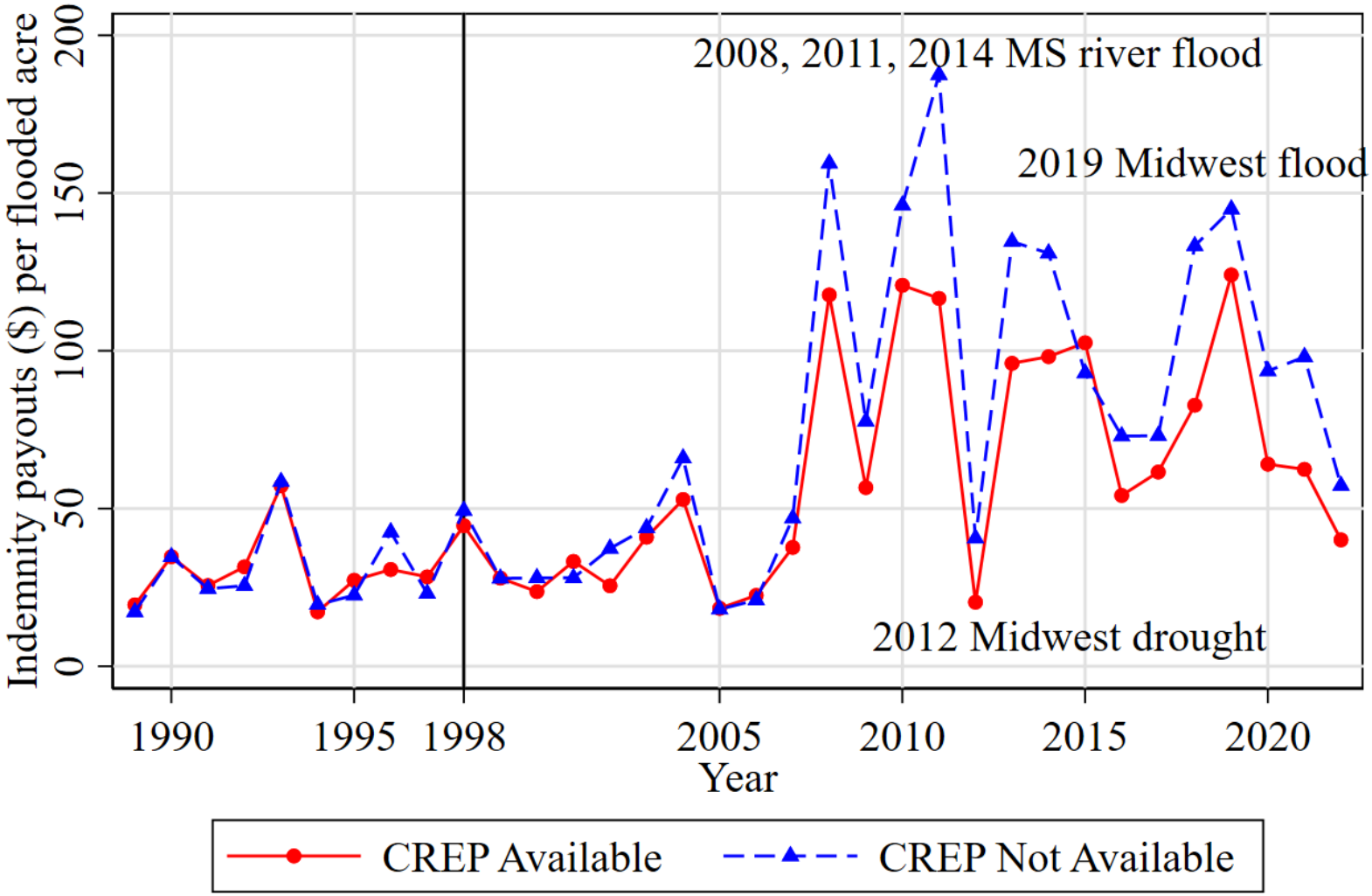
Long-term changes in the regional landscape induced by CREP

- Invested $440M to establish 280,000 acres of conservation practices



Unit of Obs.: County-by-Year; 243 CREP-available counties
Source: USDA-Farm Service Agency

Divergence in flood damage on cropland after the first CREP in 1998



CREP Available: 243 counties from 11 states; N = 8262
CREP Not Available: 141 counties from 12 states; N = 4794

