Maternal Vaccination Inequities in the U.S.: State-Level Associations with Urbanicity and Insurance Coverage, 2013–2022

Group 2: Wrangle Avengers
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Background

Women's health outcomes vary widely across U.S. states, driven by differences in healthcare access and uptake of preventive services.

Maternal vaccination is a key component of preventive care, providing protection to both pregnant individuals and their infants.

Recommended Maternal Vaccines

- Influenza
- Tdap (tetanus, diphtheria, pertussis)
- COVID-19 vaccines

Persistent challenges in maternal vaccination include:

- Suboptimal vaccination rates nationally
- Lower coverage among women with lower socioeconomic status
- Disparities affecting racial and ethnic minority groups
- Wide state-level variation in insurance coverage, limiting access to care
- Additional barriers for rural residents, who experience higher uninsured rates

Study Purpose

- To examine how **state-level urbanization** and **women's insurance coverage** are associated with **maternal influenza and Tdap vaccination rates**.

Data Sources

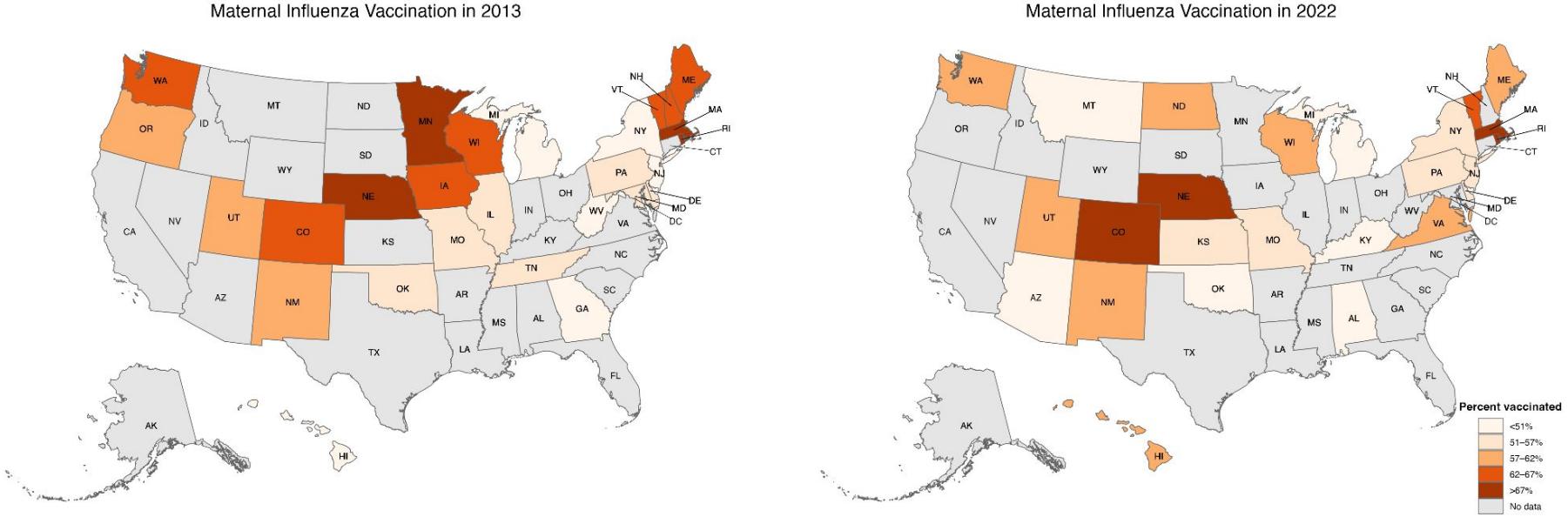
1. **Centers for Disease Control and Prevention (CDC)**
   Dataset: Vaccination Coverage among Pregnant Women (2013–2022)
   Population: Pregnant women aged 18–49 years who participated in the Behavioral Risk Factor Surveillance System (BRFSS) and Pregnancy Risk Assessment Monitoring System (PRAMS).
   Sample size: Approximately 30,000–40,000 respondents per year, varying by state and vaccine type.
   Variables used: State-level estimates of maternal influenza and Tdap vaccination coverage during pregnancy.

2. **National Center for Health Statistics (NCHS)**
   Dataset: Urban–Rural Classification Scheme for U.S. States (2013 revision).
   Variable used: Urbanicity index (1 = most urban, 5 = most rural) based on population density and metropolitan influence for each state..

3. **Kaiser Family Foundation (KFF)**
   Dataset: Health Insurance Coverage of Women Aged 19–64 by State (2013–2022).
   Variable used: Percentage of women with any form of health insurance (public or private).

