Health IT Diffusion and Physician Density

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Rising US HIT investments enables automation

- The US allocated over $30 billion to health IT adoption (e.g., EHR)
  - Health Information Technology for Economic and Clinical Health (HITECH) Act and indirect provisions in Affordable Care Act (ACA)
- Extensive research on HIT impact on quality and cost
- But: limited understanding of HIT impact on physician density
  - Focus: **C**omputerized **P**rovider **O**rder **E**ntry (CPOE), an advanced HIT and the key component of HITECH Meaningful Use (MU) criteria
    - E-enter treatment orders, integrate patient info and clinical guidelines, and communicate with pharmacy, laboratory, and other departments
  - In contrast, basic HIT systems, e.g., clinical decision systems, store patient data in digital database and provide clinical treatment support
- Research question: How does advanced HIT adoption affect aggregate hospital-based (HB) physician density at the county level?
  - # physicians per 100k population, financial measures, patient care volume

Research Question:

Q: How does advanced HIT adoption affect aggregate hospital-based physician density at the county level?

- Intuitively, aggregate physician rate can go either way (empirical Qs):
  - More: “Time to hire more physicians to take full advantage of HIT!”
  - Less: “Time to automate and reduce docs (recover costs from HIT)!”
  - Same: “Docs come and go, on the net things may stay similar?”
- Exploit the county-level sharp adoption of advanced HIT (CPOE)
- Show how the plausibly exogenous HIT diffusion patterns affect county-level HB physician density, the heterogeneity by specialties, physician career stage, physician shortage area status
- Test financial mechanism and downstream impact on care utilization

Literature and Contribution

- **The impact of Health IT**: new evidence on how HIT automation affect aggregate physician labor density (high-skilled labor), and how the effects vary by specialty, career stage, shortage area status, and care utilization.

  (Miller & Tucker, 2011; Agha, 2014; Dranove et al., 2014; McCullough and Snir, 2010; McCullough et al., 2016; Freedman et al., 2018; Lu et al., 2018; Greenwood et al., 2019; Wang, 2021; Wang & Bloch, 2023; Lin & Olson, 2024; Glenn, 2026)

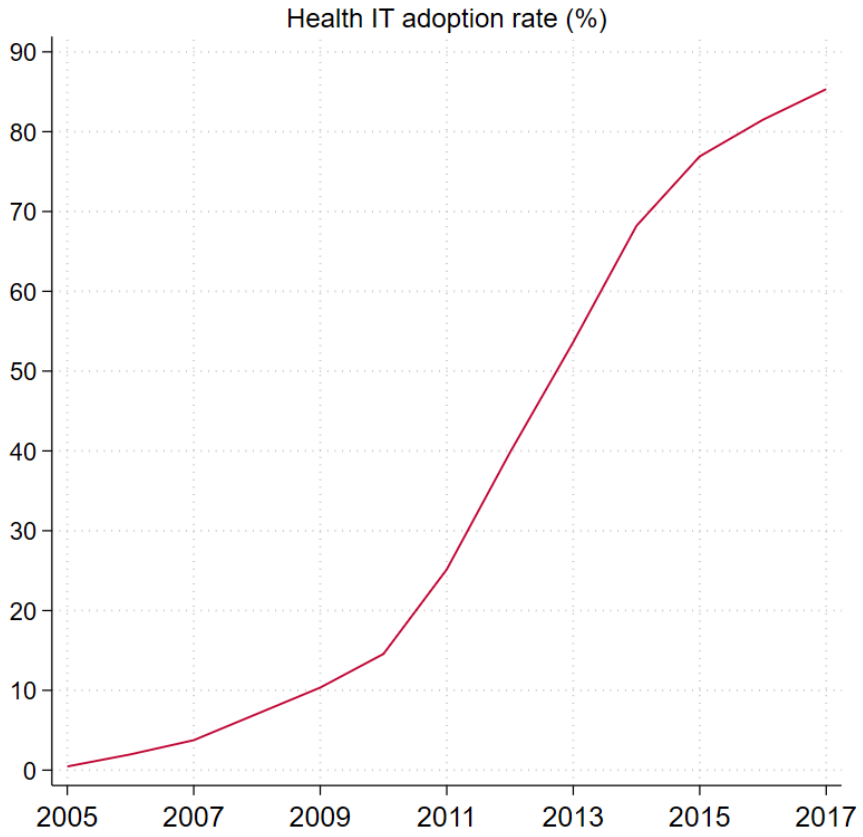
- **Physician labor supply**: new technological angle that combines market-driven incentives and policy-led changes in the past decades, and study how digital technologies affect physicians, hospitals, and care provisions.

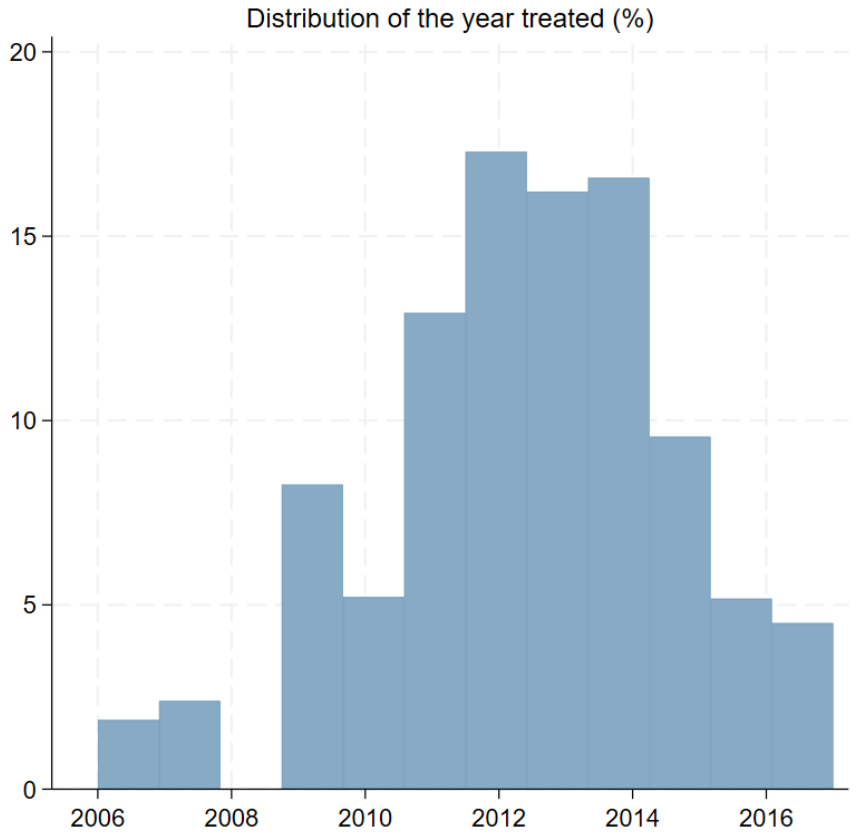
  (Baker & Royalty, 2000; Garthwaite, 2012; Buchmueller et al., 2016; Falcettoni, 2018; Kulka & McWeeny, 2018; Neprash et al., 2018; Huh, 2021; Curto & Bhole, 2022; Huh & Lin 2024; Khoury et al., 2024)

- **Policy implications** and relevant insights for managerial practices. HIT investment can attract physicians, expand access to care (reduce disparity in access), while sustaining providers' financial health.

Institutional context and HIT adoption trends

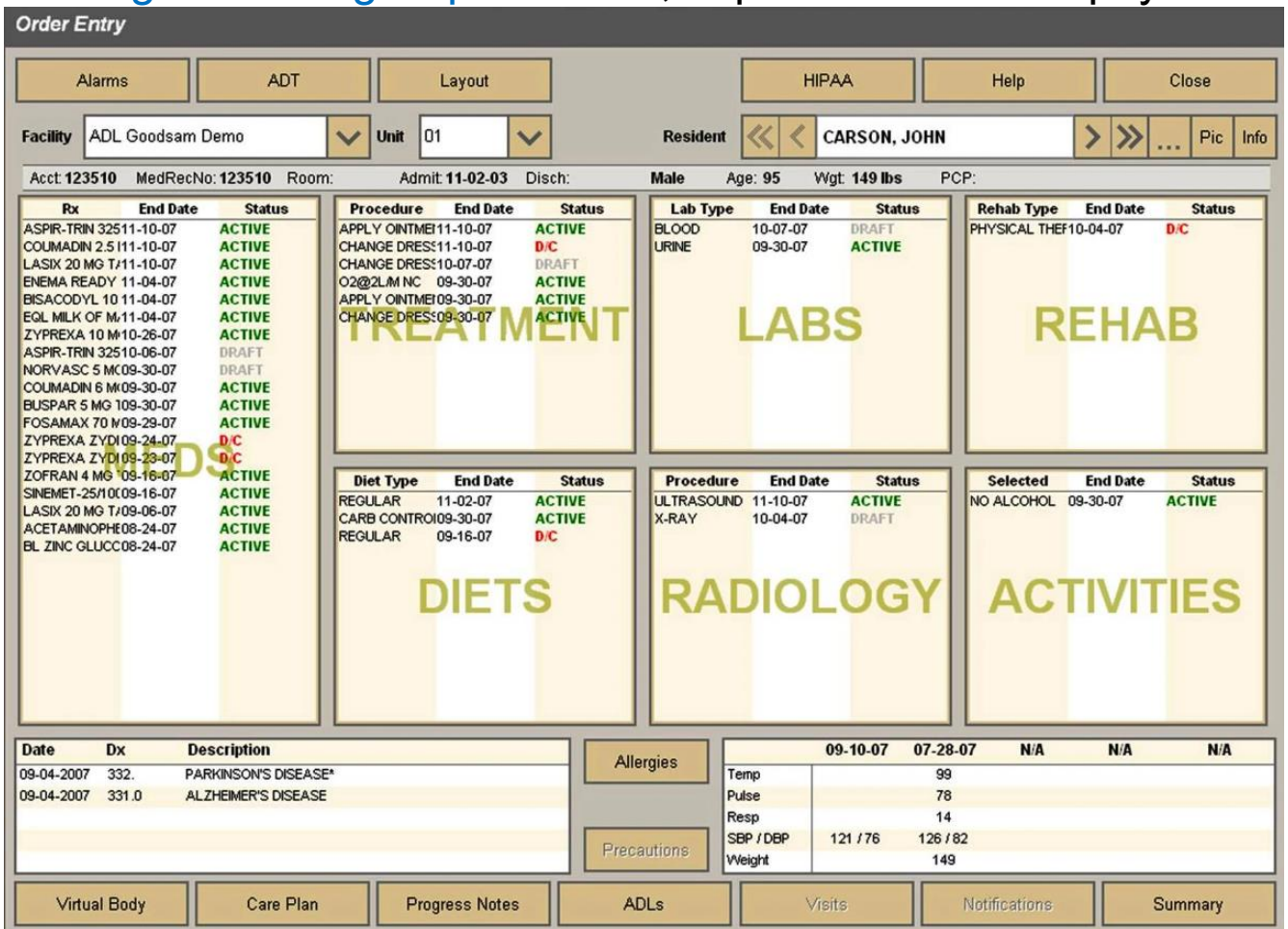
- Electronic health records (EHRs), the core component of HIT, were invented in 1970s but saw limited adoption until the 2000s. We focus on hospital HIT.
- 2010s: widespread hospital HIT adoption, driven by federal incentives
  - 2009 HITECH Act provides incentive payments for HIT meaningful use (MU); ACA indirect incentives (initiatives/provisions) require/facilitate HIT use.





HIT adoption measures: CPOE & its functionality

- Computerized Provider Order Entry (CPOE): advanced HIT, automation
  - Enable providers to electronically enter medication, laboratory, and radiology orders, often with built-in clinical decision support tools, core in MU criteria
  - Unlike other HIT component, CPOE directly structures patient data to align with coding and billing requirements, esp. relevant when payment matters



Conceptual Considerations

- Local physician density (per 100k pop) is affected by aggregating individual location choices and broader market dynamics.
- Hospitals' perspectives:
  - HIT investment can affect strategic hiring of docs to fully leverage technology
  - Esp in geo-areas with *moderate* but *growing* demand for medical services
  - If increase patient throughput, boost revenue -> can hire/retain more docs
- Physicians' perspectives
  - Response to HIT diffusion may vary by specialty, career stage, tech-savviness
  - HIT can be a pull factor for early-career physicians adapted to digital tech
- Patients' perspectives
  - HIT can make access to services more convenient with faster scheduling
  - can seek elective procedures earlier and easier (limited sorting within county)

Data Construction

- **Physician supply data**: Area Health Resources Files (AHRF)
  - Hospital-based (HB) physicians: non-federal MDs under hospital contracts providing direct patient care, measured as rate per 100k county population
  - **Specialty categorization**: medical, surgical, general practitioners, others
- **Health IT adoption data**: Healthcare Information and Management Systems Society (HIMSS) Analytics Database
  - Records basic and advanced HIT adoption by hospitals, including CPOE
  - County-level adoption rate weighted by capacity (hospital beds)
- **Medicare provider and service data**: CMS Medicare physician & other practitioners by provider and service dataset (available starting 2013)
- **Market structure and profit data**: Healthcare Provider Cost Reporting Information System (HCRIS), CMS; calculate hospital HHI and profit
- **Sample**: ~2,394 US counties during 2006-2018 outcome years matched with one-year lagged HIT adoption (excl. 2009 b/c missing AHRF data)