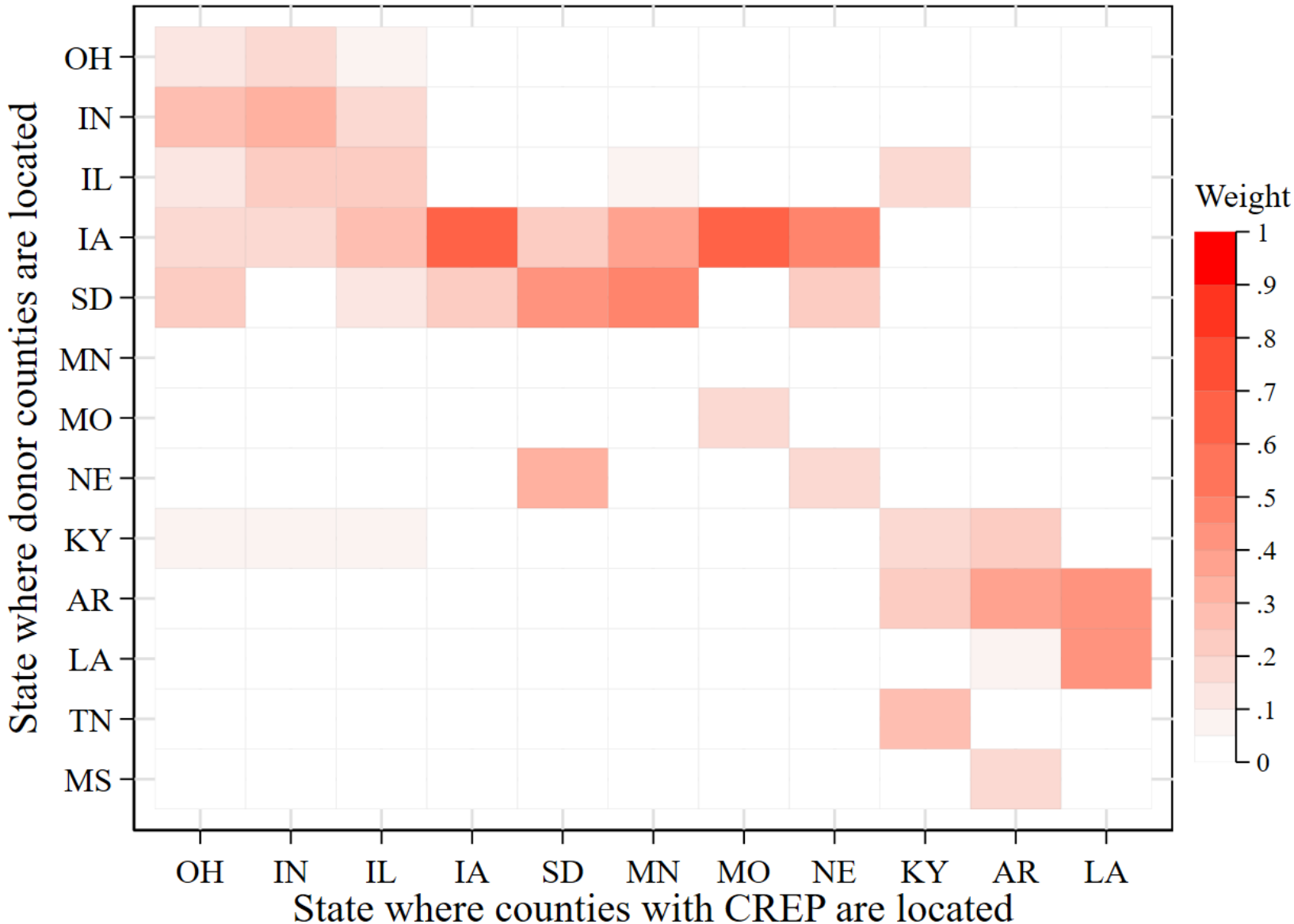
Synthetic control method to estimate the counterfactual crop loss

- Estimand: **post-policy** average crop loss that CREP-available counties would have experienced in the **absence** of the program

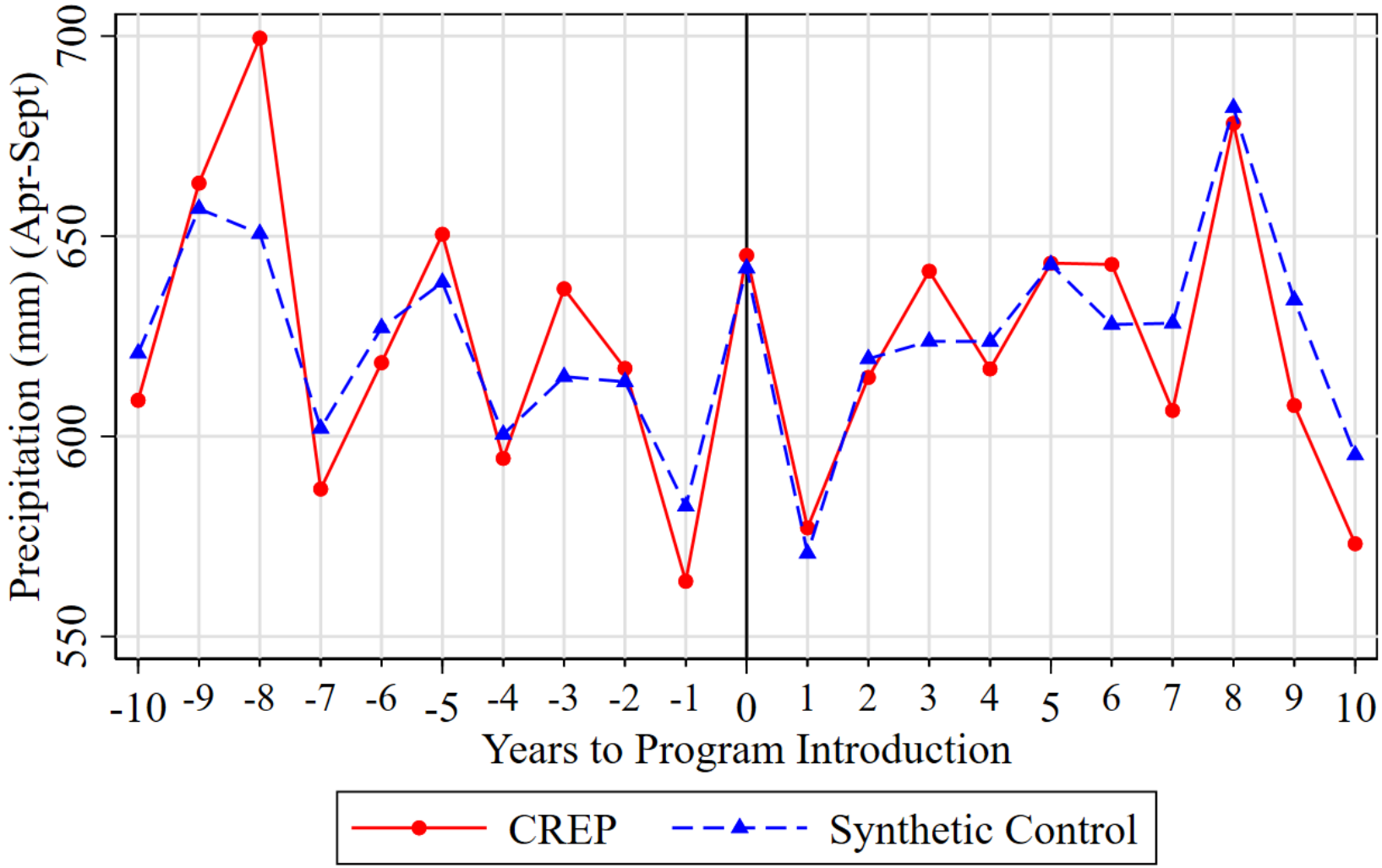
- Weighted combination of untreated counties with **similar pre-policy trend in crop loss** (Abadie, 2021; Arkhangelsky et al., 2021; Doudchenko & Imbens, 2016; Ferman & Pinto, 2021)
  - Partially pooled SCM with an intercept shift (Ben-Michael, Feller, Rothstein 2022)
  - Covariates: Weather conditions