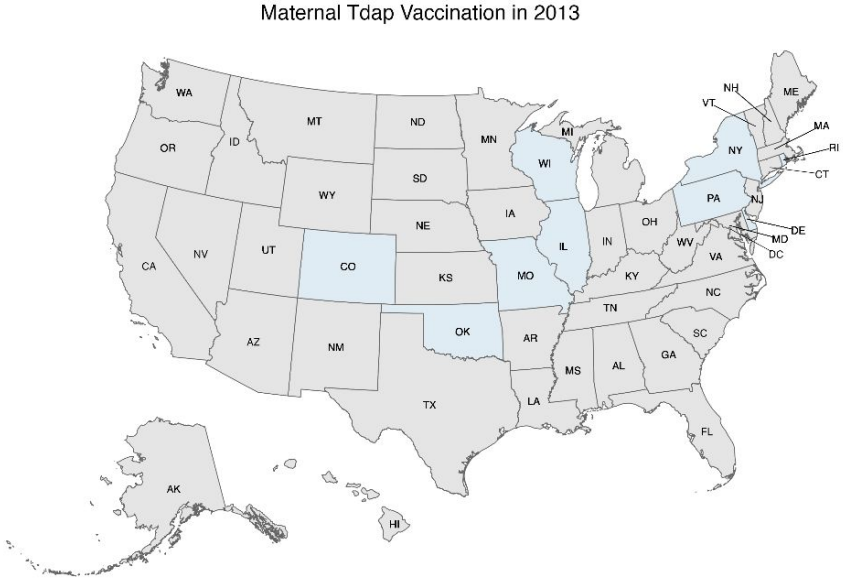
Aim 1 : Geographic and Sociodemographic Pattern of Vaccination Coverage Among Pregnant Women Across the States by Influenza and Tdap

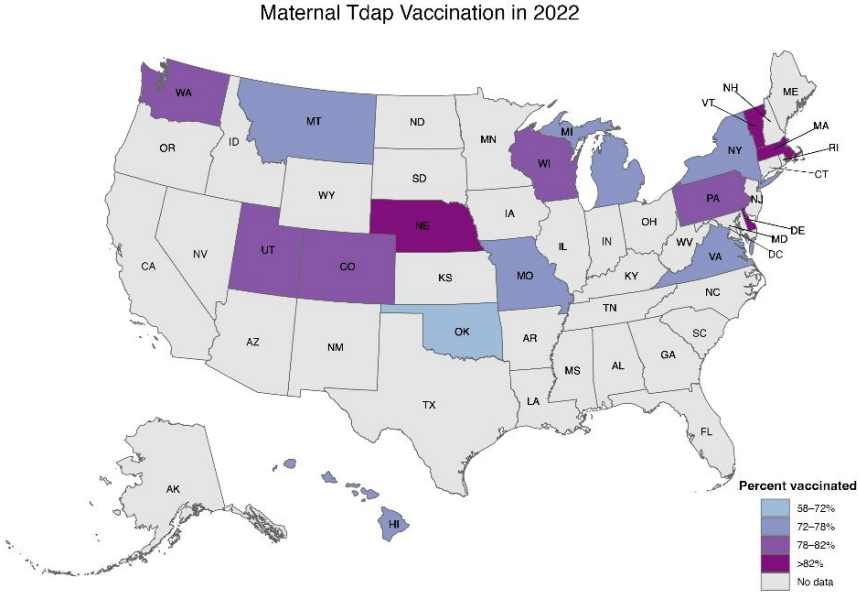
Spatial Patterns of Maternal Influenza Vaccination (2013 vs 2022)



- No evidence of systematic improvement or significant spatial expansion was observed in maternal influenza vaccination coverage. In other words, regional disparities persist and remain stable over time.
- The relative ranking among states has remained nearly unchanged: states with high coverage in 2013 remain high, while those with low coverage remain low.

Spatial Patterns of Maternal Tdap Vaccination (2013 vs 2022)

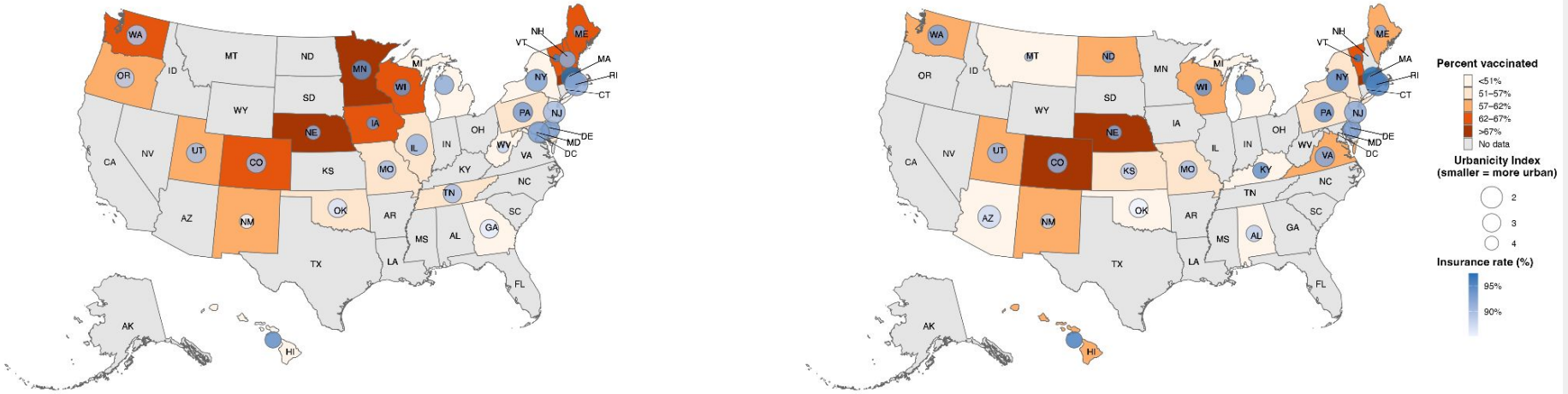




- Between 2013 and 2022, maternal Tdap vaccination coverage increased substantially and became more widespread across U.S. states.
- In 2013, several states lacked available data or had limited participation in maternal Tdap programs. By 2022, data availability and geographic representation improved, with more states reporting measurable vaccination rates, reflecting broader program implementation and monitoring.