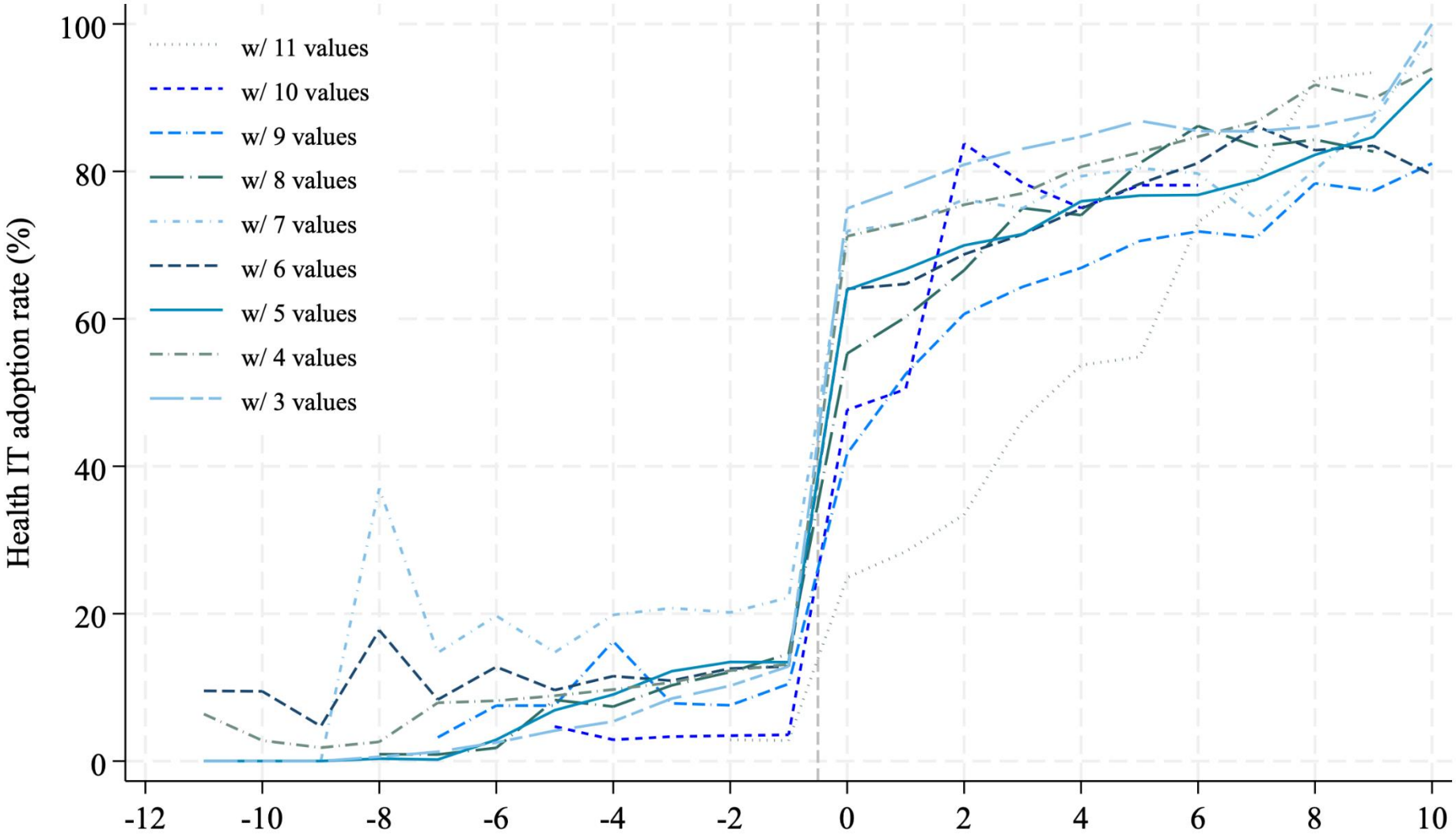
data.HRSA.gov

HIMSS℠

CMS
CENTERS FOR MEDICARE & MEDICAID SERVICES

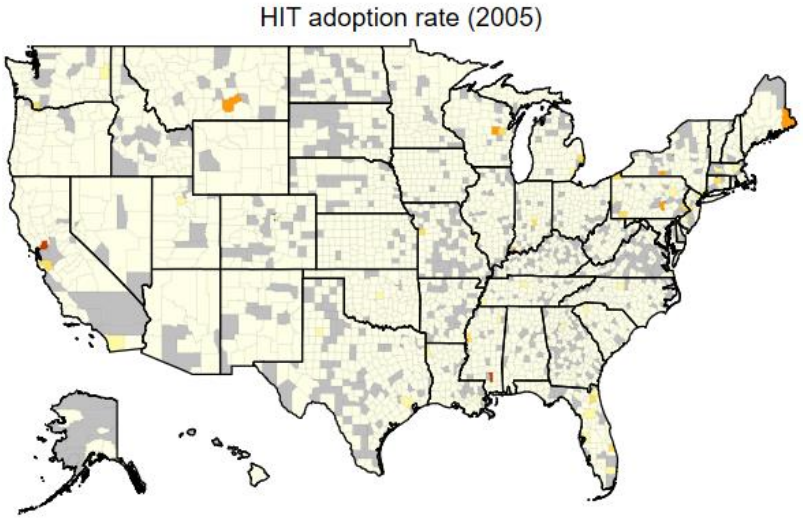
HIT treatment measure: sharp jumps in HIT rates

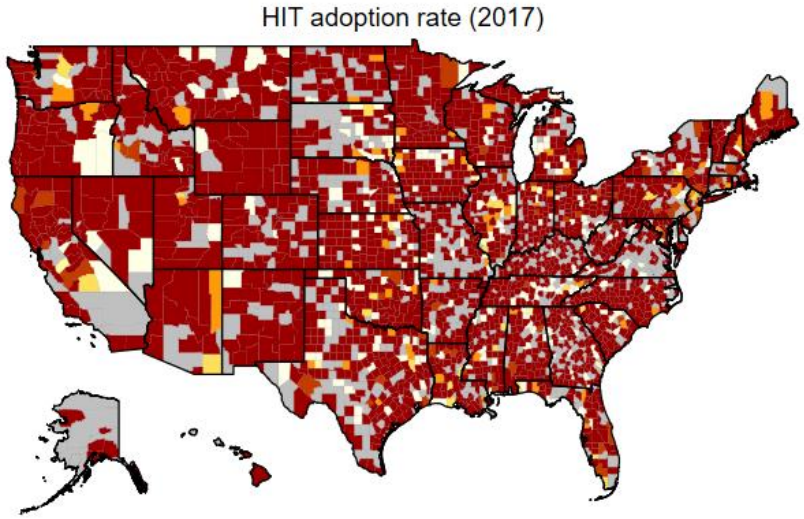
- Define treatment/control group à la the strategy in East et al. (AER 2023)
- Identify the sharpest jump in year τ (roughly = if 0→ +, or ↑ 100+% at τ)



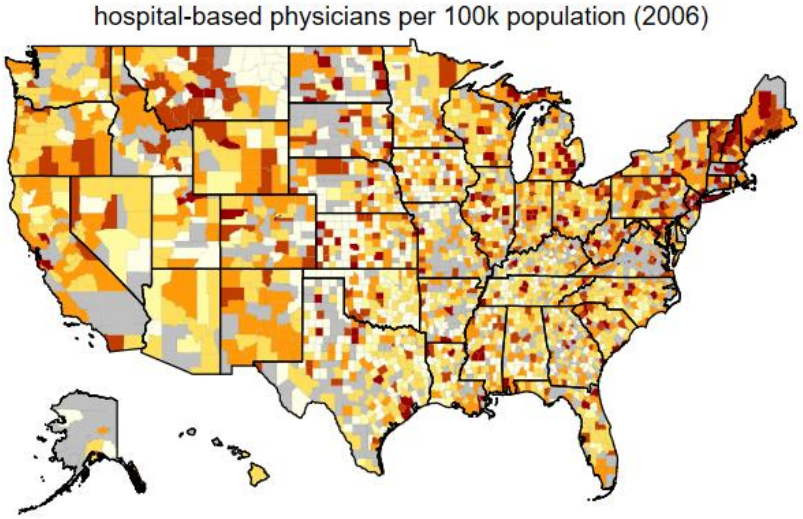
Geographic variation in HIT and physician supply

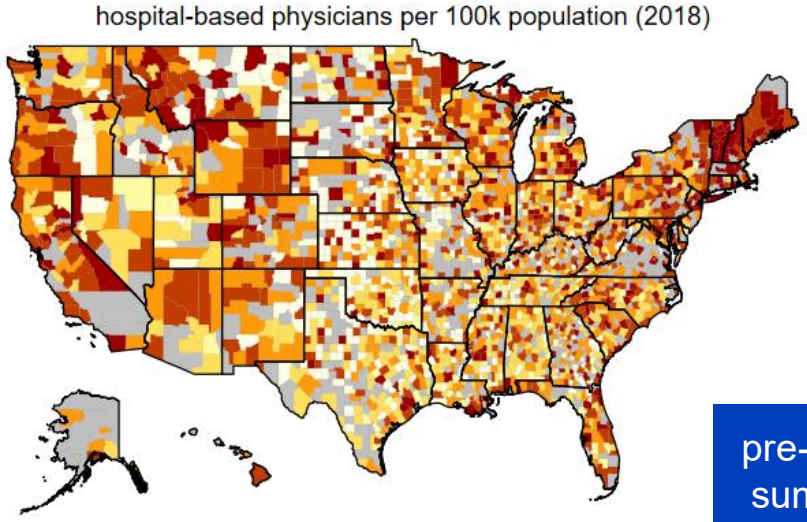
- Outcome periods 2006-2018 with one-year lagged HIT 2005-2017





80< ≤100% 60< ≤80% 40< ≤60% 20< ≤40% 0< ≤20% 0 NA





>40.23 21.49< ≤40.23 10.94< ≤21.49 4.07< ≤10.94 0< ≤4.07 0 NA

pre-T sum stats

Empirical strategy: dynamic DiD & event studies

- Staggered DiD design exploits the variation in the timing of the sharp increase in county HIT adoption (De Chaisemartin & d'Haultfoeuille, 2024)

$$Y_{it} = \beta_0 + \boldsymbol{\beta_1}\, Treat_{i(t-1)} + \gamma\, X_{\{i,2005\}t} + \lambda_{st} + \delta_i + \delta_t + \varepsilon_{it}$$

  - Y_{it} : physician density in t matched with one-year lagged HIT treatment (t-1)
  - X_{it}: 2005 county demographics (share aged 65+, poverty rate, income per capita, Medicare Advantage penetration, share eligible for Medicaid, and college attainment rate), each x a linear time trend to capture time variation while mitigating endogeneity from treatment, à la Dranove et al (2014)
  - λ_{st}: state-specific time trends, where s denotes the state of county i
  - δ_i & δ_t: county and year fixed effects; ε_{it} clustered at the state level
  - Regressions are weighted by county-year level population

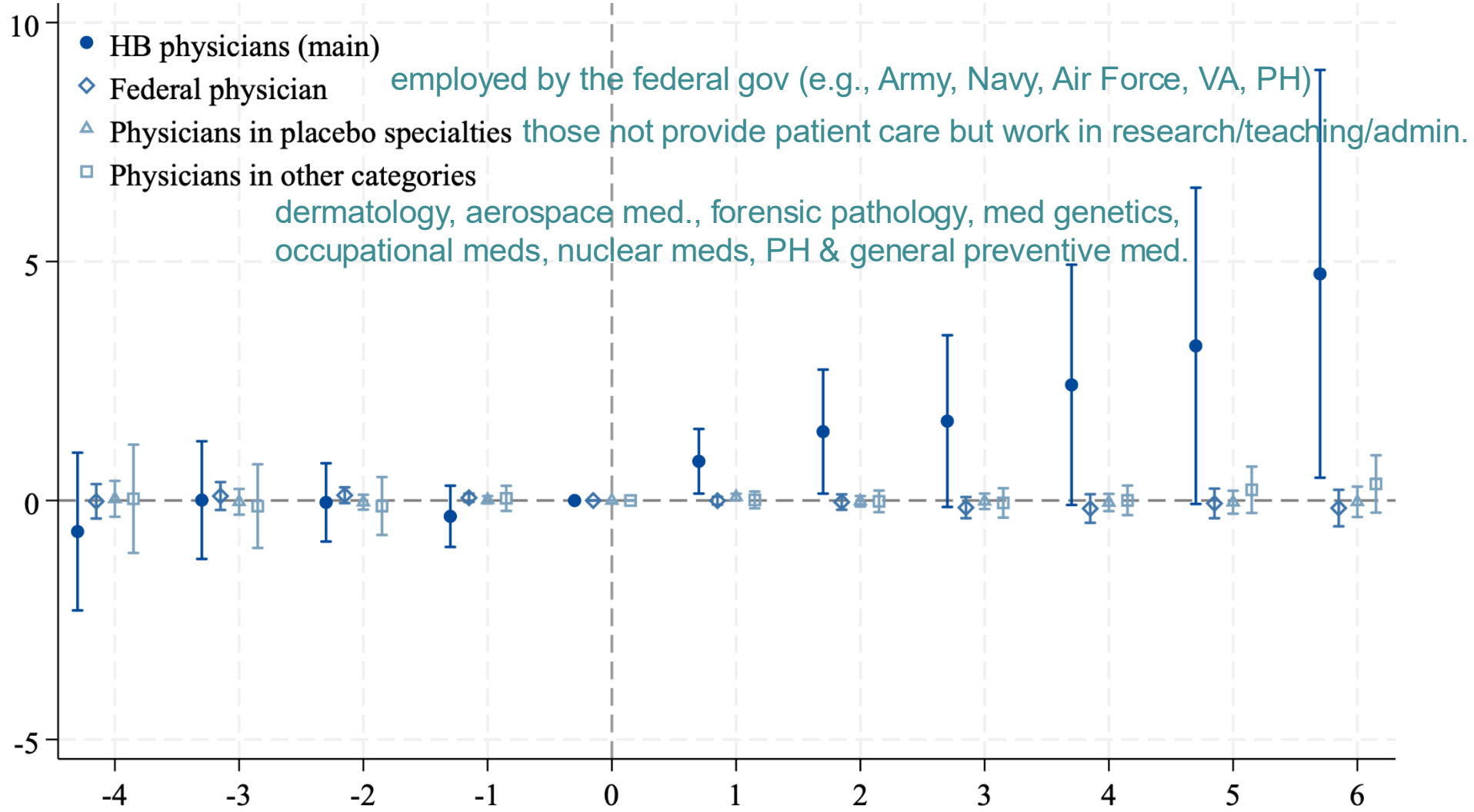
- Event study specification:

$$Y_{it} = \beta_0 + \sum_{\tau=-4,\, \tau\neq 0}^{6} \boldsymbol{\beta_1^{\tau}} \times 1\{\, t = \tau \,\} EverTreated_i + \gamma X_{\{i,2005\}t} + \lambda_{st} + \delta_i + \delta_t + \varepsilon_{it}$$