- **Weighted DID estimator** (Arkhangelsky et al., 2021; Callaway & Sant'Anna, 2021; Chaisemartin & d'Haultfoeuille, 2020; Sun & Abraham, 2021)
  - Allows for program effect heterogeneity and timing variation of program adoption (Goodman-Bacon, 2021)
  - No anticipation and spillover effects
  - No time-varying confounding factors

1. Synthetic control consists of neighboring untreated counties

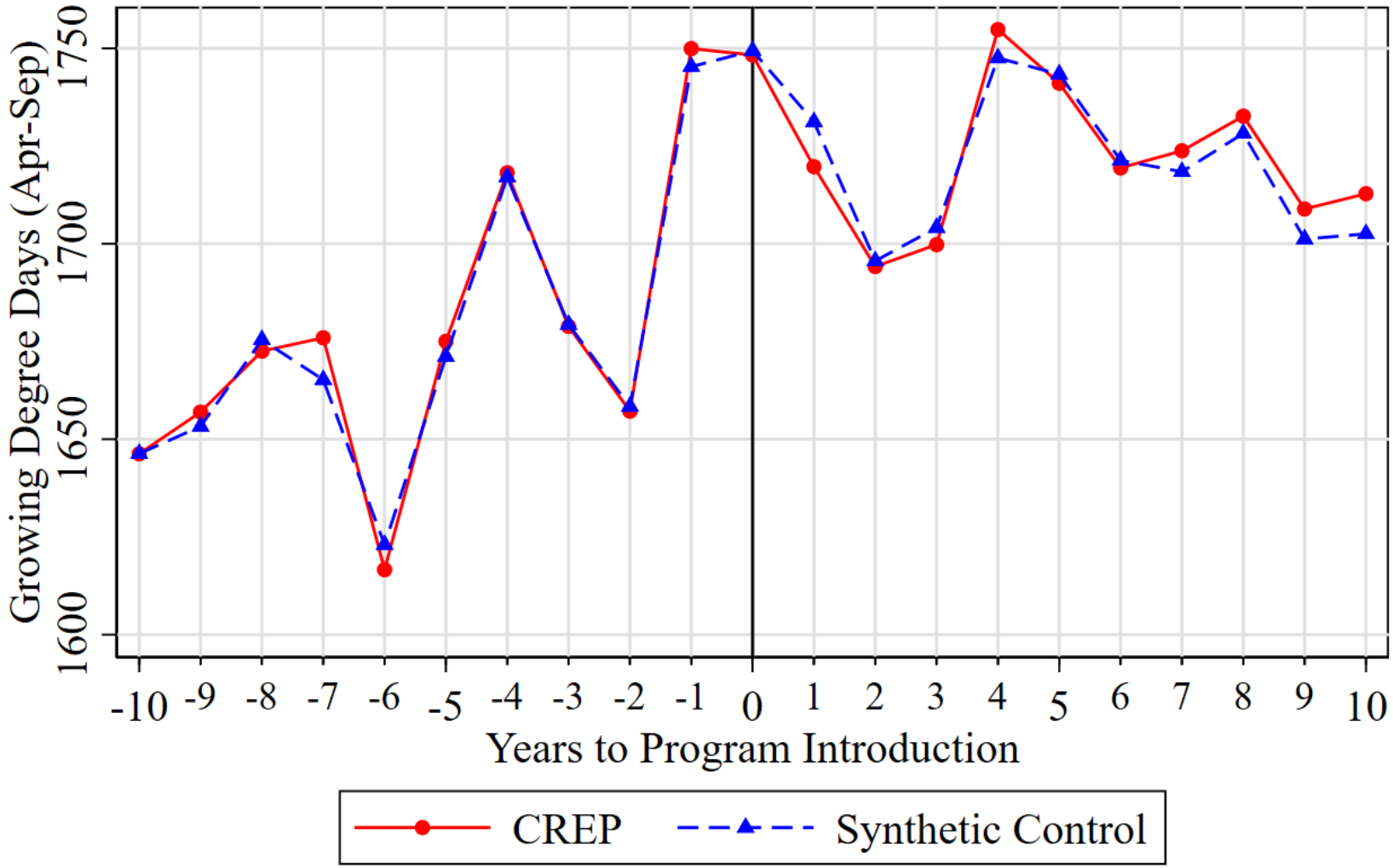


2A. Similar production conditions: **precipitation**



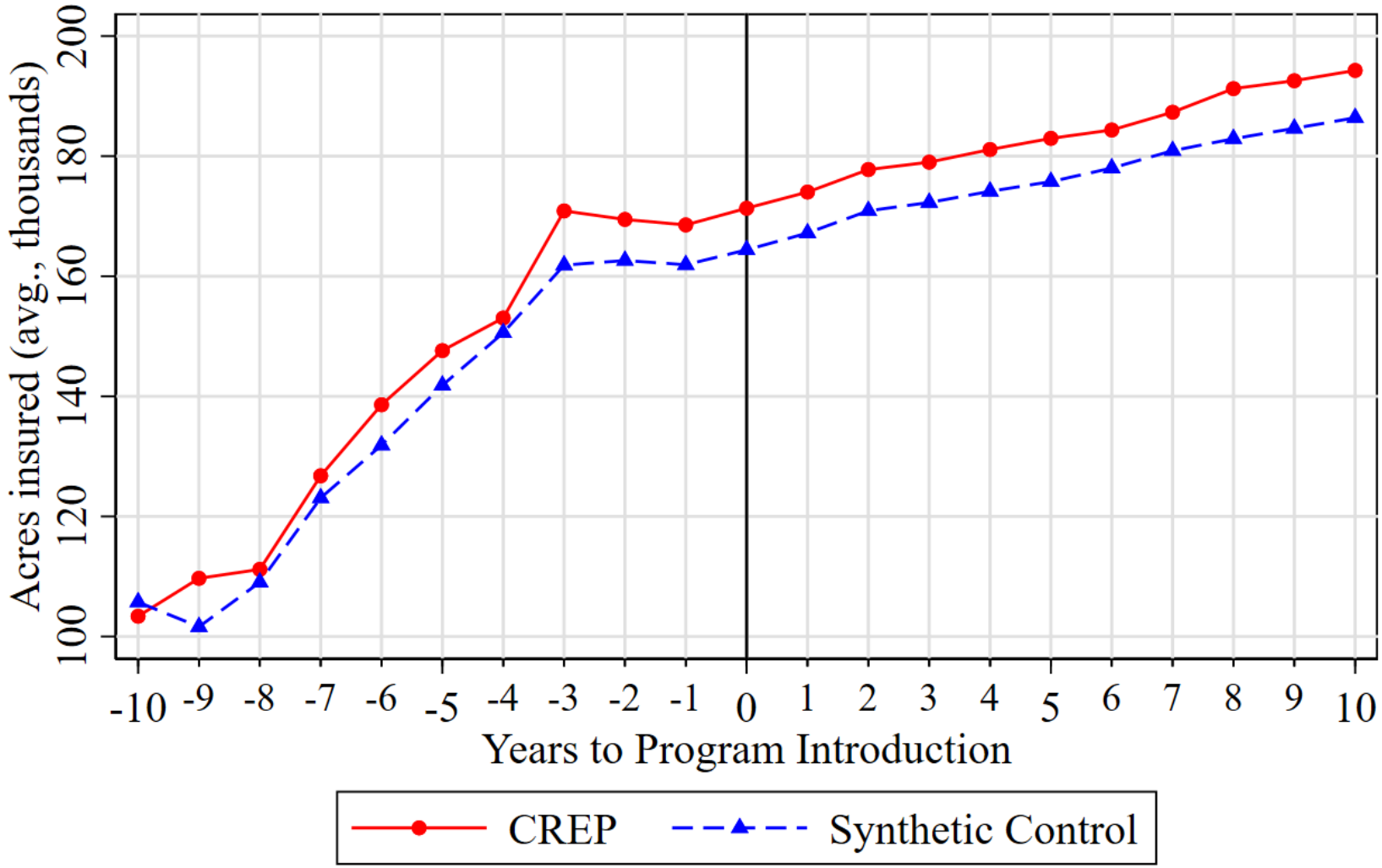
Pre-outcome Avg.: CREP 624, Synthetic Control 621, Pre-Diff. = 3