Maternal Influenza Vaccination by Urbanicity and Insurance (2013 vs 2022)

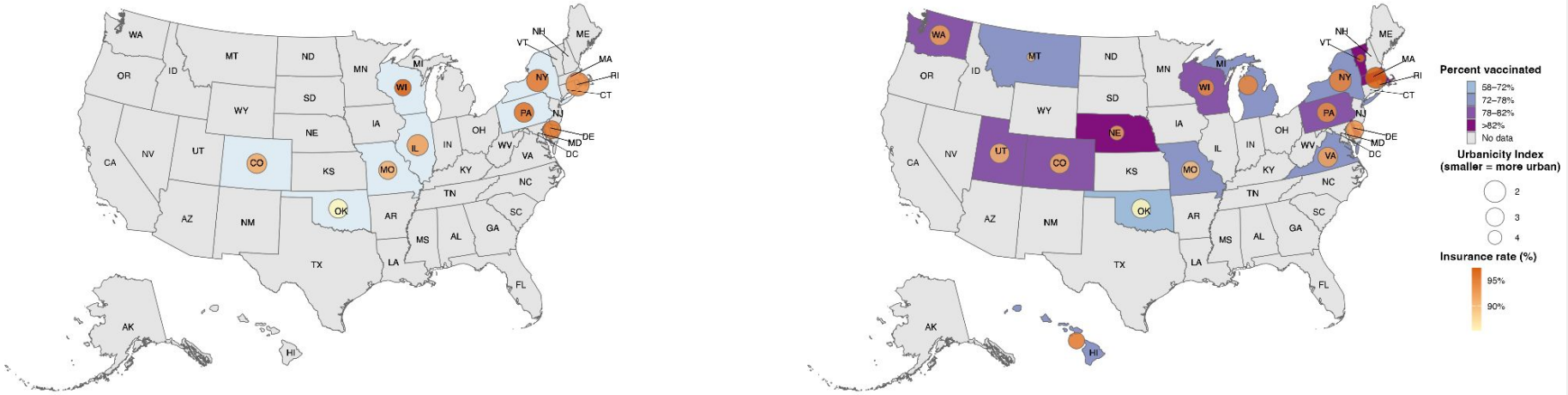
Orange fill: maternal vaccination rate | Blue fill: insurance rate | Bubble size: urbanicity index



- Vaccination rates show limited improvement between 2013 and 2022.
- While states with higher insurance coverage tend to have higher vaccination rates, there is no clear clustering pattern by urbanicity index.

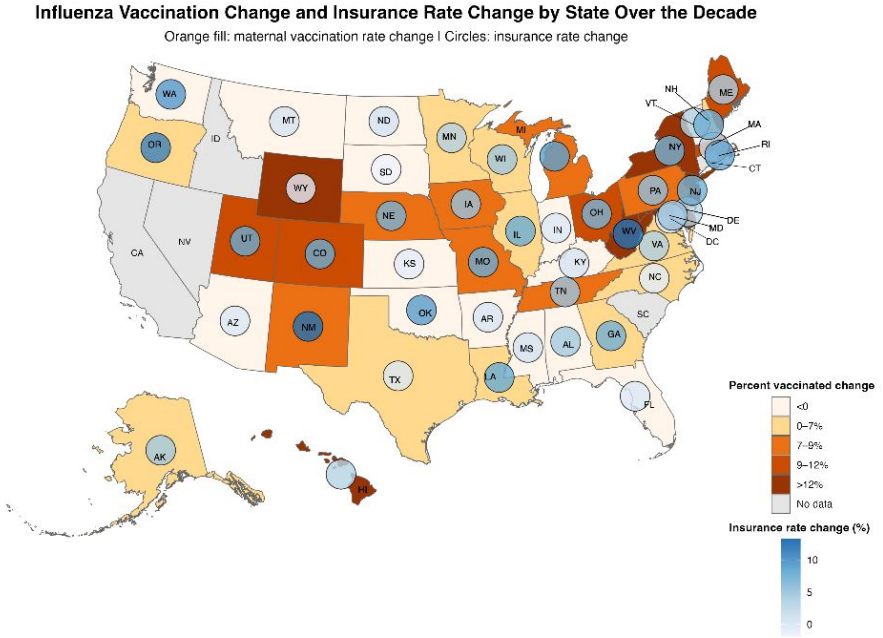
Maternal Tdap Vaccination by Urbanicity and Insurance (2013 vs 2022)