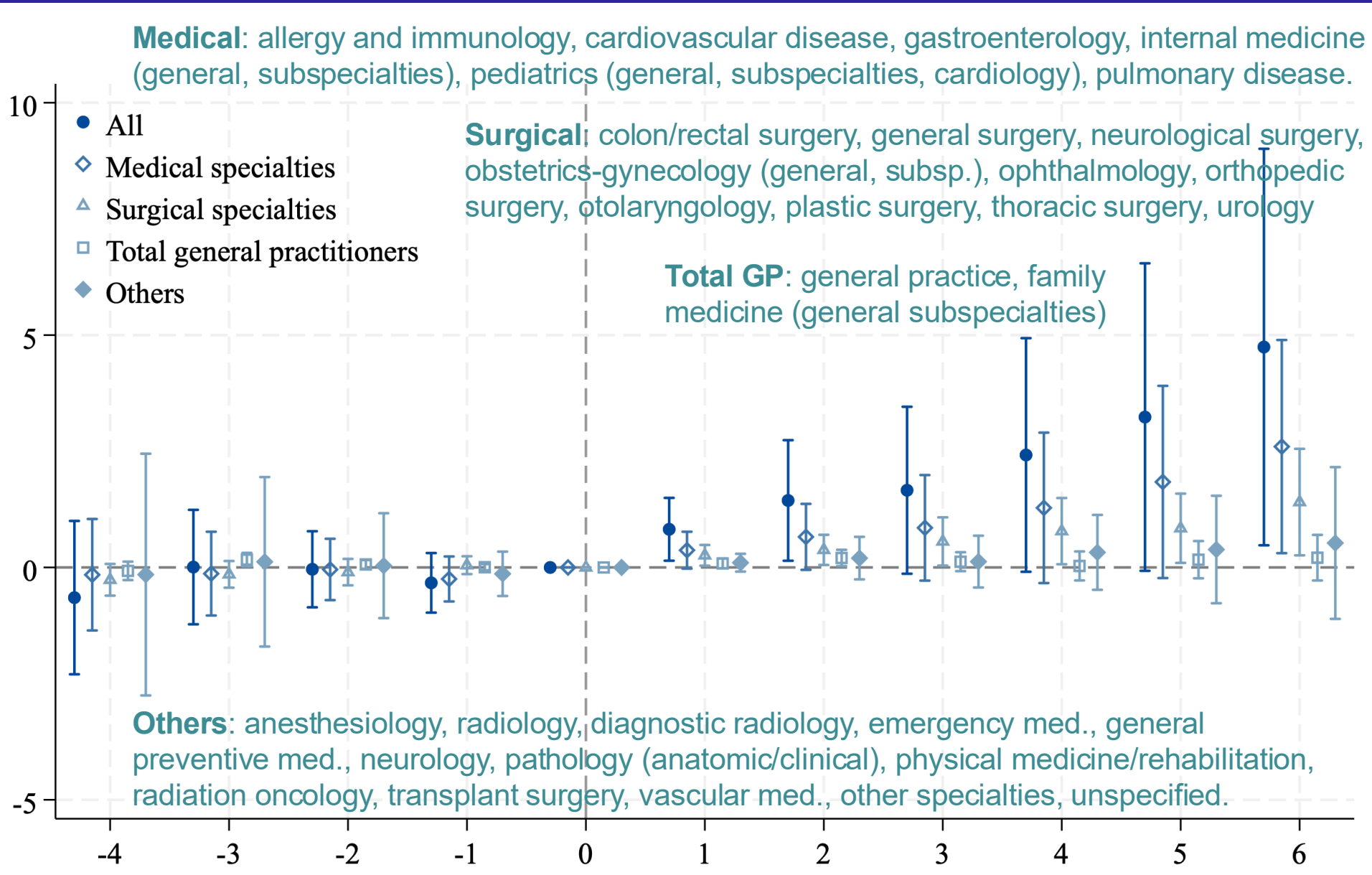
  - Reference period t=0, treatment occurred in year 1 (as in dCDH 2024 setup)

HIT diffusion & HB physician: main results

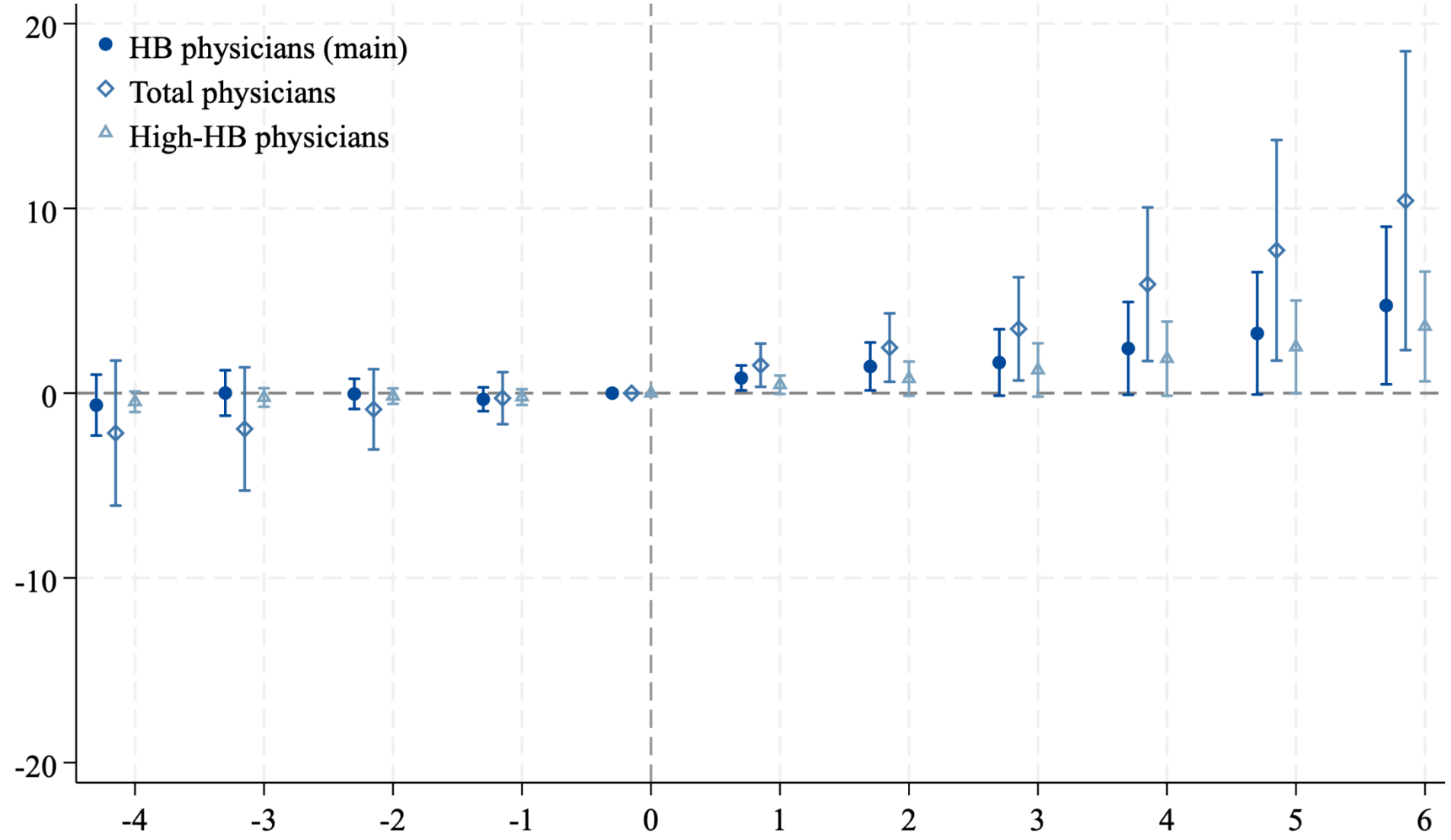
- Main outcome: HB physicians per 100k pop. *vs.* three falsification groups



Heterogeneity cross-specialty within HB physicians



Expanded firm boundary or higher total doc density?

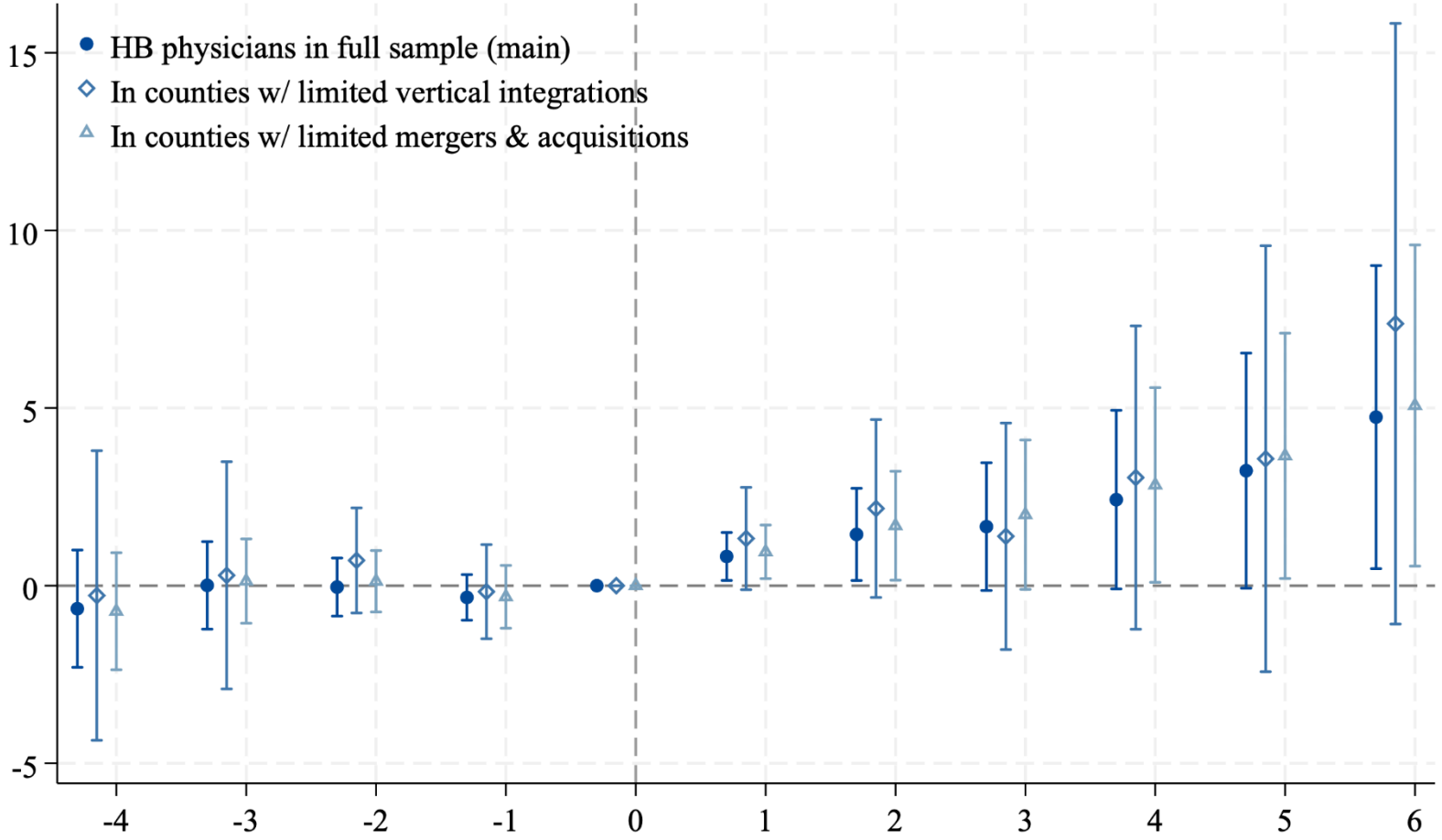


matched DiD

HRR level analysis

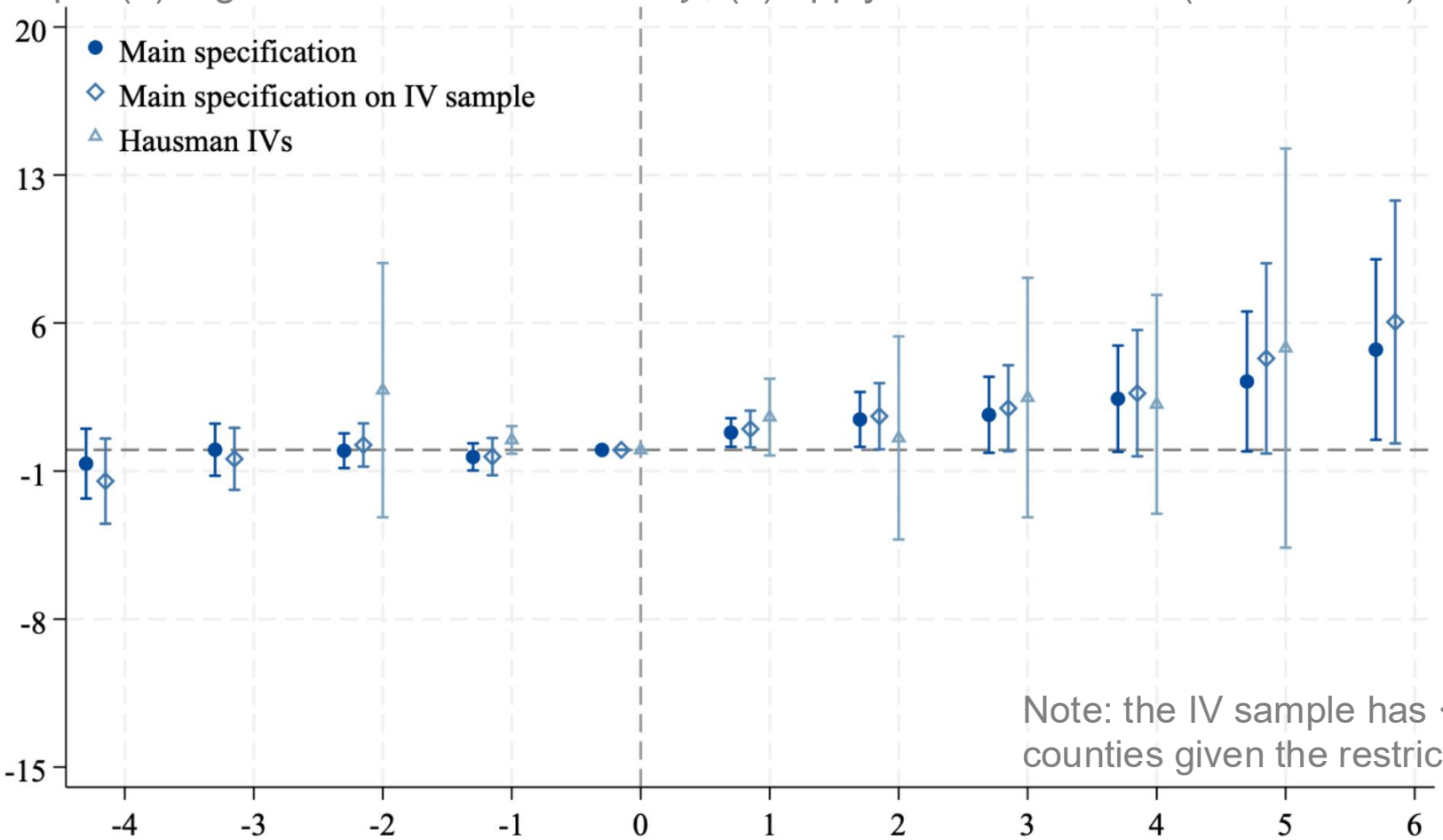
HIT Diffusion or Physician Practice Consolidation?