Post-outcome Avg.: CREP 624, Synthetic Control 627, Post-Diff. = -3
Unit of Obs.: County-by-Year
Num. of Obs.: 13056; 384 counties in year 1989-2022 (CREP Available 243, CREP Not Available 141)

2B. Similar production conditions: **temperature**



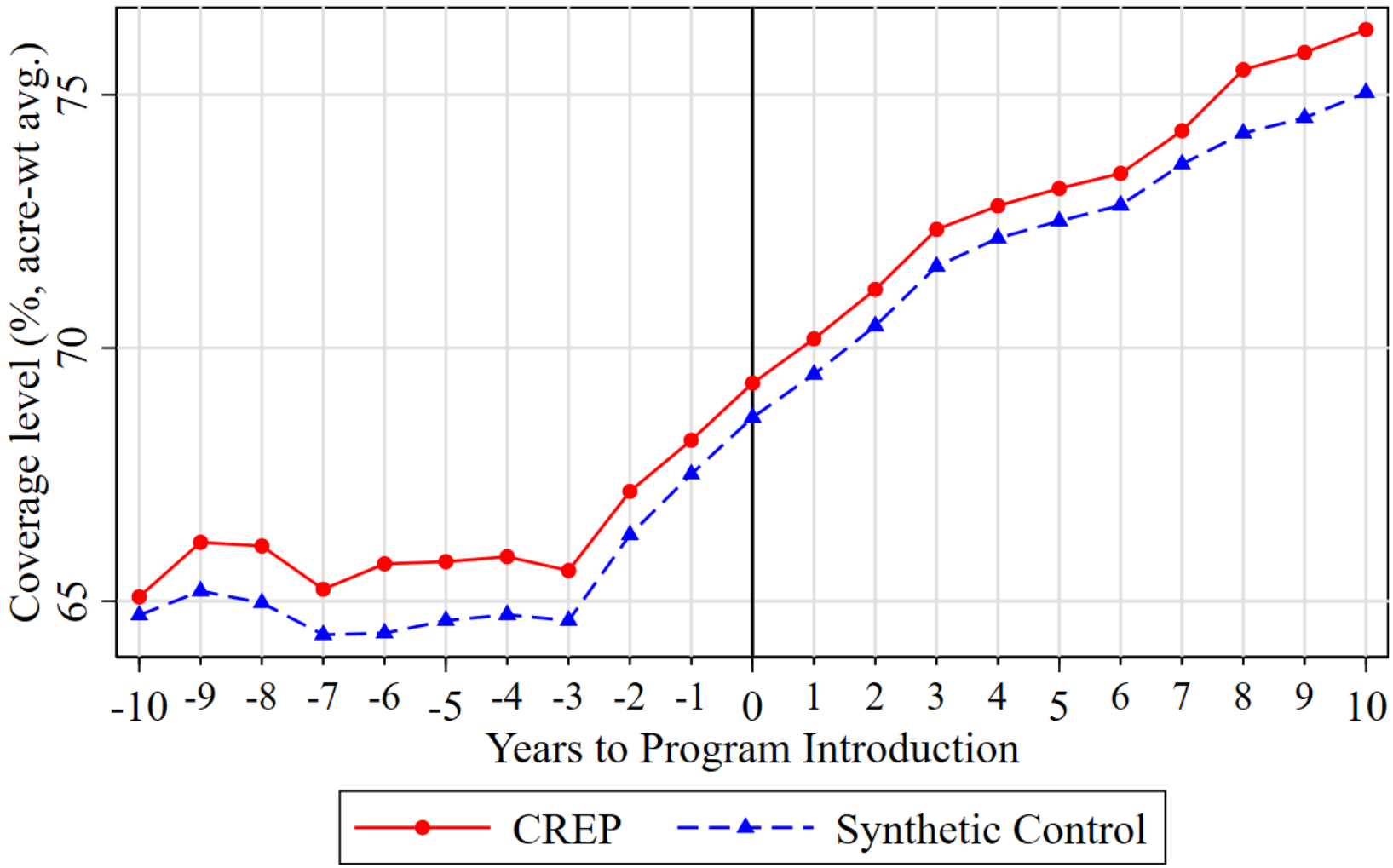
Pre-outcome Avg.: CREP 1675, Synthetic Control 1673, Pre-Diff. = 2
Post-outcome Avg.: CREP 1724, Synthetic Control 1723, Post-Diff. = 1
Unit of Obs.: County-by-Year
Num. of Obs.: 13056; 384 counties in year 1989-2022 (CREP Available 243, CREP Not Available 141)