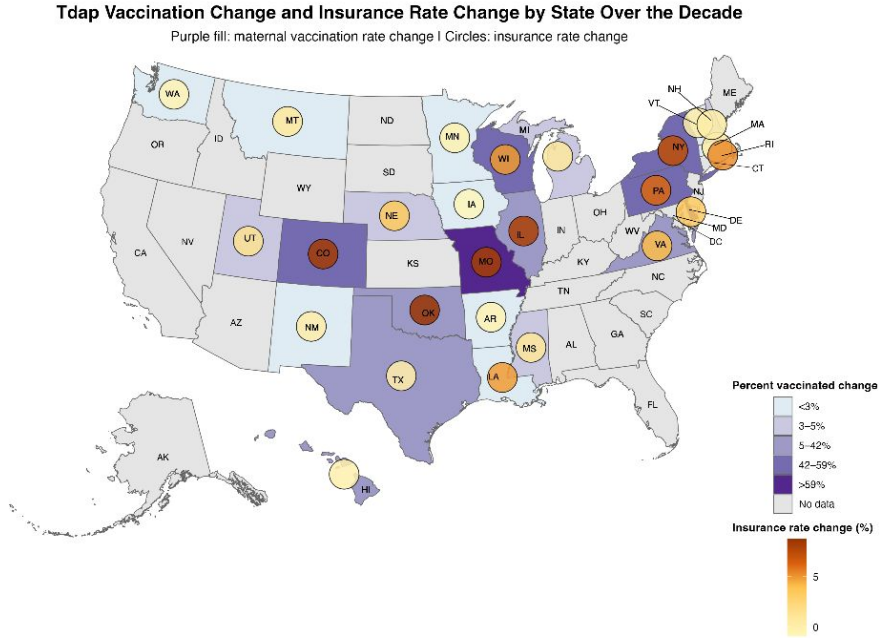
Orange fill: maternal vaccination rate | Blue fill: insurance rate | Bubble size: urbanicity index



- Substantial increase in vaccination coverage was observed.
- States with higher insurance coverage often correspond to higher vaccination rates, while urbanicity index does not show clear spatial clustering.

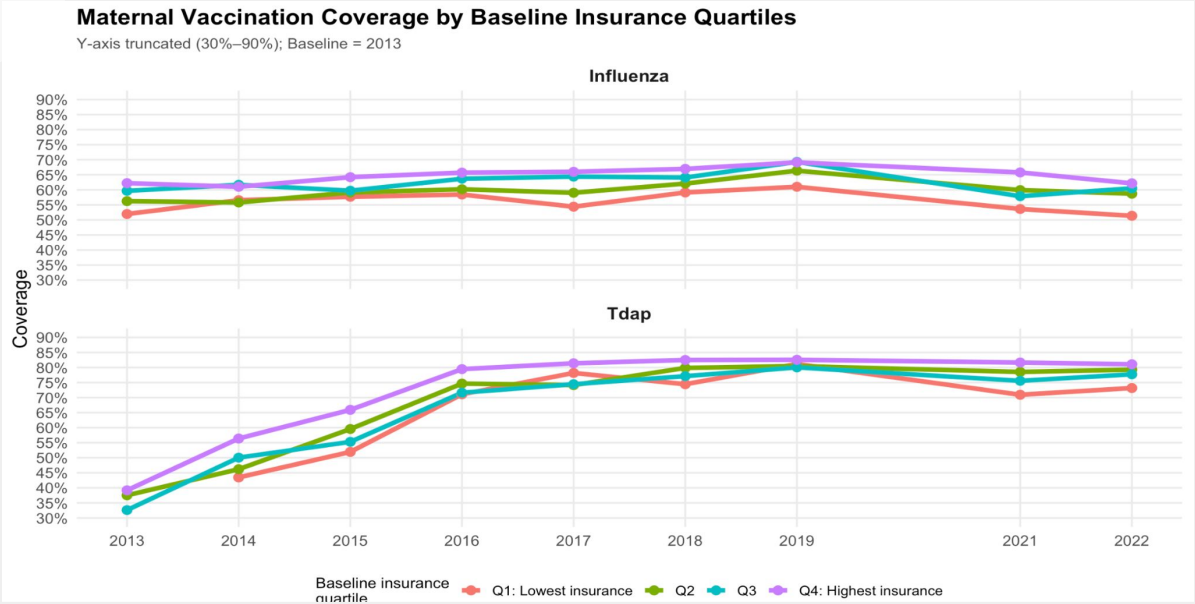
Maternal Vaccination Change and Insurance Rate Change Over Decade (2013-2022)