- Health systems acquire physician practices to get more patients (Baker et al., 2016)
- Systems, w greater financial & tech capacities, often adopt HIT early (Agha 2014)
- We identify health system that experienced a merger & acquisition (M&A), if the # hospitals within the system increased in a given year compared to the previous year.
- a vertical integration (VI), if the # ambulatory care units in the system increased…



Additional Strategy: Hausman-style IV

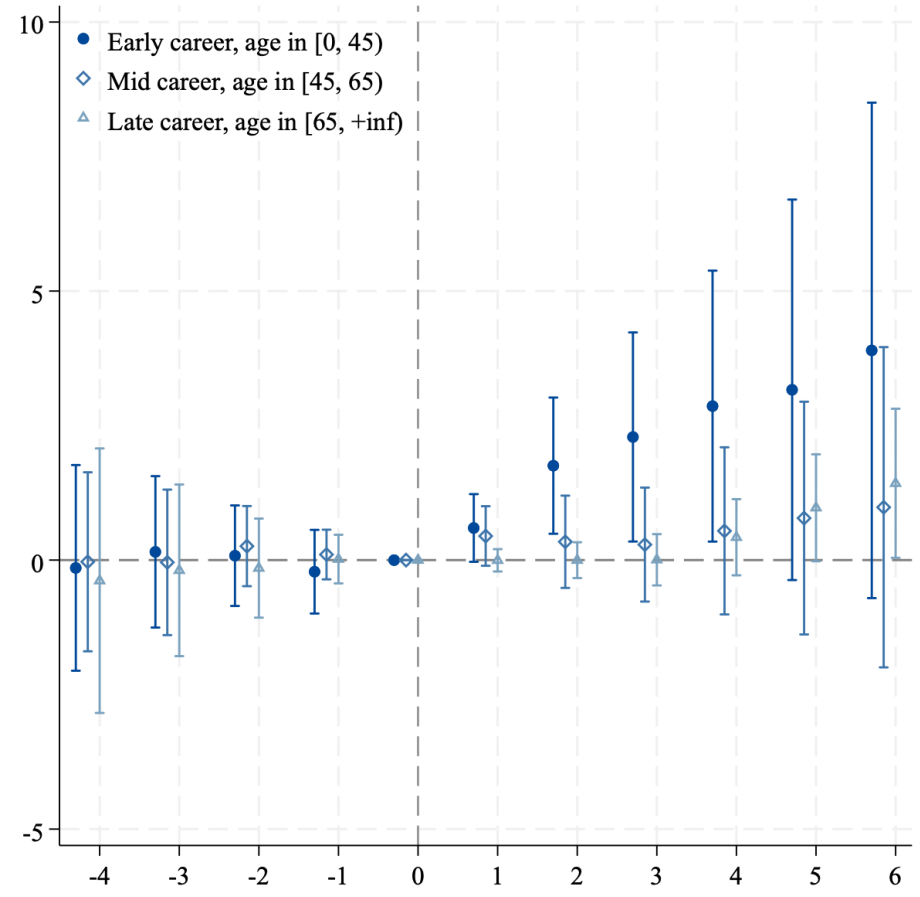
- Unobserved country characteristics may drive both HIT adoption & doc density
  - Regressions using contemporaneous county characteristics as DV: no significant changes
- **IV**: HIT adoption rate of "sibling" hospitals in the same system but in different states
  - Hausman (1996) logic: correlated supply-side shocks, w/o local demand confounders.
- 2-steps: (1) reg treat on IV + controls -> $\hat{y}$; (2) apply continuous DiD (dCDH 2024) w/ $\hat{y}$

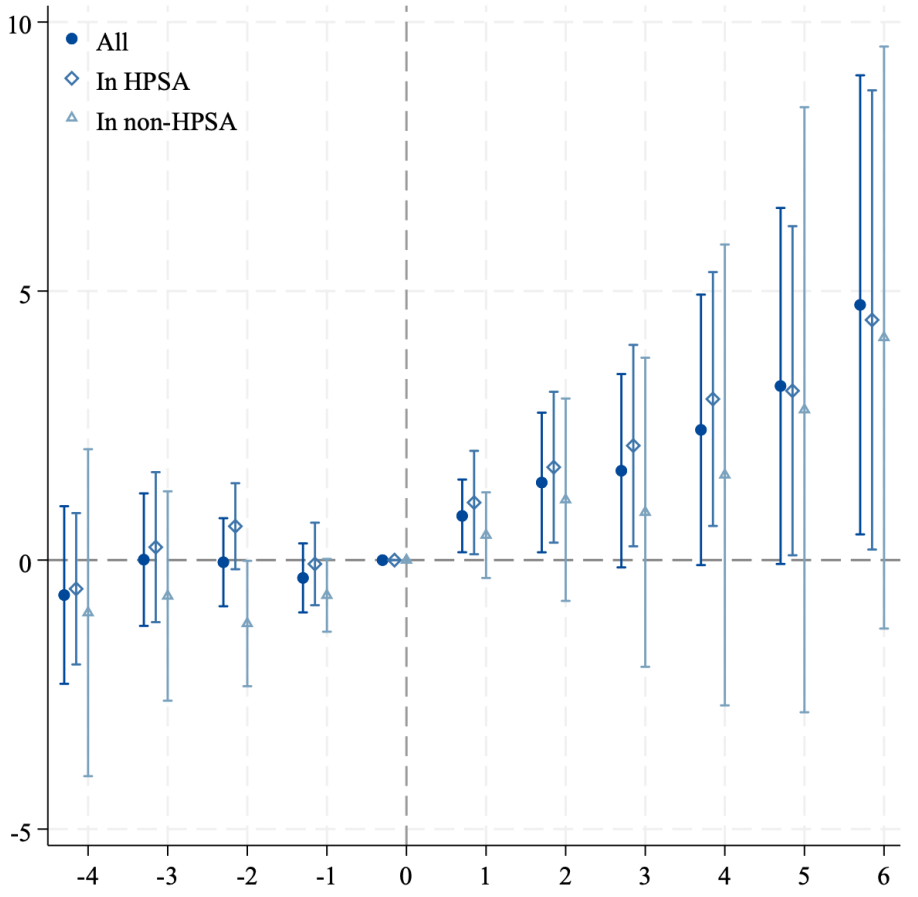


Note: the IV sample has <1,000 counties given the restrictions.

Heterogeneity by Physician Age & Shortage Status

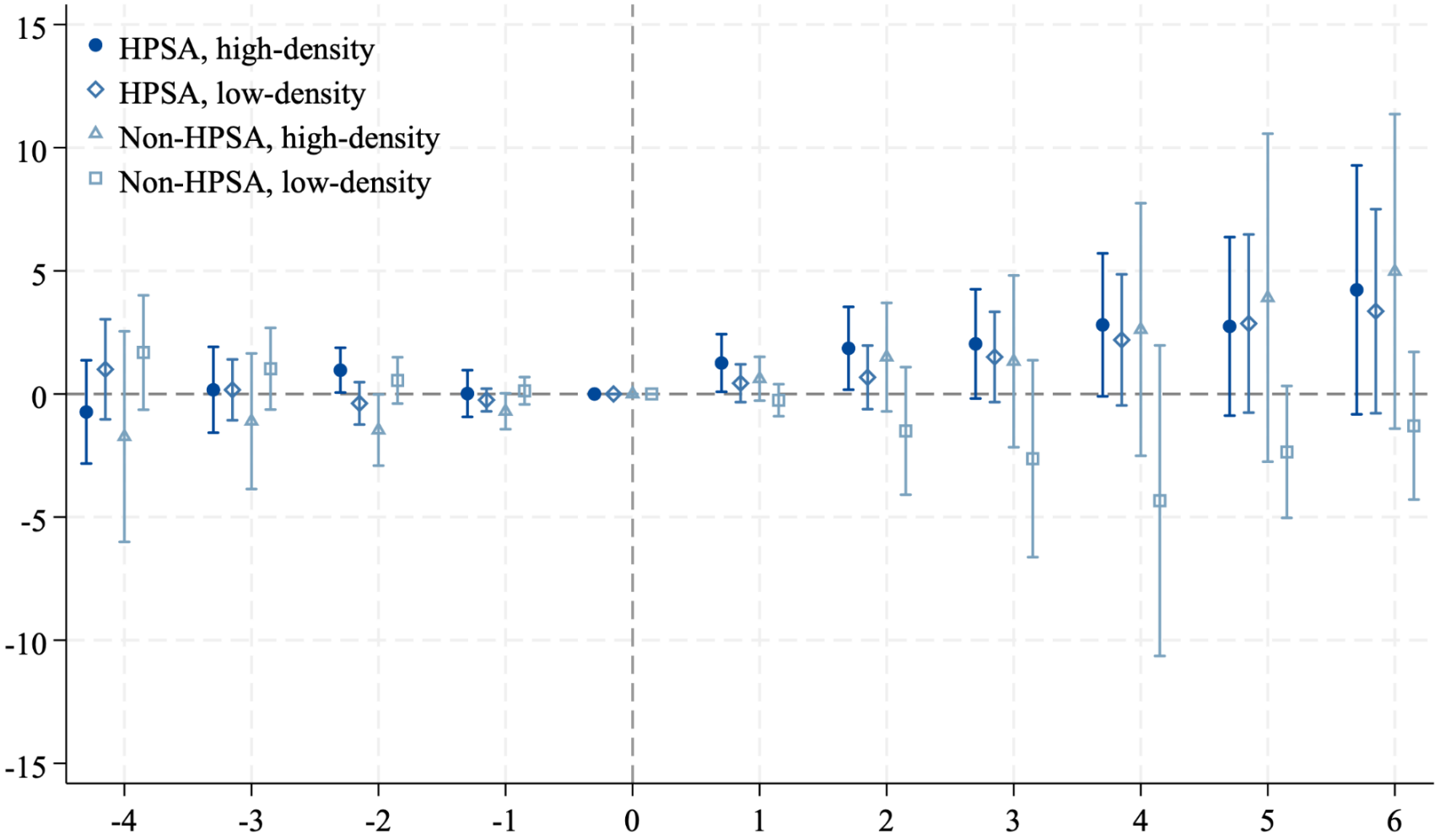
- Early-career (under 45), mid-career (45-64), late-career (65+), total docs
- by Health Professional Shortage Area (HPSA) designation status
  - A county is ever-HPSA if at least part of the county was ever designated as having a shortage of primary care practitioners.





Heterogeneity by HPSA Status × Population Density

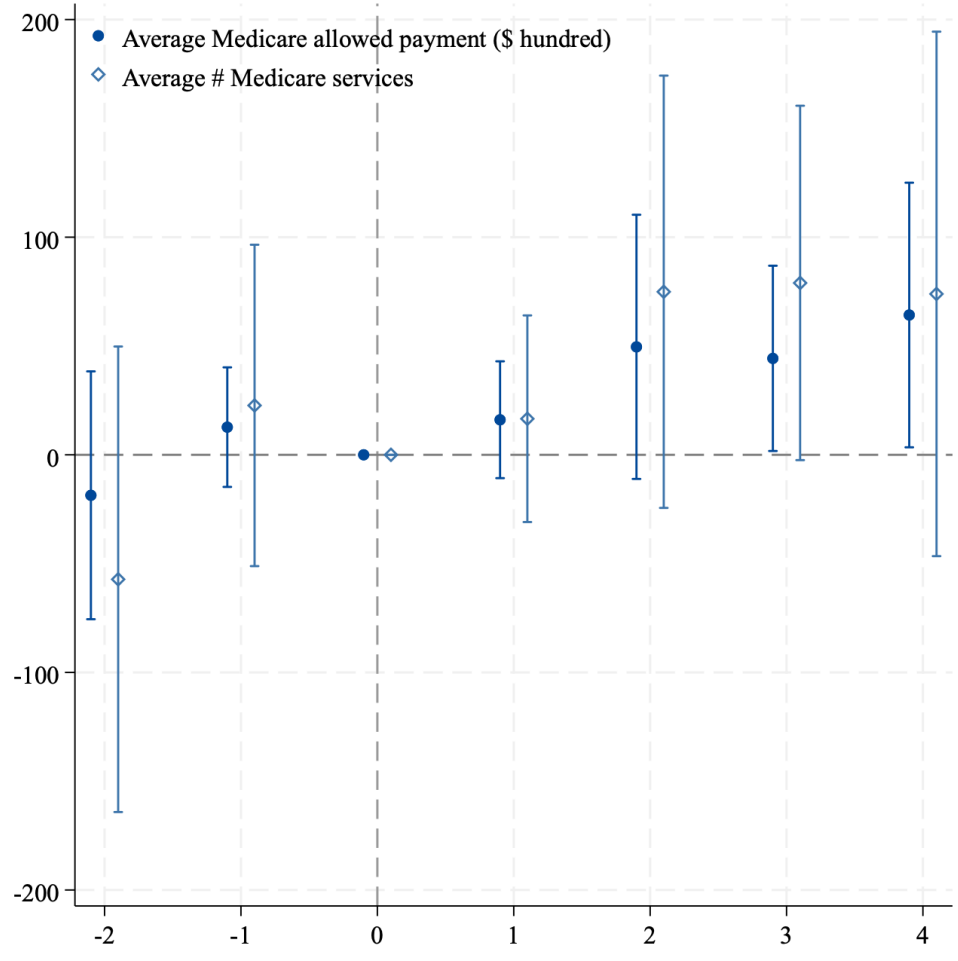
- Effects concentrated in HPSA counties w/ above-median population density
- Non-HPSA and low-density counties: no significant effects
- HIT attracts physicians where there is both *excess demand* and *scale*