3A. Similar insurance adoption: **acres insured**



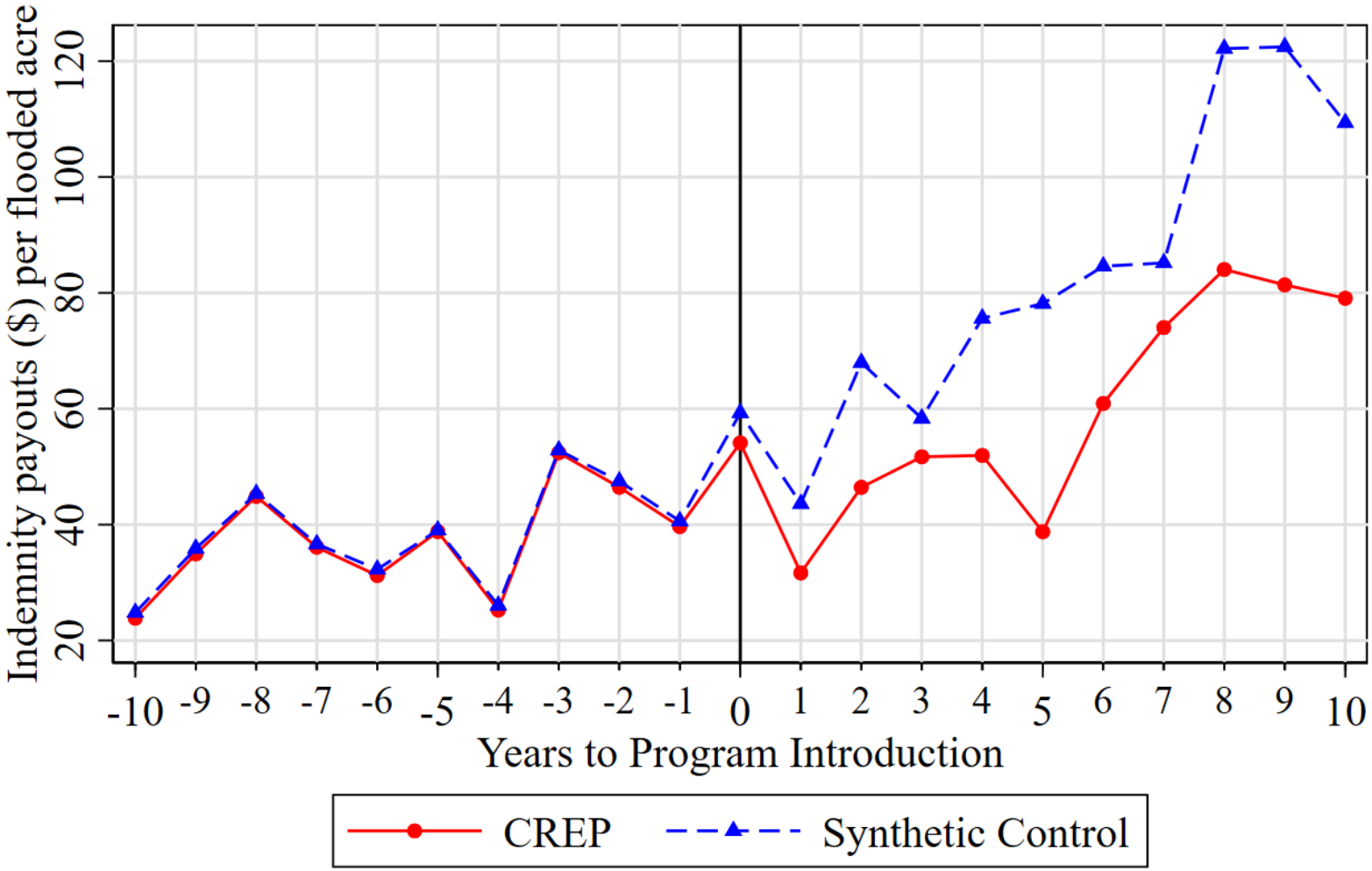
Pre-outcome Avg.: CREP 141, Synthetic Control 135, Pre-Diff. = 6
Post-outcome Avg.: CREP 183, Synthetic Control 176, Post-Diff. = 7
Unit of Obs.: County-by-Year
Num. of Obs.: 13056; 384 counties in year 1989-2022 (CREP Available 243, CREP Not Available 141)