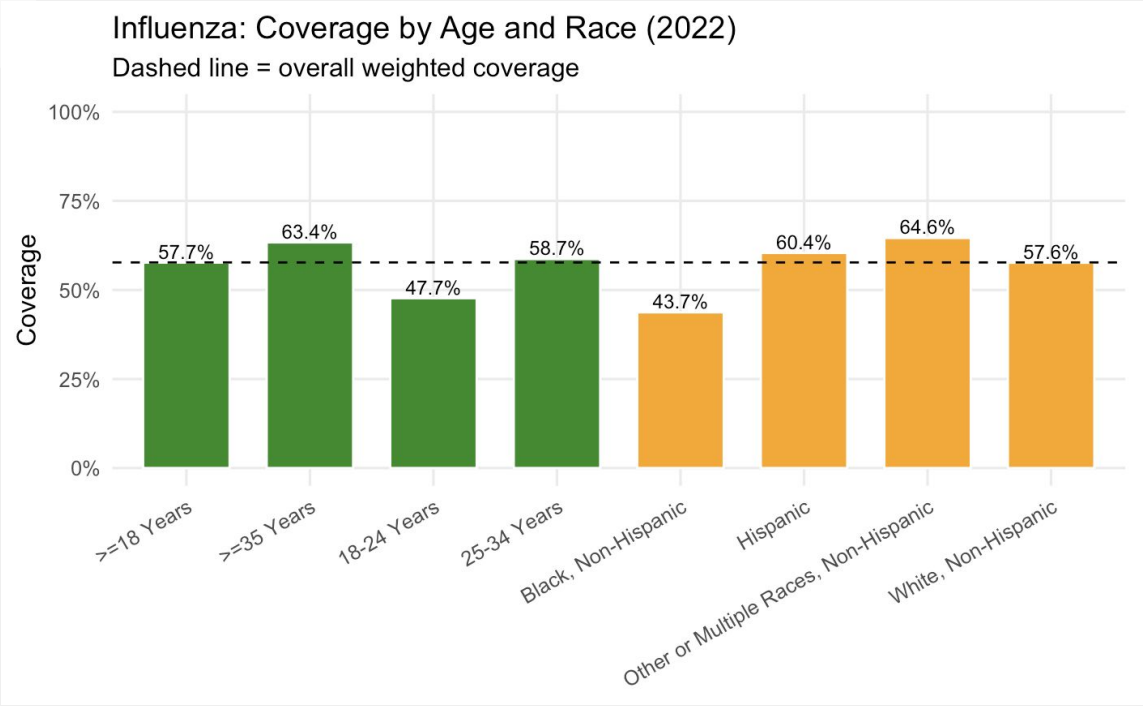
- Influenza vaccination changes are moderate overall while Tdap vaccination shows broader and stronger increases.
- Insurance coverage changes are generally positive across states for both vaccines, though the magnitude varies regionally.
- States with higher insurance coverage tend to have higher maternal vaccination rates for both influenza and Tdap.

Maternal Vaccination Trends by Insurance Quartiles



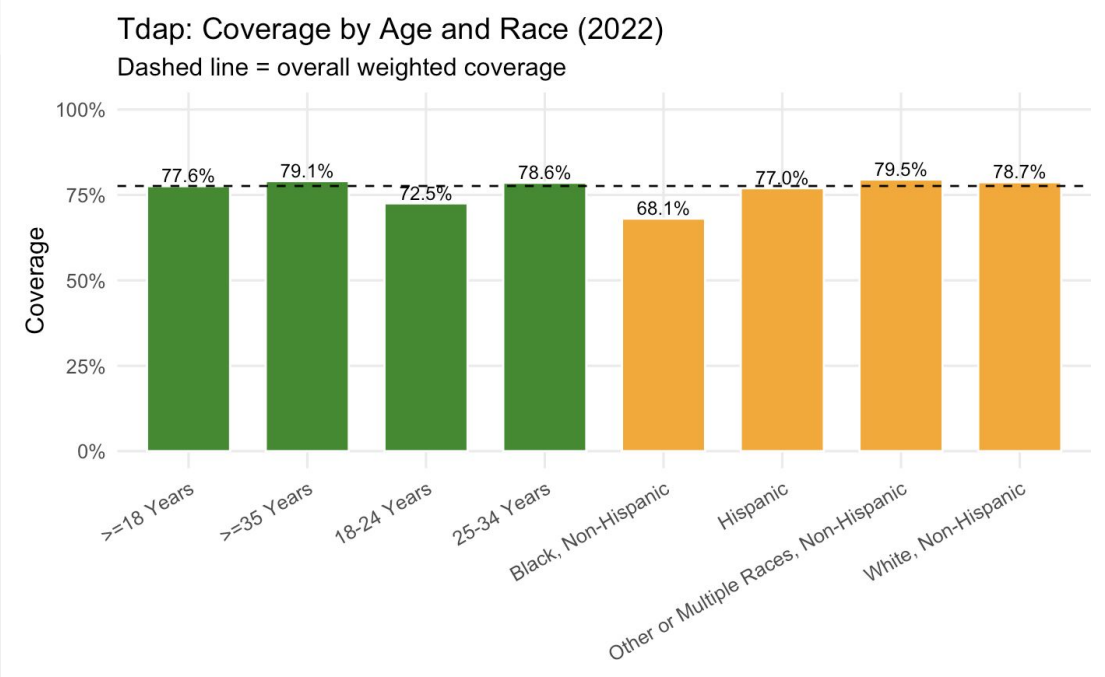
- Line plot shows influenza and Tdap coverage trends from 2013–2022
- States grouped by baseline insurance levels (lowest to highest quartiles)
- States with more insurance coverage consistently had higher vaccination rates
- Tdap coverage climbed quickly after 2013, then stay around **75–85%**
- Influenza coverage stayed moderate around **55–70%** and decline slightly after 2019
- States with better insurance access kept higher and more stable maternal vaccination rates

Influenza Coverage by Age and Race (2022)



- Bar chart displaying influenza vaccination by age group and race
- Dashed line: overall weighted U.S. coverage (~58%)
- Older age (>=35) and Non-Hispanic groups show the **highest coverage**
- Young (18–24) and Black, Non-Hispanic groups show the **lowest coverage**
- Flu vaccination rates still **vary by age and race**, not everyone is getting vaccinated at the same level.