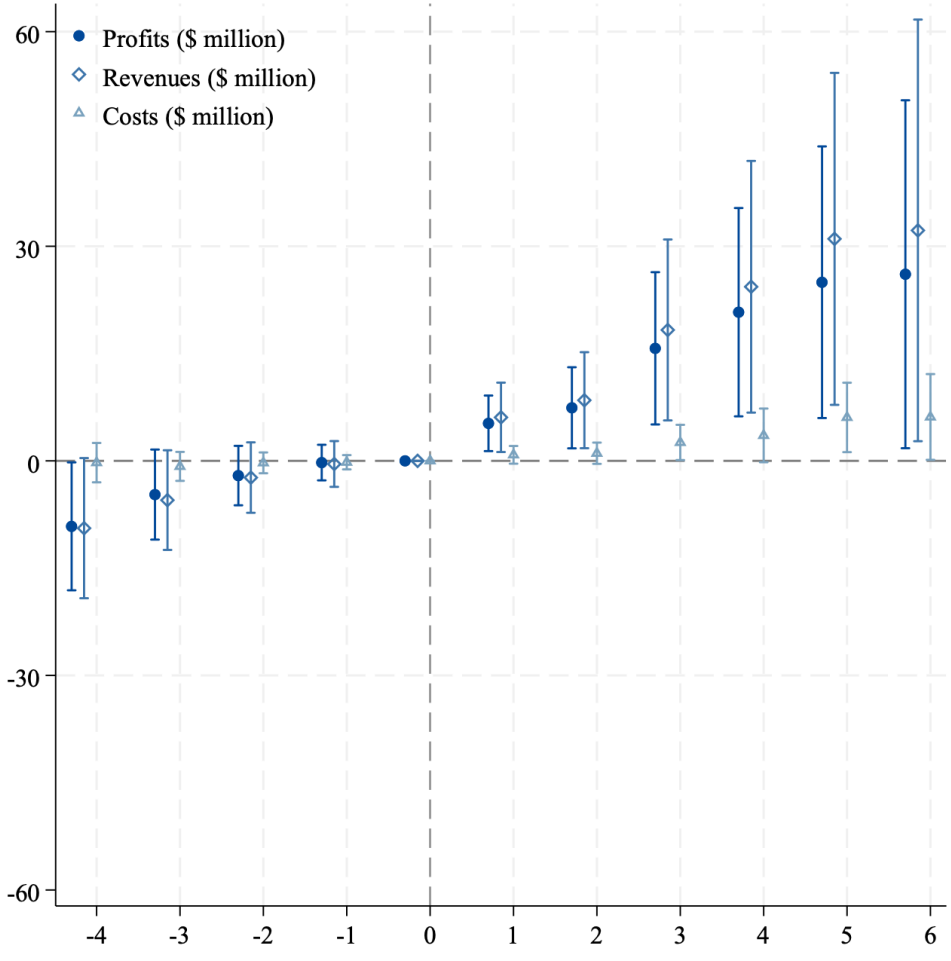


pop density vs MSA

Mechanism: HIT-rel. Financial & Productivity Impact

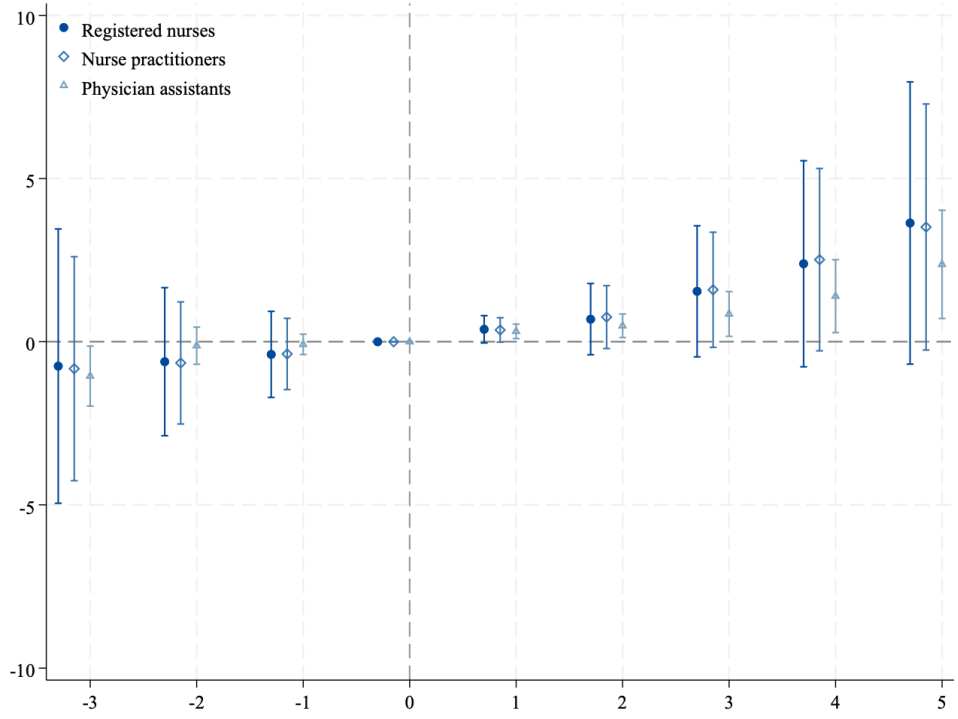
- Is it worth it financially? We use proxies for physician/hospital's performance:
- [per physician] avg Medicare-allowed amounts (incl. Medicare payments, patient deductibles and coinsurance, and 3rd-party contributions), avg # of Medicare services
- [hospital] average hospital profit, revenue, and cost within each county

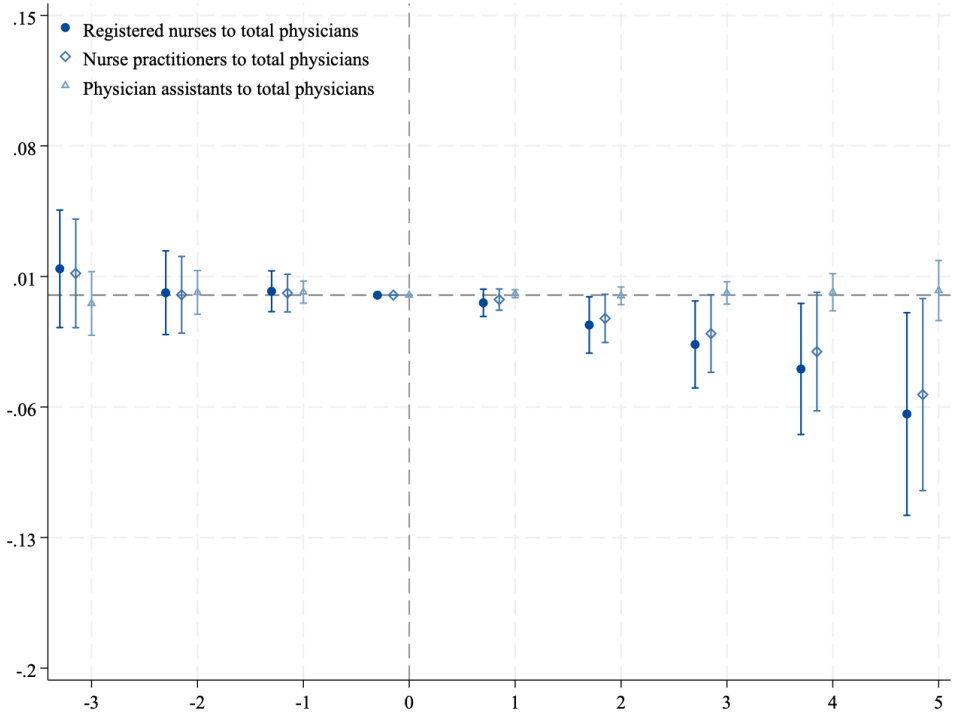




HIT and Physician Extenders: rates and ratios

- PA-to-physician ratio remains similar; nurse-to-physician ratio declined, consistent w HIT automated routine charting tasks, freeing nurses to offer more direct patient care

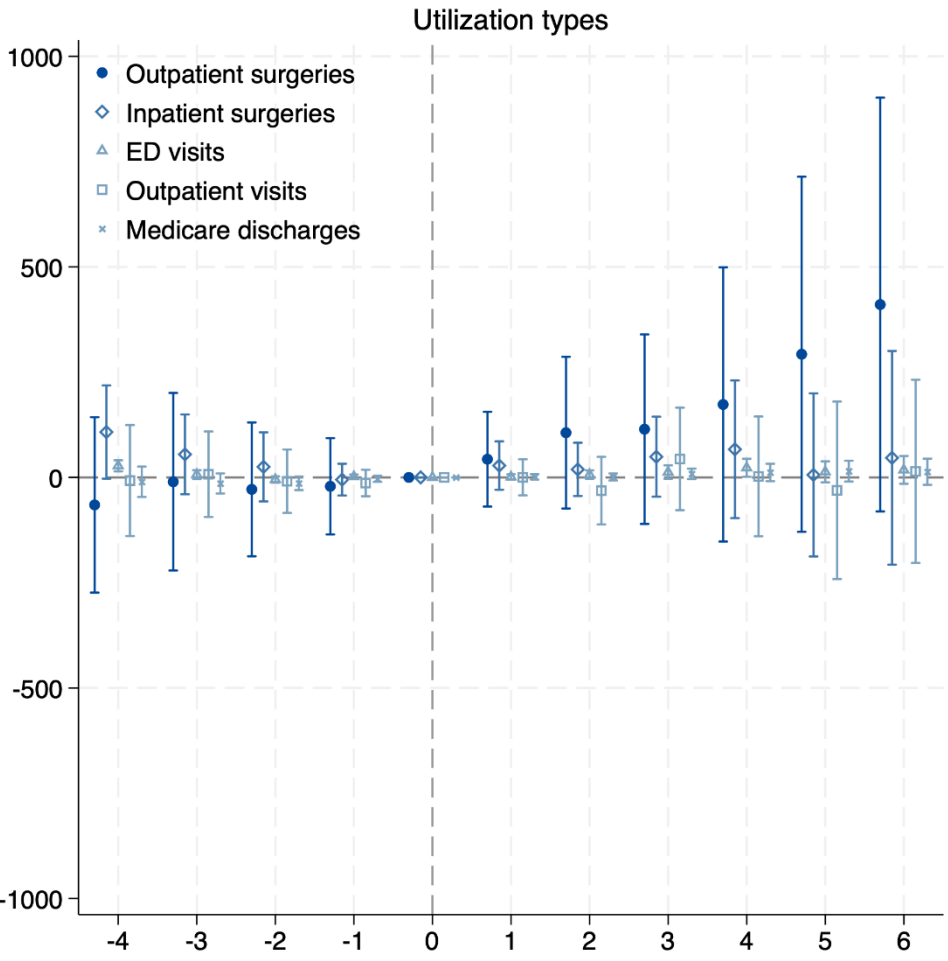


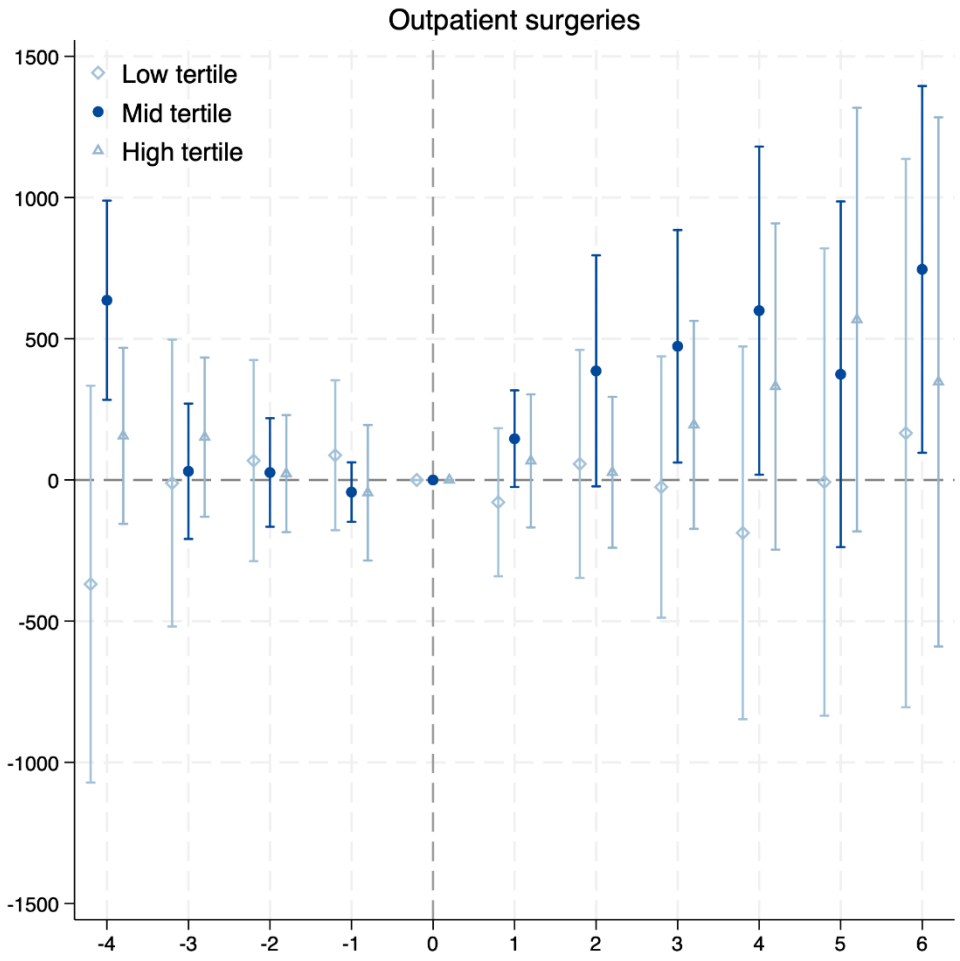


Heterogeneity by utilization: doc supply & care vol.

- Knowing that $ goes up. Given the interplay between provider capacity and service demand, how about patient care utilization post treatment?
- Specifically, whether **care utilization** responses to HIT diffusion vary by pre-period local care utilization levels?
- Tested across all utilization measures available, note that:
  - Outpatient elective surgeries has the highest profit margins, thus are where we expect highest increases in docs/vols (extensive, intensive margin)
  - Inpatient surgery volume may not respond, but more HB docs are still good
  - Others: ED visits, outpatient visits and Medicare inpatient discharges
  - Pre-period utilization matters: competition, disease mix, growth potential

Heterogeneity by utilization (pre-T p.c. Medicare tertile)





Separate tertiles based on pre-treatment care utilization, measured by standardized, risk-adjusted per capita Medicare costs in 2006

Robustness checks

- Alternative subsamples — subsample
  - Counties with ≤ 5 distinct adoption rates; those never had zero HB physicians
  - Counties not with extreme population sizes (exclude top/bottom 10%)
  - Balanced panel with ≥ 4 periods before and after treatment
  - Leave-one-out analysis: not driven by uncertain outlier specialties — drop-1-out
  - Matched DiD (top 10 counties, outside own census region) — match-DD
- Alternative model specifications — specifications
  - Models without state-specific time trends; without county level controls
  - Models without either state-specific time trends or county level controls
- Alternative staggered DiD estimators or specifications — estimators
  - Borusyal et al., 2024; Callaway & Sant'Anna, 2021; Sun & Abraham, 2021
  - Continuous DiD; count data as DV (# rather than rates) — cont. DD — count DV
- Alternative HIT measures — measures
  - CPOE or physician documentation (PD), another advanced HIT
  - CPOE or PD or CDR (clinical data repository), not much effect with basic HIT

Conclusion & Discussion

- We find that aggregate HB physician density (county-level) **increases** after rapid adoption of advanced HIT, with effects concentrated among
  - Medical & surgical specialties: tied with data & scheduling
  - Early-career physicians: age ≤ 45, more movable and tech savvy
  - Health professional shortage areas (HPSA): places w excess demand to care

limitations

- Mechanism: treated counties showed better financial performance
  - Higher (per physician) avg Medicare allowed payments and services provided
  - Increased hospital profits, and greater outpatient surgical volumes