3B. Similar insurance adoption: **loss coverage level**



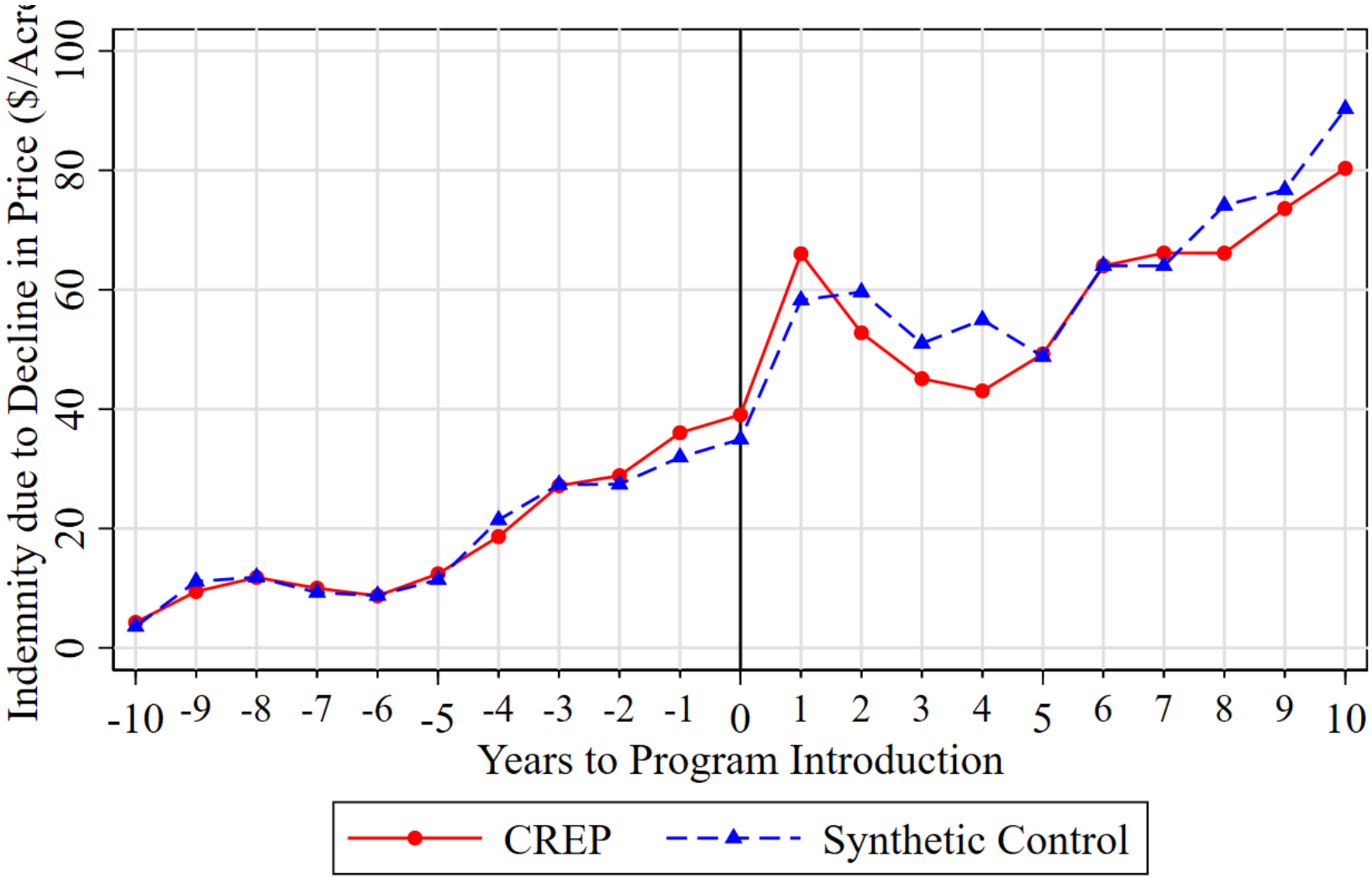
Pre-outcome Avg.: CREP 66, Synthetic Control 65, Pre-Diff. = 1
Post-outcome Avg.: CREP 73, Synthetic Control 72, Post-Diff. = 1
Unit of Obs.: County-by-Year
Num. of Obs.: 13056; 384 counties in year 1989-2022 (CREP Available 243, CREP Not Available 141)

Post-policy divergence in the extent of **flood damage** on cropland



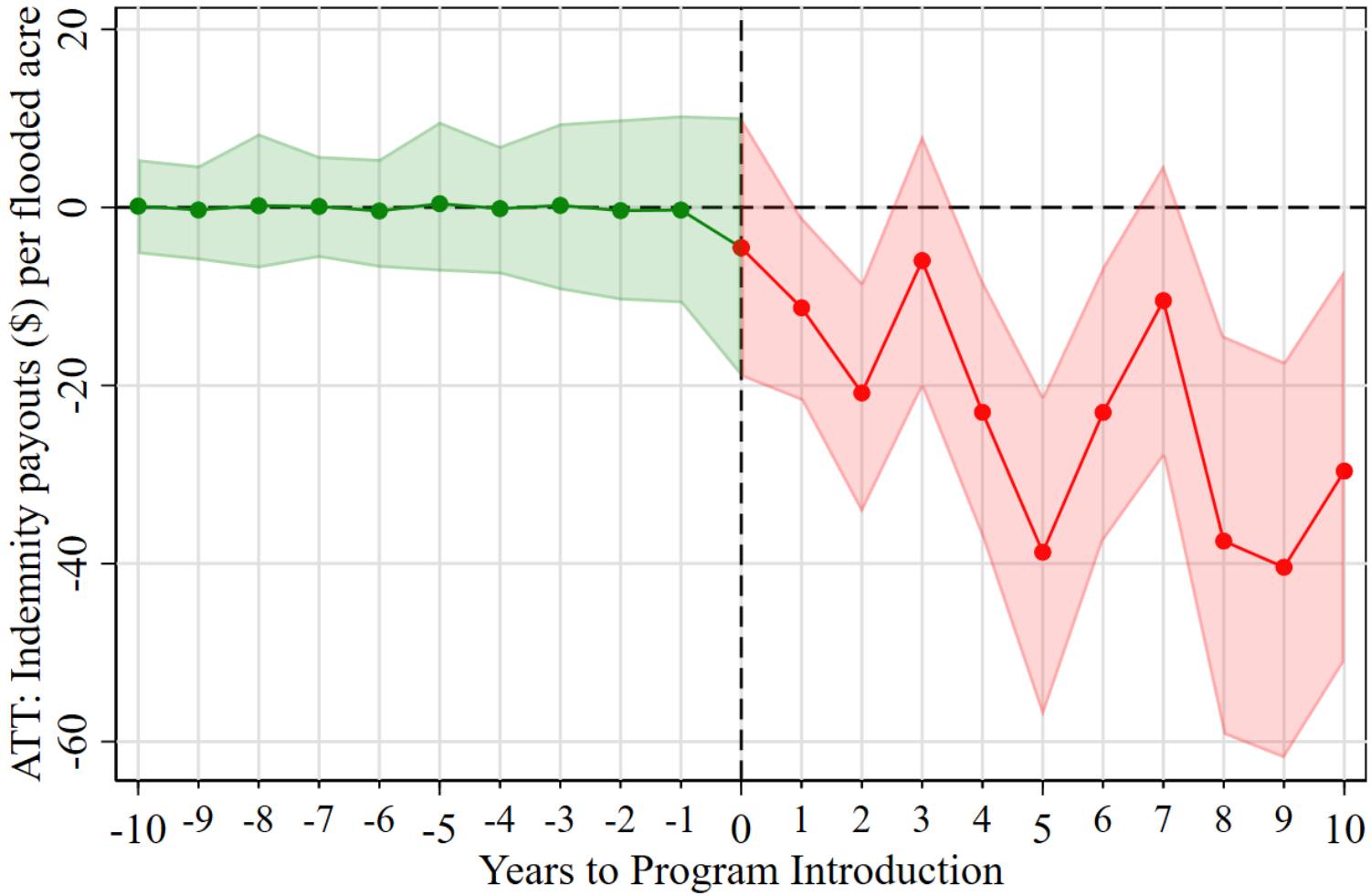
Pre-outcome Avg.: CREP 34, Synthetic Control 35, Pre-Diff. = -1
Post-outcome Avg.: CREP 59, Synthetic Control 82, Post-Diff = -23
Unit of Obs.: County-by-Year; Num. of Obs.: 13056