Tdap Coverage by Age and Race (2022)



- Bar chart displaying Tdap vaccination by age and race
- Dashed line: overall weighted U.S. coverage (~78%)
- Older (>=35) and Non-Hispanic women maintain the **highest** coverage
- Black, Non-Hispanic women show the **lowest** Tdap uptake around 68%
- Although Tdap coverage is generally high, racial and age-related inequities remain

Key Findings in Aim 1

Overall Trends (2013–2022):

- Maternal vaccination coverage has increased modestly over the past decade.
- Tdap coverage improved more substantially than influenza coverage.

Insurance Disparities:

- States with higher insurance coverage consistently achieved higher vaccination rates.
- The coverage gap between insurance quartiles has persisted but slightly narrowed over time.

Sociodemographic Patterns (2022):

- Younger and Black, Non-Hispanic women remain the least likely to be vaccinated.
- Older and multiple race, Non-Hispanic women have the highest coverage.

Public Health Implications:

- Progress in maternal immunization equity is evident but incomplete.
- Continued focus on improving access among uninsured, younger, and minority populations is needed.

Aim2.1 : Does Insurance Coverage Predict Maternal Vaccination Rates?

· **Goal:** To examine whether states with higher uninsurance rates have lower influenza and Tdap vaccination coverage among pregnant women.

·**Hypothesis:** Higher uninsurance ➡️ Lower vaccination coverage.

·**Vaccines Studied:**
-Influenza
-Tdap

·**Target Group:** Pregnant women, stratified by age and race/ethnicity.

Aim2.1 : Data and Variables Used

Variable	Description	Source
Coverage	% of vaccinated pregnant women (flu or Tdap)	CDC,Vaccination Coverage among Pregnant Women
UninsuredRate	Uninsured / (Insured + Uninsured), age 19–64	KFF, Women's health insurance coverage
Vaccine	Flu or Tdap	CDC,Vaccination Coverage among Pregnant Women
Dimension	Age Group or Race Group	CDC,Vaccination Coverage among Pregnant Women

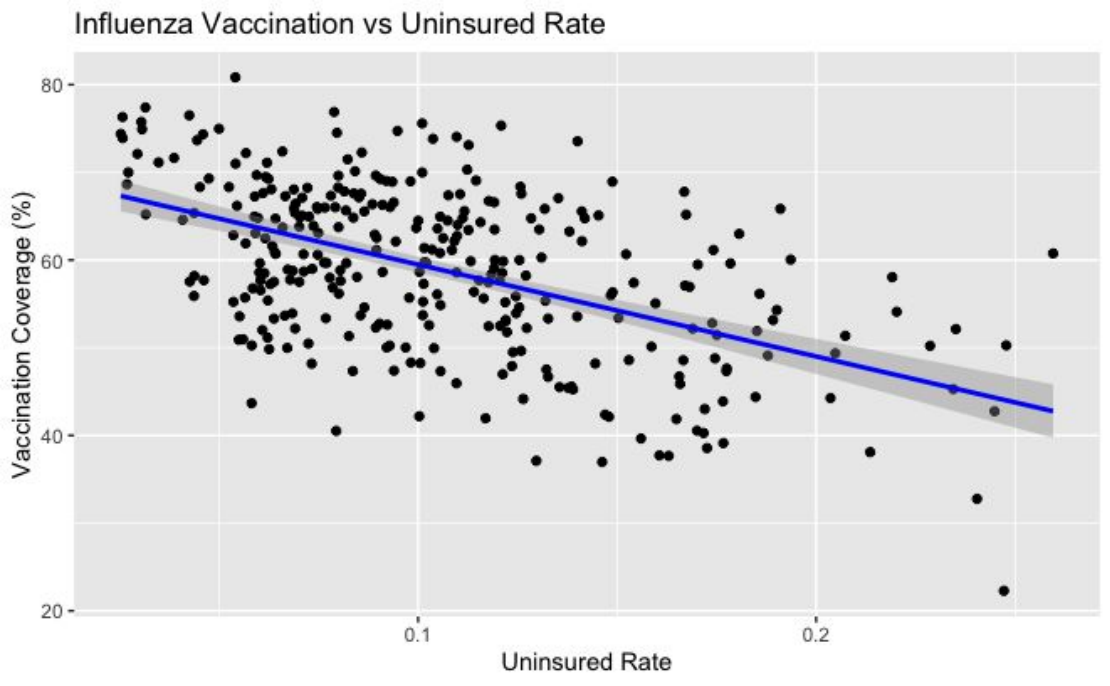
Aim 2.1 : Method: Linear Regression

· **Approach:** Simple linear regression: Vaccination Coverage ~ UninsuredRate

· **Stratified by:**
- Age group
- Race/ethnicity

· **Visualization:**
- Scatter plot with regression line
- One combined plot per stratification (color-coded)