- Policy and managerial implications
  - Strategic HIT investment can attract (/retain) physicians to underserved areas
  - HIT (automation) appears to complement physician labor rather than substitute
  - Health tech diffusion may help reduce geographic disparity in care access

Health IT Diffusion and Physician Density

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Preview of Methods and Results

- Methods:
  - Event-study approach à la East et al. (AER 2023), leveraging the sharp increase in adoption rates to separate sample into treatment and control groups
    - Here: use sharp increase in county-level advanced HIT adoption rate
  - Compare HB physicians per 100k in counties with rapid diffusion vs controls
  - Use De Chaisemartin & d'Haultfoeuille (2024) as our main DiD estimator
  - Robust to other DiD estimators, continuous D, count data Y, other specifications

- Main results:
  - 11.1% increase in county-level HB physicians per 100k post HIT adoption
    - Effects primarily driven by medical and surgical specialties
  - Stronger effects among early-career docs and in areas with doc shortages
  - Physicians (hospitals) in treated counties received higher payments (profits)
  - Increased outpatient surgeries in counties w/ moderate pre-period volumes

Summary statistics in pre-treatment period

	Overall	Never-treated	Ever-treated
HB physician counts per 100k population	17.2 (37.8)	13.0 (17.0)	17.7 (39.6)
Health IT adoption rate (%)	1.46 (5.39)	0 (0)	1.64 (5.69)
% 65+ population	15.7 (4.07)	17.2 (4.35)	15.5 (4.00)
Poverty rate (%)	15.9 (5.95)	16.6 (6.10)	15.8 (5.92)
Income per capita	32,356 (8,325)	34,872 (10,304)	32,046 (7,996)
Medicare Advantage penetration rate (%)	4.06 (7.73)	2.87 (5.58)	4.21 (7.95)
% Medicaid eligibles	20.3 (8.35)	21.1 (9.10)	20.2 (8.25)
% above college degree	12.6 (5.7)	11.4 (5.1)	12.8 (5.7)
Hospital HHI	0.80 (0.27)	0.92 (0.15)	0.78 (0.27)
Population density	239 (1,722)	107 (520)	256 (1,815)
# counties	2,394	265	2,129

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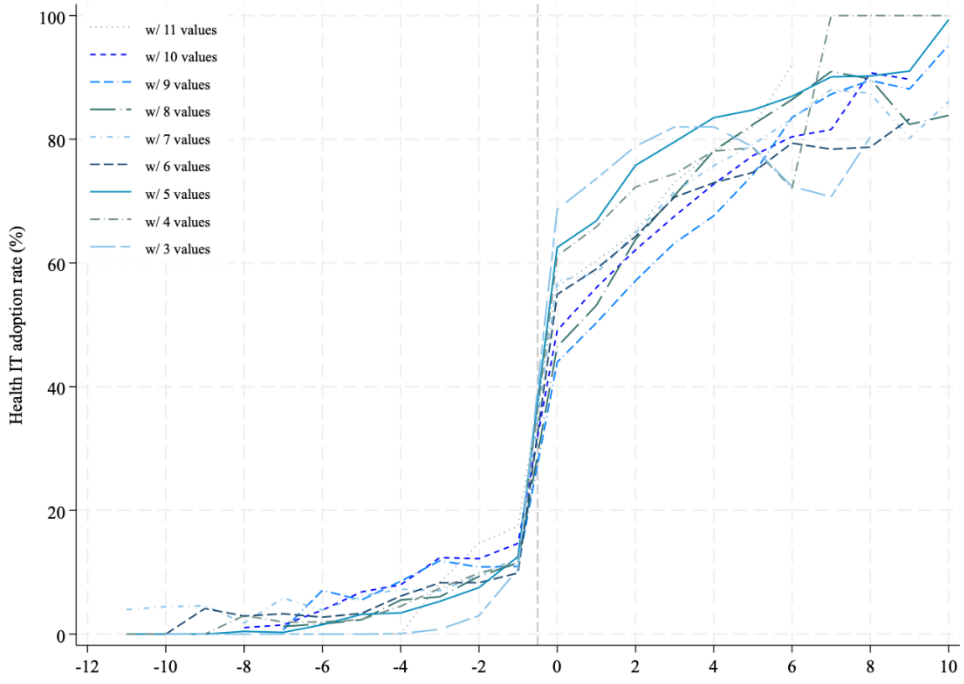
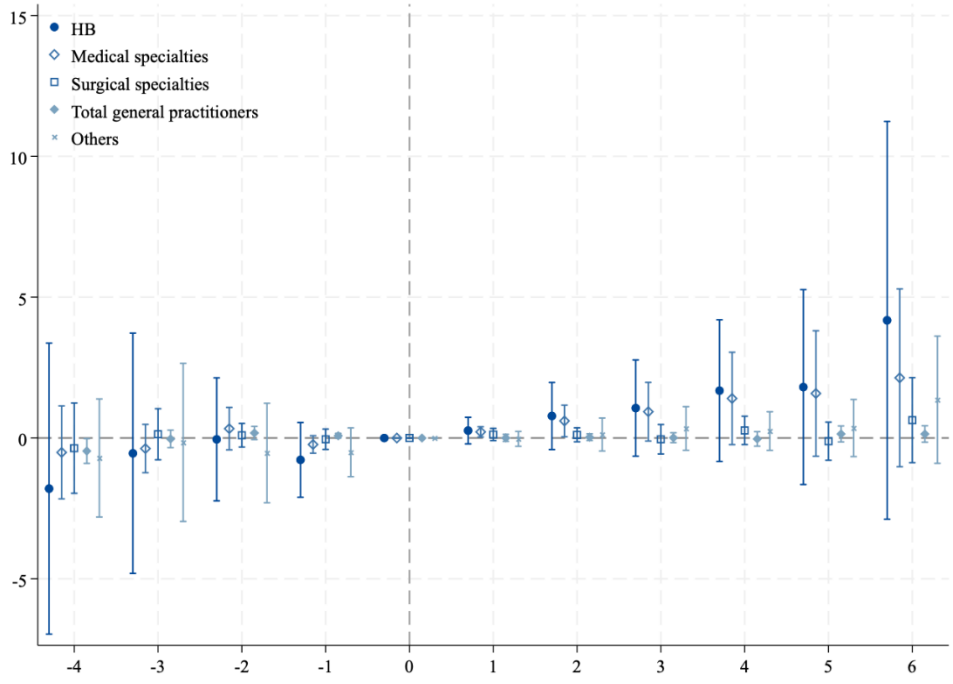
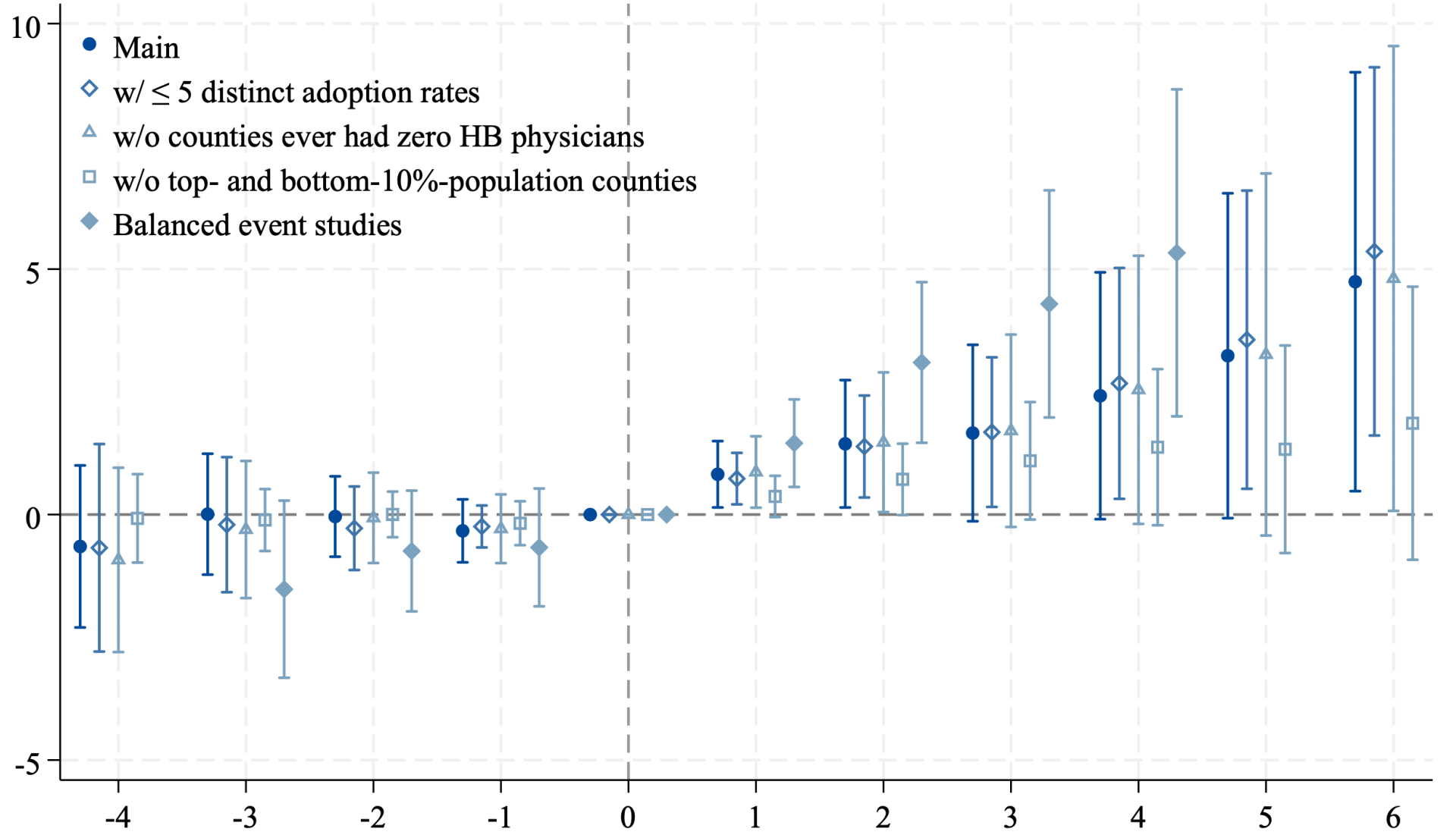
Hospital Referral Region (HRR) level analysis





Robustness check: subsample sensitivity checks



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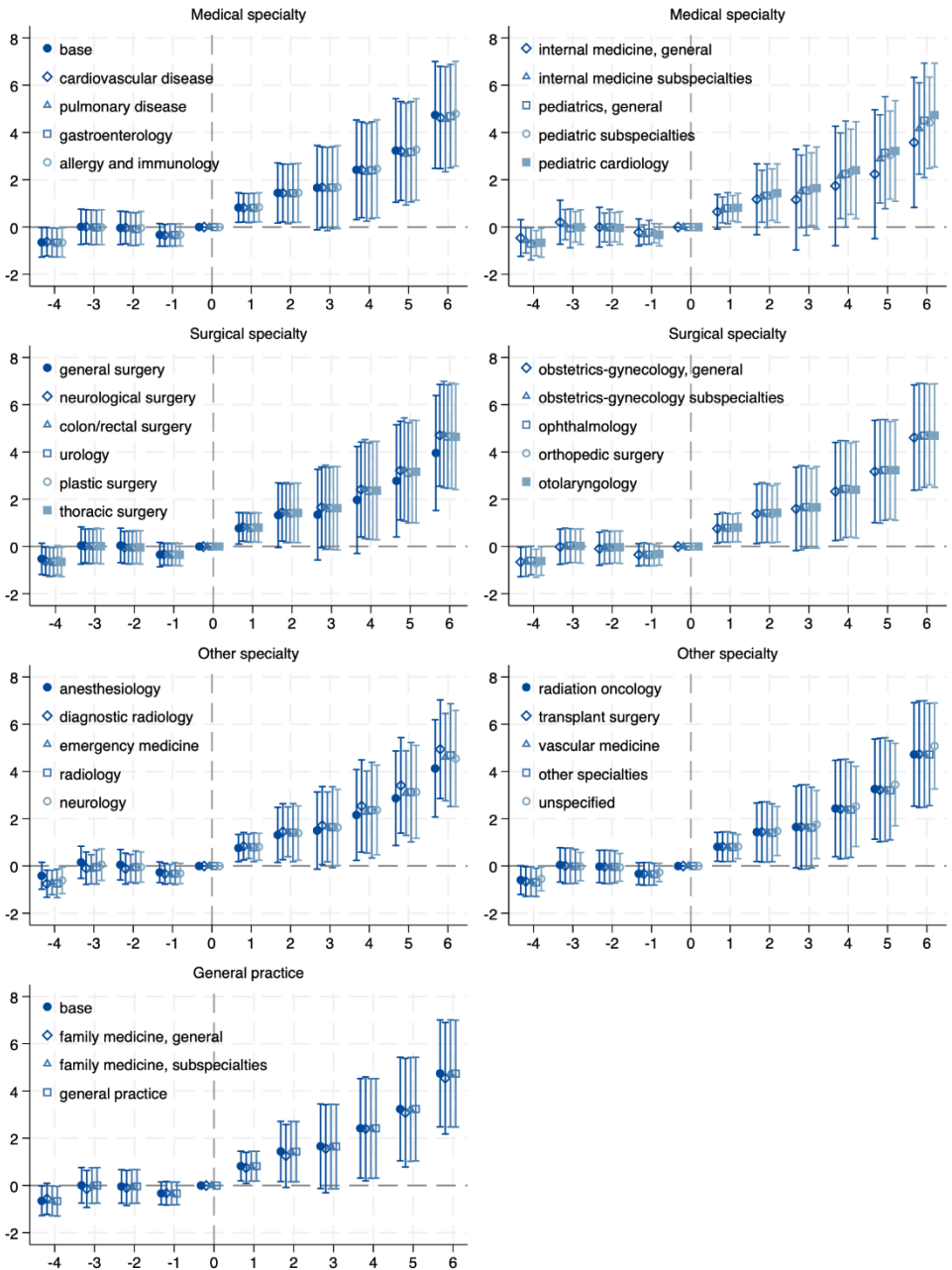
Leave-one-out analysis by specialty