Placebo outcome: extent of loss due to decline in crop price



Pre-outcome Avg.: CREP 17, Synthetic Control 16, Pre-Diff. = 1
Post-outcome Avg.: CREP 59, Synthetic Control 62, Post-Diff. = -3
Unit of Obs.: County-by-Year
Num. of Obs.: 13056; 384 counties in year 1989-2022 (CREP Available 243, CREP Not Available 141)

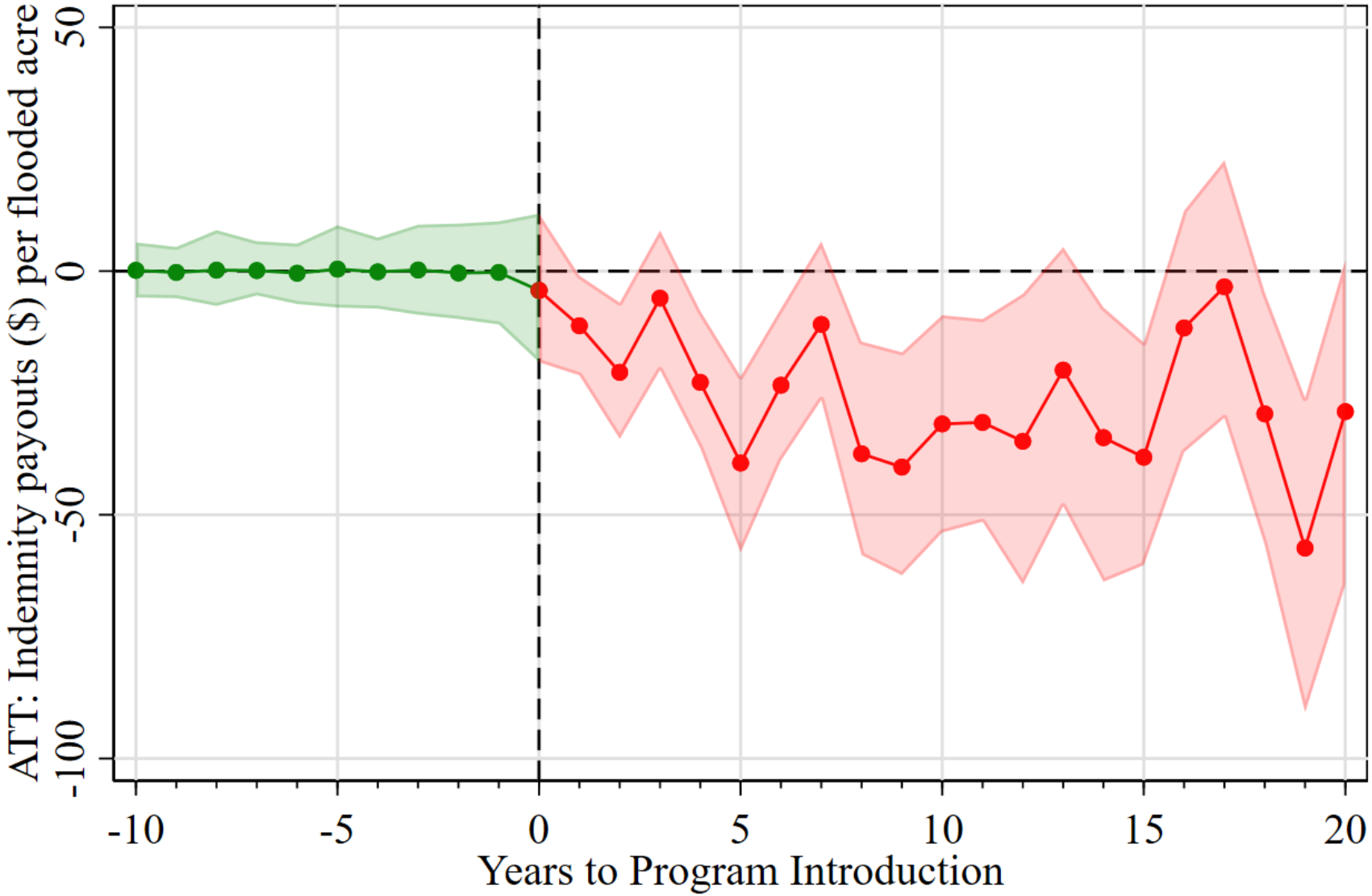
The extent of damage on flooded acres decreased by 27%



Overall ATT ($/acre) = -22 (se. 5)
Unit of Obs.: County-by-Year; Num. of Obs.: 13056

- The number of flooded crop acres also decreased by 39%

Persistent loss mitigation benefits of the PES program



Overall ATT ($/acre) = -25 (se. 6)
Unit of Obs.: County-by-Year; Num. of Obs.: 13056

Falsification analysis

- **Confounding factors**
  - Spatial distance
  - Insurance adoption
  - Weather conditions
  - Enrollment in other conservation programs