Influenza Model Visualization



· Scatterplot of Influenza coverage vs. uninsurance across all states

· Clear downward trend

· Regression line with 95% confidence band

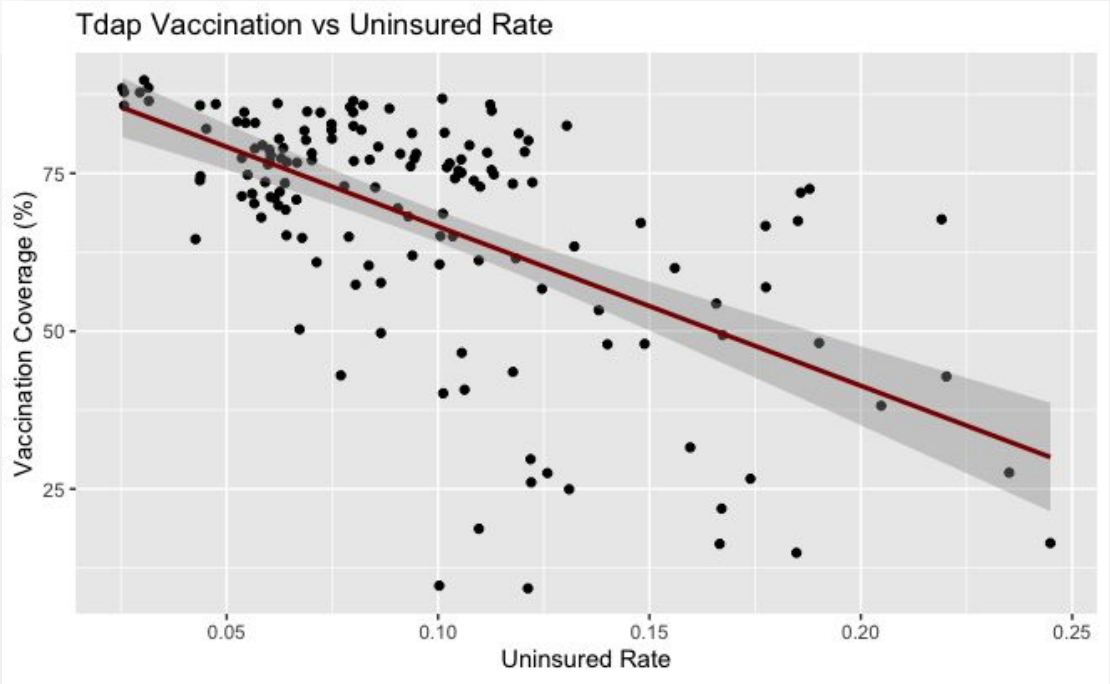
· Interpretation: States with higher uninsured rates tend to have lower influenza vaccination rates among pregnant women.

Influenza Model Output

Predictor	Estimate (β)	Std. Error	p-value
(Intercept)	69.97	1.12	¡0.001
Uninsured Rate	-104.81	9.66	¡0.001
Residual Std. Error = 8.14; $R^2 = 0.275$; $n = 313$			

- Model: Linear regression
- Key Predictor: Uninsured Rate (β = −104.81, p < 0.001)
- Interpretation: Higher uninsured → lower vaccine coverage
- $R^2 = 0.275$: Model explains 27.5% of variance
- Residual Std. Error = 8.14: Suggests reasonable fit
- Note: Other factors (e.g., public health access, attitudes) may also influence coverage

Tdap Model Visualization



· Scatterplot of Tdap coverage vs. uninsurance across all states

· Strong negative linear trend

· Regression line with 95% confidence band

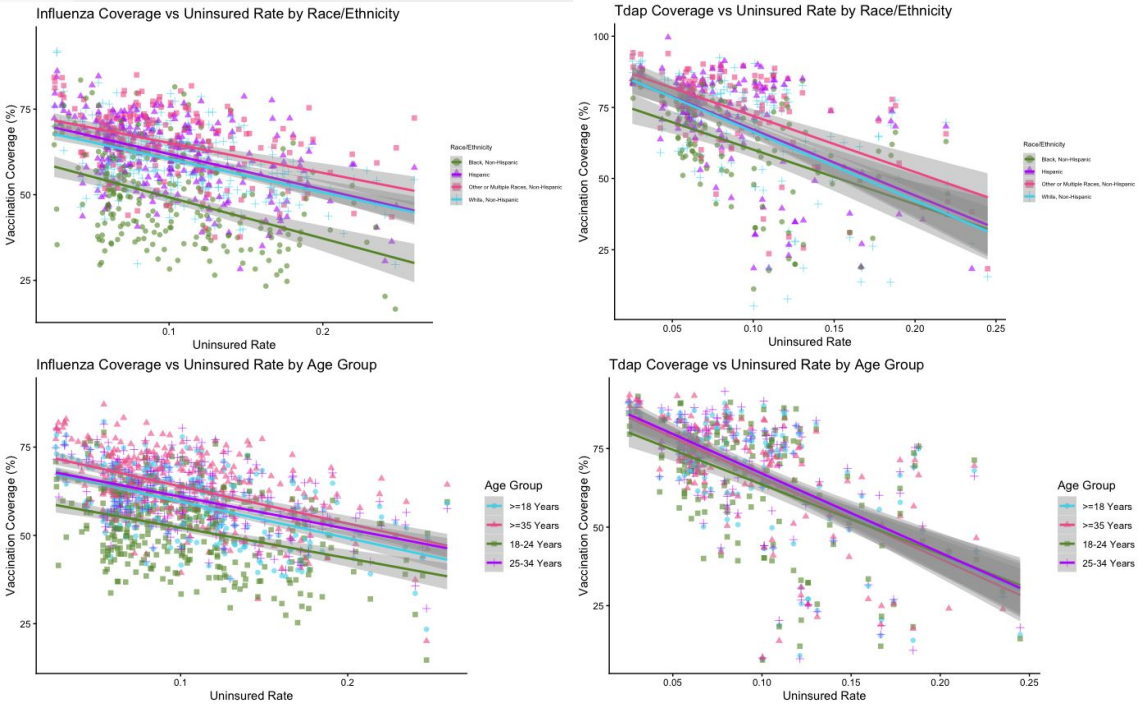
· Interpretation: The effect of insurance coverage is even more pronounced for Tdap vaccination.