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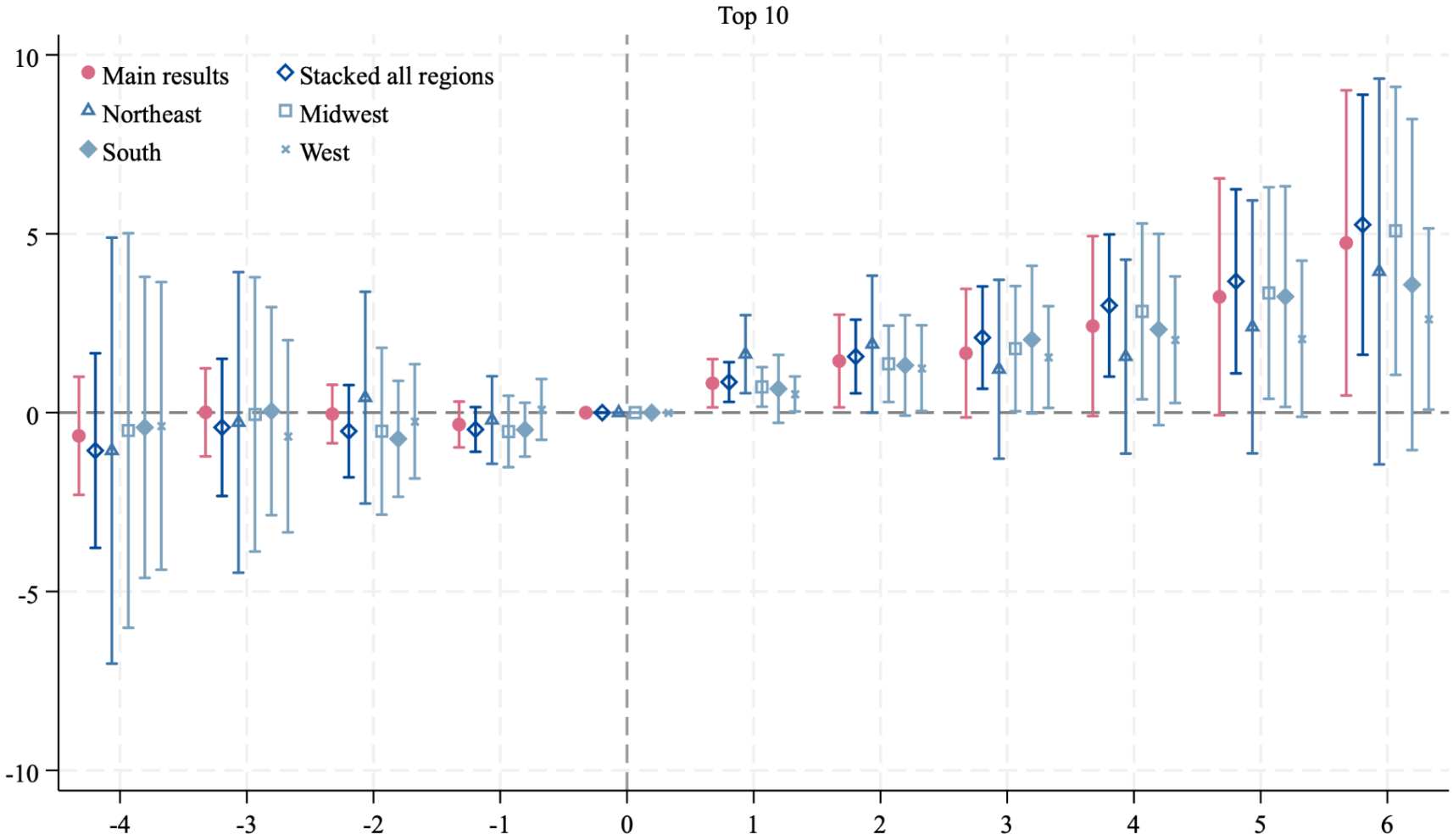
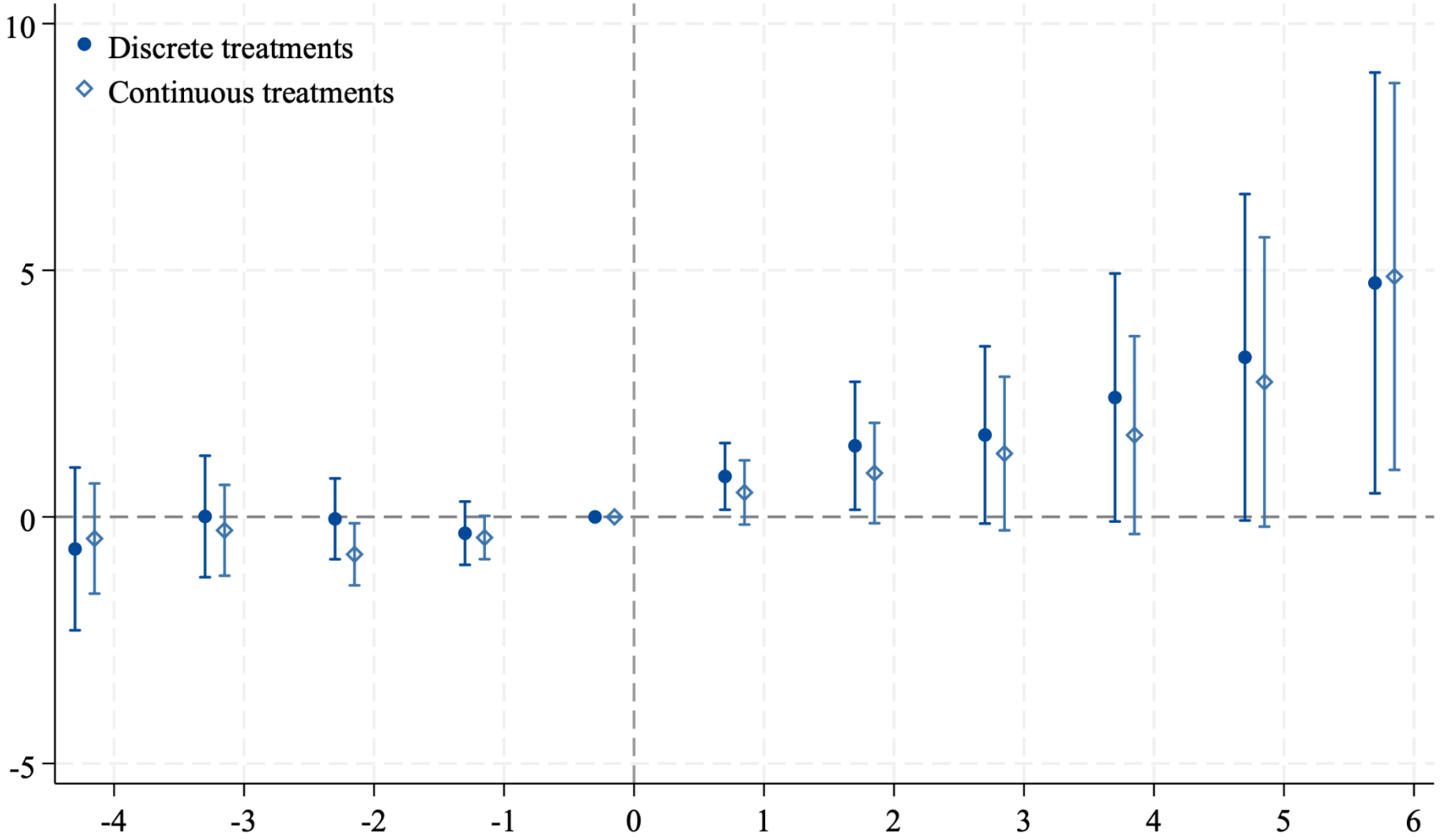
Matched-DiD: overall stacked & by census region



method à la Deryugina et al. (2018 AEJ) and identify the top 10 control counties for each ever-treated county, based on the following county characteristics in 2000-2004: HB physician density, annual % change in HB physician density, Medicare advantage penetration rate, % 65+ population, income per capita, and unemployment rate. We then further restrict the control counties to be far enough (≥300 miles and in a different census region from the focal county).

back (main) back (robust)

Discrete vs continuous HIT adoption treatment



The estimated ATE from a continuous DiD estimation approach is 2.72** (1.35), compared to our main estimates under discrete DiD of 2.16** (1.04).

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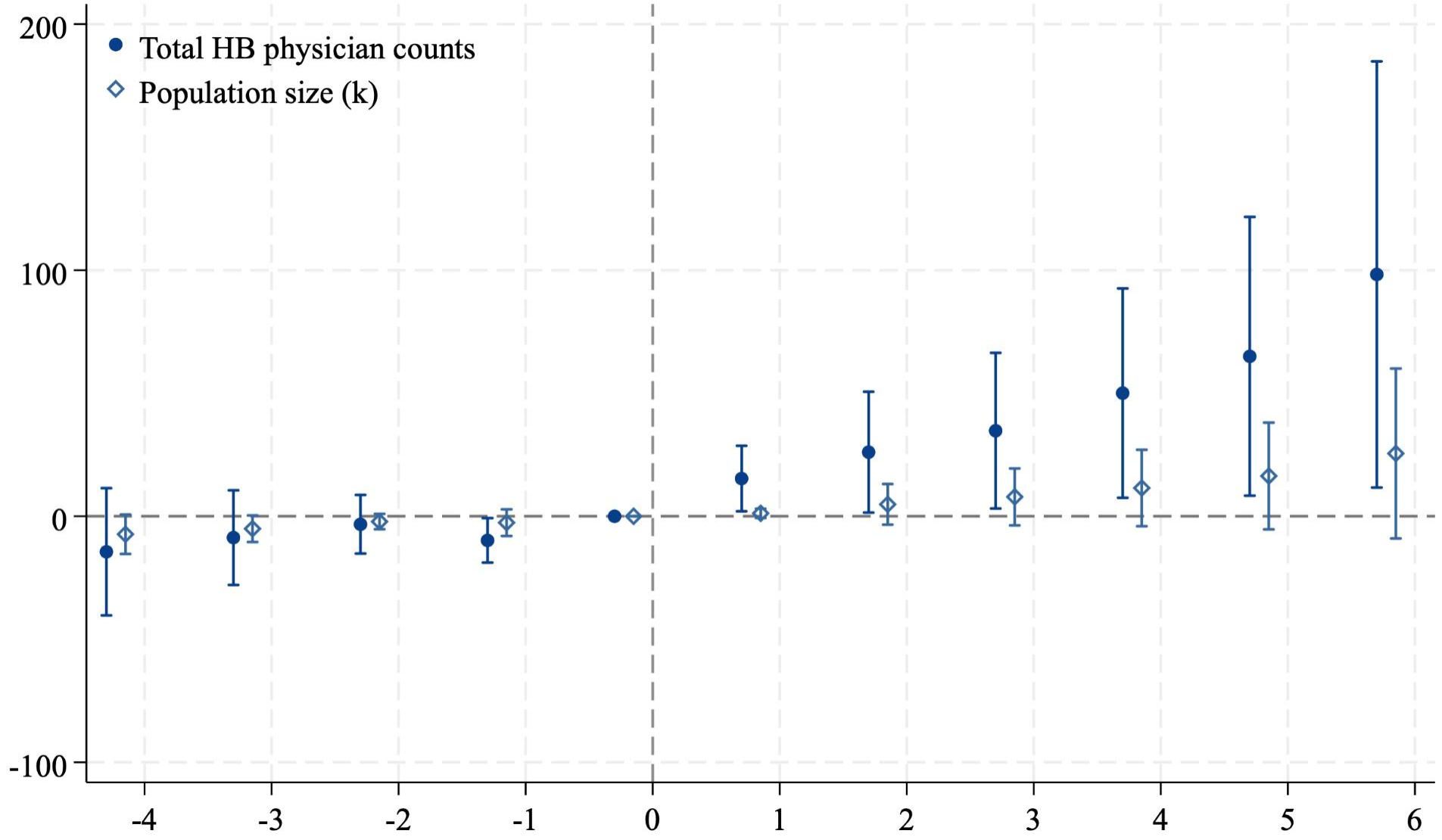
Count data DVs for main results (num./denom.)



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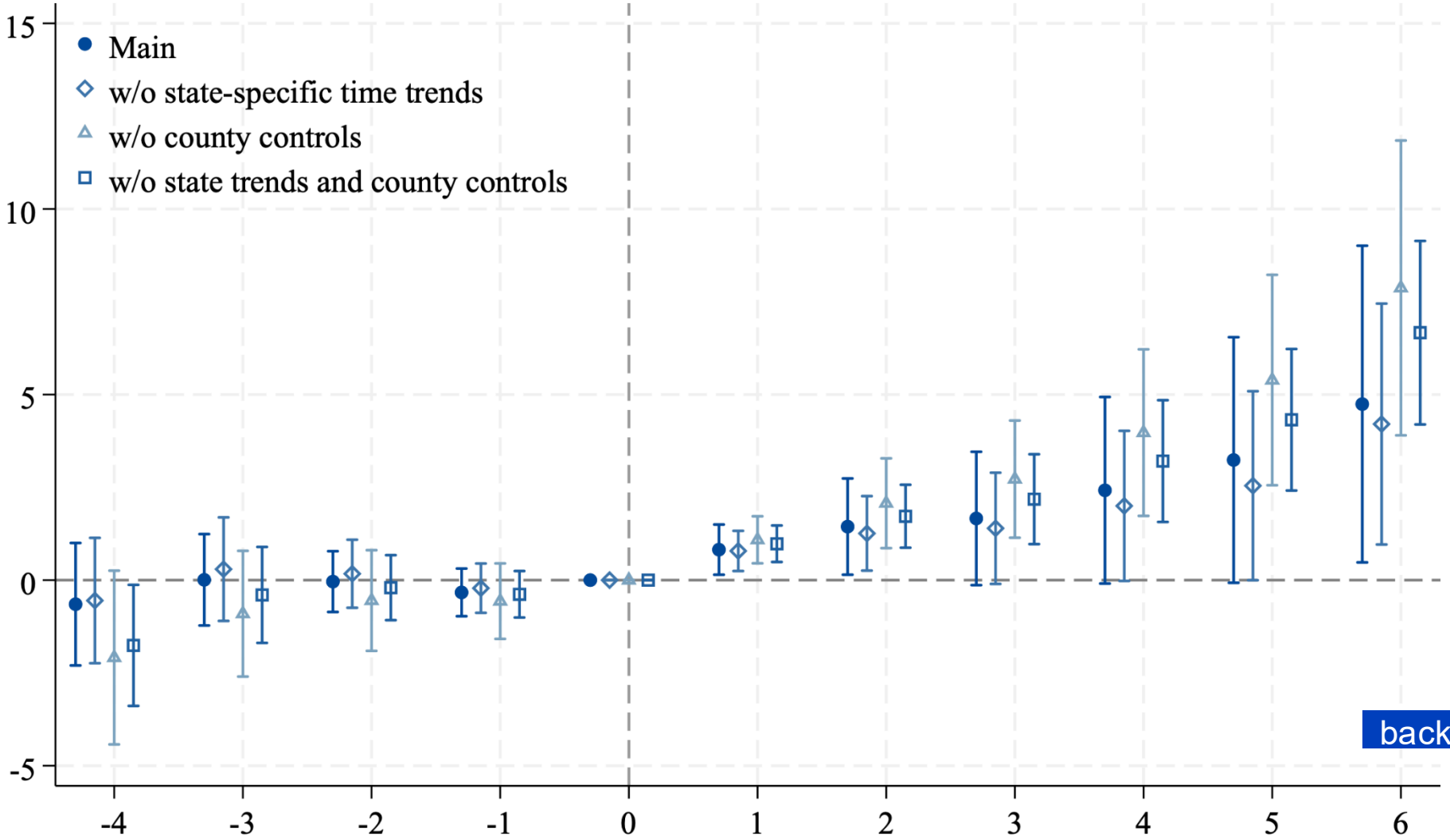
Robustness check: specification checks

- Note the main specification always include state-specific time trends and a set of county-level observables in 2005 each times a linear time trend.