▸ Wt.Dist. ▸ AcreIns ▸ CovLev ▸ Prec. ▸ GDD ▸ Non-CREP CRP

- **Placebo outcome:** payouts due to decline in crop price

▸ Placebo

- **Results are robust to:**
  - Excluding outliers
  - Diff. outcome measures (indemnity payouts per liability or insured acres)
  - Diff. functional form (log or inverse hyperbolic sine) (Bellemare & Wichman, 2020)
  - Persistent benefits after the first 11 years
  - Excluding covariates
  - Other weighted DID estimators

Spatial and temporal heterogeneity of the loss mitigation benefits

- **Mechanism**: Duration of program availability and participation extent +
- **Interaction with the existing "Grey" infrastructure**: leveed area −
- **Interaction with crop insurance**: Extent of crop insurance adoption +
- Little inter-county **spillover effects**

Caveats

1. **Uninsured crop loss**
   - 82% of eligible crop acre were insured from 2000 to 2021 (USDA-ERS)

2. **Two different mechanisms of loss mitigation benefits**
   - Protection services from established natural infrastructure
   - Removal of cropland under flood risk

3. **Data limitations**
   - Previous land use (cropland vs pastureland)
   - Annual payment only

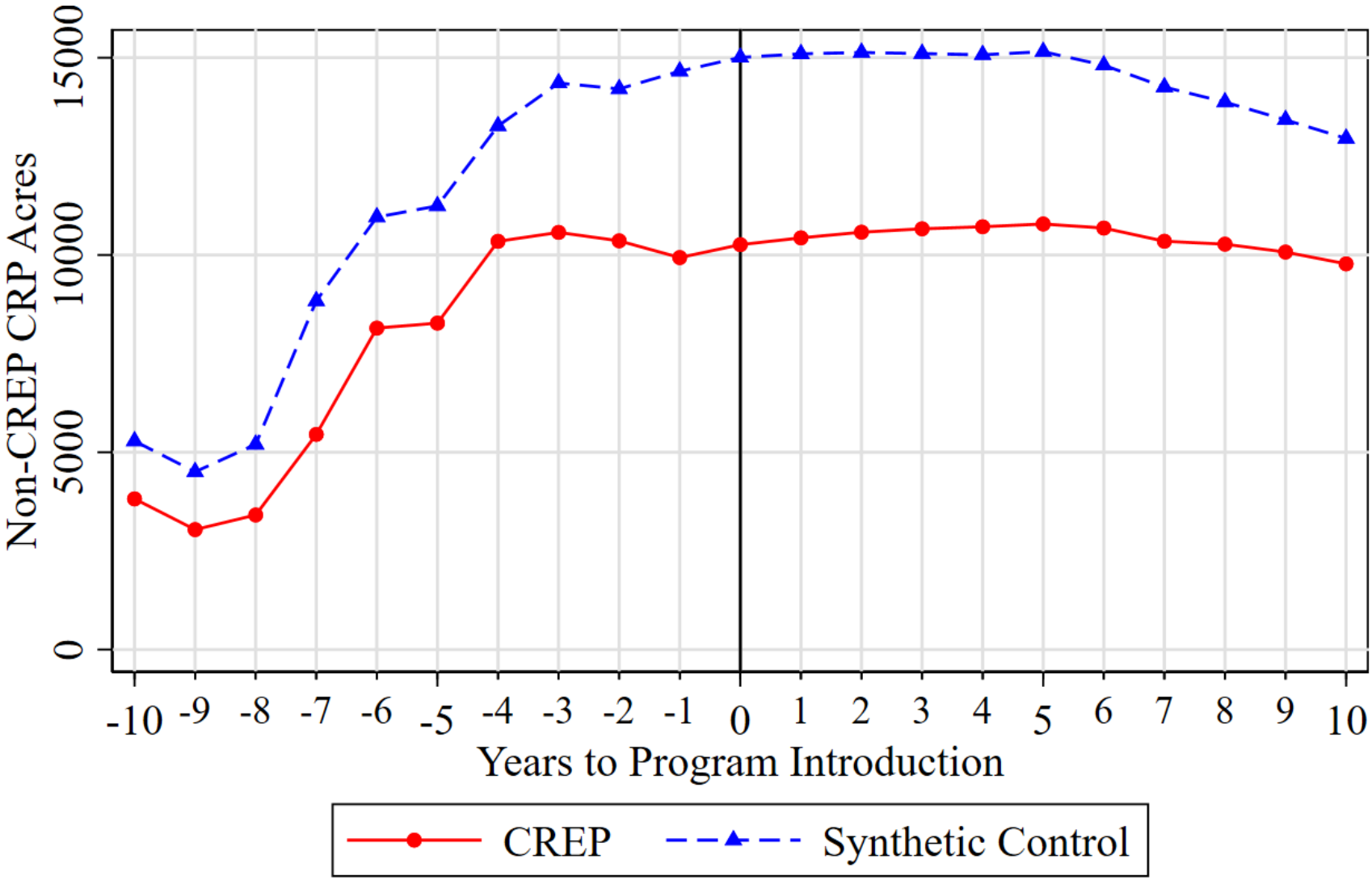
PES programs contribute to climate change adaptation in agriculture

1. **Persistent loss mitigation benefits**
   - Protected 900,000 crop acres from flooding (3 flooded acres per acre of conservation practice)

2. **Financial spillover effects to existing risk management programs**
   - Reduced $73M in insurance payouts ($170 per $1,000 program payments)

- Questions: youngk@umd.edu
- Website: https://www.econyoungkim.com
- Webinar Slides and Recording will be available at: https://www.fsa.usda.gov/programs-and-services/economic-and-policy-analysis/natural-resources-analysis/webinars/index
- USDA FSA Outreach: fsaoutreach@usda.gov

Trends in Non-CREP CRP: CREP vs. Synthetic Control



Pre-outcome Avg.: CREP 7314, Synthetic Control 10239, Pre-Diff. = -2925
Post-outcome Avg.: CREP 10418, Synthetic Control 14535, Post-Diff. = -4117
Unit of Obs.: County-by-Year
Num. of Obs.: 13056; 384 counties in year 1989-2022 (CREP Available 243, CREP Not Available 141)

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