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Alternative DiD estimators for the main outcome

- All estimators use t=-1 as the reference except Borusyak et al., which uses the earliest period as the baseline period.

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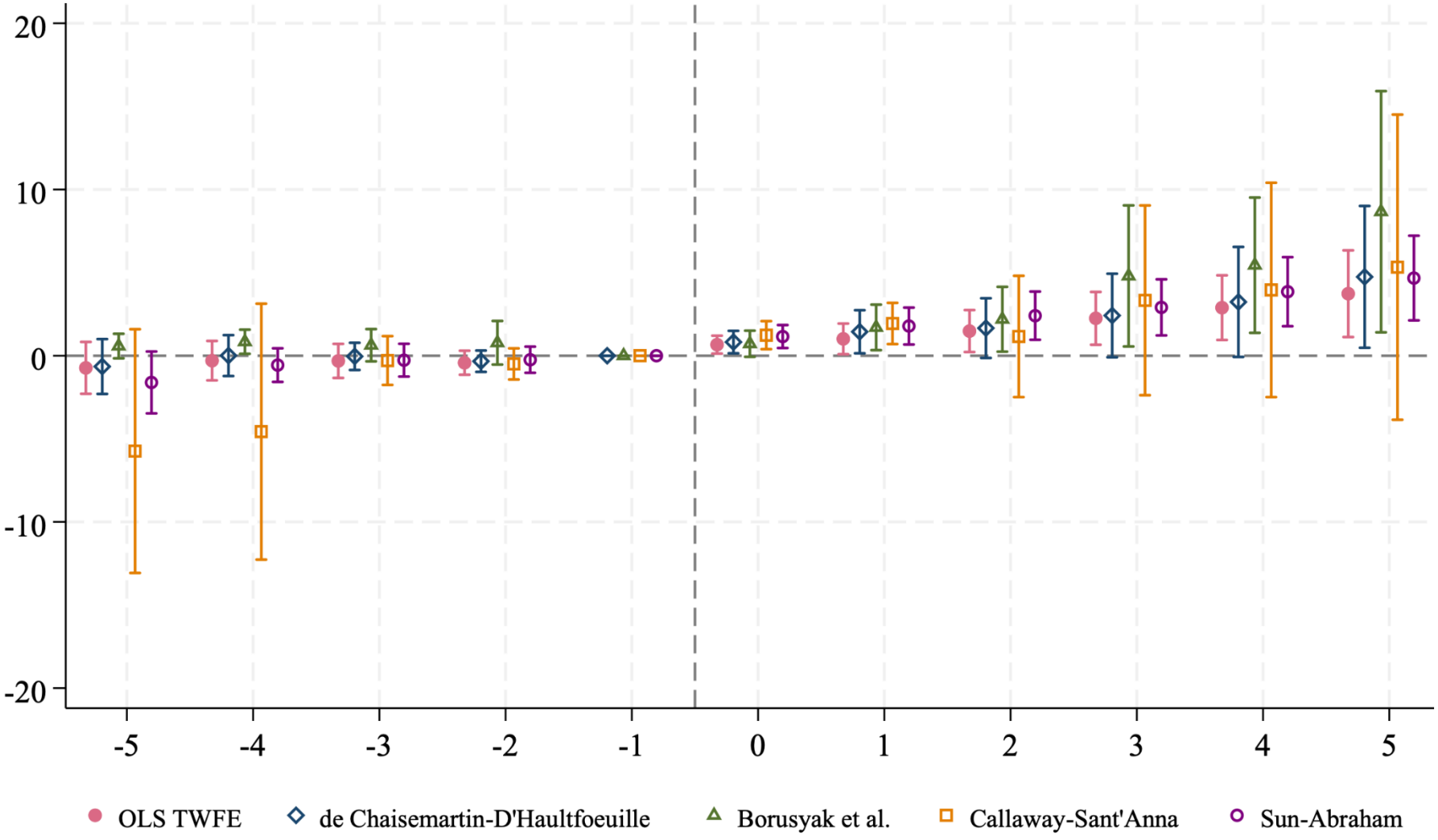
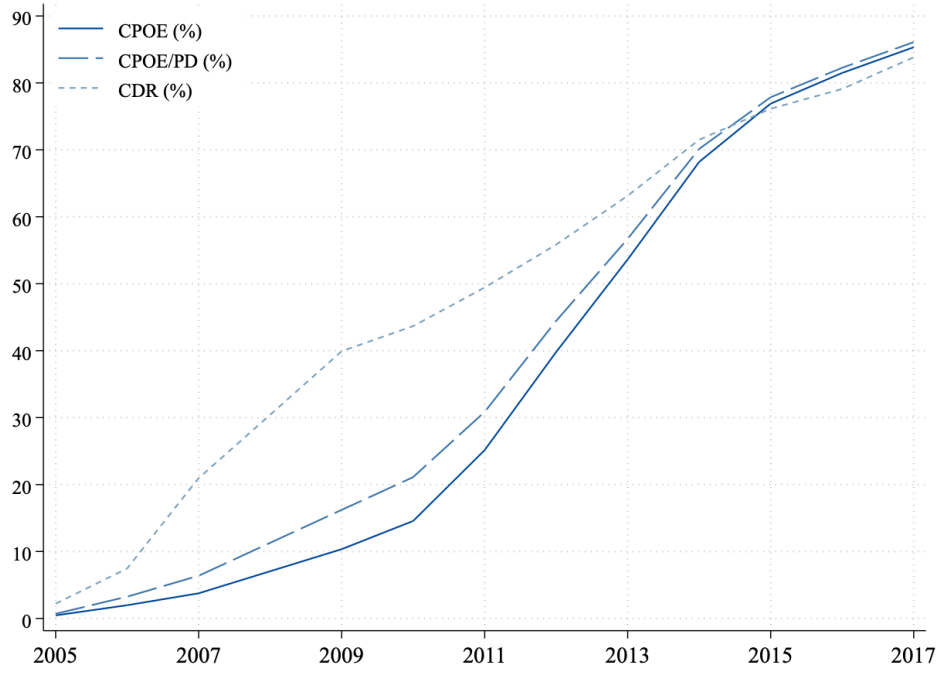
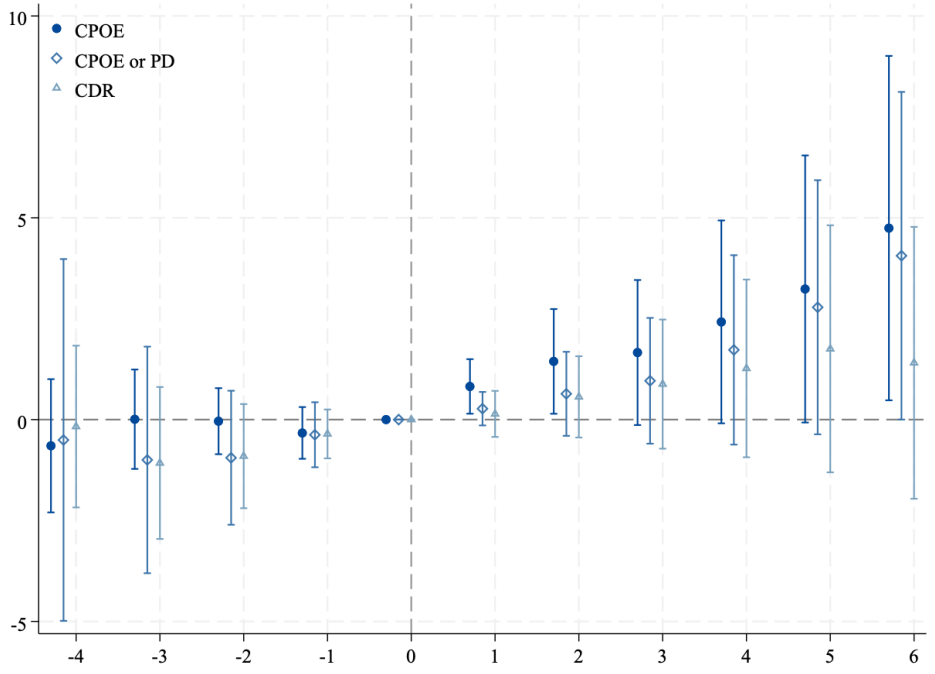


Alternative HIT measures: CPOE/PD adoption

- Alt. HIT adoption measures: county-level sharp adoption of either CPOE or physician documentation (PD) – another advanced HIT component (noted in Dranove et al., 2014) but not core for HITECH act MU criteria.
  - Clinical Data Repository (CDR), in contrast, is a basic HIT w/ limited functions





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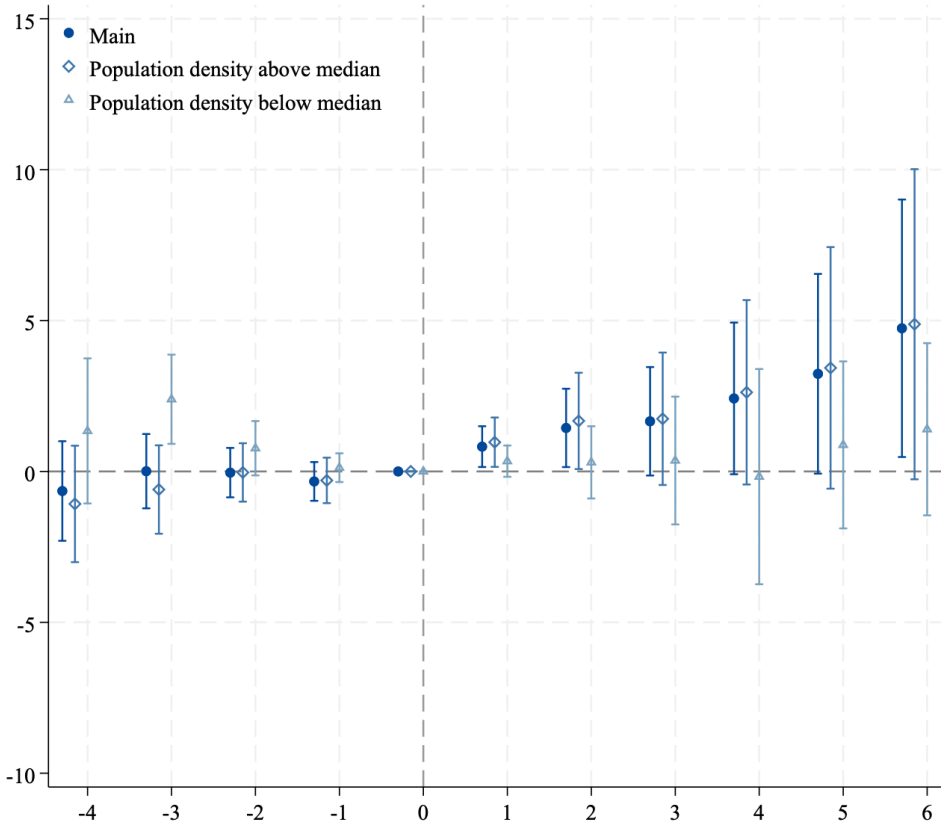
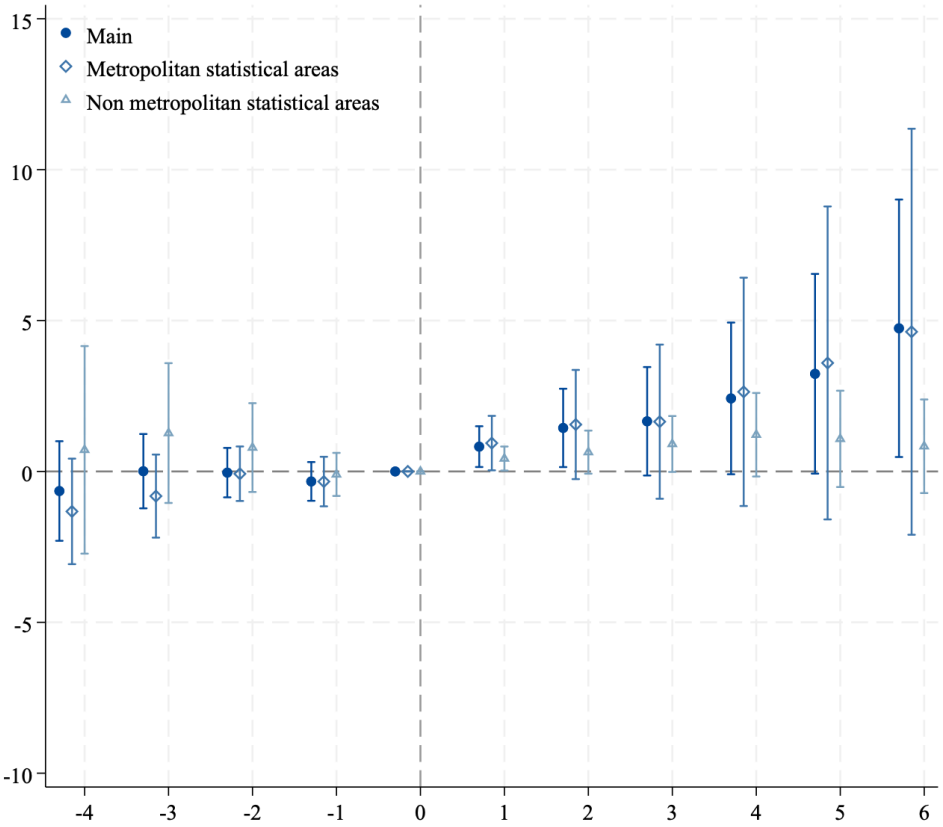
Heterogeneity by Rural/Urban (by pop density, MSA)





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Limitations and Future Work

- Analyses based on *aggregate* data
  - ☺ mitigate concerns about patient sorting (limited sorting at county level)
  - ☹ limit our ability to disentangle changes at the physician level (e.g., senior to junior doc replacements, PCP vs specialists, roles, interoperability, …)
- Focus on *digital* tech but not fully capture *physical* med tech (data limit)
  - comprehensive controls mitigate concerns that other tech drive the results
- Not directly link with downstream *health outcomes*: HIT or docs?
  - HIT is one element within broader, team-based care delivery process
  - We demonstrate there can be direct and indirect effects via physician supply

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