Tdap Model Output

Predictor	Estimate (β)	Std. Error	p-value
(Intercept)	91.81	3.00	¡0.001
Uninsured Rate	-252.30	28.14	¡0.001
Residual Std. Error = 15.31; R^2 = 0.358; n = 146			

- Model: Linear regression
- Key Predictor: Uninsured Rate (β = −252.30, p < 0.001)
- Interpretation: More uninsured → much lower Tdap coverage
- R^2 = 0.358: Model explains 36% of variation
- Residual Std. Error = 15.31: Higher than for influenza
– Note: Uninsurance explains more of the variation in Tdap coverage than in influenza, suggesting a stronger link between insurance access and Tdap uptake.

Stratified Analysis by Race/Ethnicity and Age Group



- Tdap plots are more tightly clustered

➡️Suggests less variation across groups

➡️Especially true for Tdap by Age Group (almost a straight line)

- Tdap by Race/Ethnicity

➡️Black, Non-Hispanic starts lower but converges later

➡️Other/Multiple Races become more spread out

➡️White and Hispanic stay close

- Influenza by Race/Ethnicity

➡️Black, NH group is clearly lower across all levels

➡️Stronger visible disparities than in Tdap

- Influenza by Age Group

➡️More clustered than race, but less extreme than Tdap age plot

- Tdap by Age Group

➡️18–24 group in Tdap is slightly lower, but gap is small

Aim 2.2 & 2.3: Overview

Aim 2: At the state-year level, quantify the association between urbanicity(NCHS 1-5) and women's insurance coverage(insured/uninsured) with vaccination coverage among pregnant women (flu and Tdap), and test their interaction(whether rurality amplifies the impact of uninsurance on uptake).

- Q2.2: Are more rural states(higher NCHS score) associated with lower coverage?
  Hypotheses: Higher NCHS(more rural) -> lower coverage
- Q2.3: Is there an interaction such that uninsurance harms coverage more in rural states?
  Hypotheses: $\beta_{uninsured \times NCHS} < 0$

Aim 2.2 & 2.3: Data

Outcomes (CDC pregnancy vaccination)

- State–year coverage (%) among pregnant persons, modeled separately for Influenza and Tdap.
- If multiple rows exist per state–year–vaccine, use sample-size weighted mean.

Predictors

- Uninsurance rate (uninsured / (insured + uninsured)) by state–year.
- Urbanicity = NCHS index (baseline 2013; if missing, use 2023).

Weights

- Use vaccine-specific state–year sample sizes n_flu / n_tdap as precision weights.

Aim 2.2 & 2.3: Panel Assembly & Missing-Data Handling

Assembly

- Pivot vaccination long→wide: vacc_flu_pct, vacc_tdap_pct; retain n_flu, n_tdap.
- Merge with Uninsurance by (state, year); merge NCHS by state (time-invariant baseline).

Missing data

- No imputation; complete-case per figure/model.
- NCHS baseline = coalesce(NCHS2013, NCHS2023), restricted to 1–5.
- Tdap coverage sparser across some state–years → wider CIs.

Standardization

- Use z-scores for Uninsurance and NCHS within analytic sample for interpretability.

Aim 2.2 & 2.3: Model Choice & Identification

Aim 2.2 (Between-state)

Compute state-level means (coverage weighted by vaccine n).

Regress state-mean coverage on standardized NCHS (z), separately for Flu and Tdap.

Aim 2.3 (Within-state over time)

Two-way fixed effects (TWFE): $Coverage_{it} = \alpha_i + \tau_t + \beta1 \cdot Unins\_z_{it} + \beta3 \cdot (Unins\_z_{it} \times NCHS\_z_i) + \varepsilon_{it}$.

State FE absorb time-invariant heterogeneity; year FE absorb common shocks.

Cluster SEs by state; weight by vaccine-specific n.

Interpretation

β1 = within-state effect of uninsurance (pp per 1 SD).

β3 = moderation by rurality (NCHS).

Aim 2.2: Between-State Associations

Regression of state-mean coverage on NCHS (z)

Outcome (state mean)	NCHS z (β)	SE [p]	R^2
Flu	0.681	1.361 [0.619]	0.006
Tdap	4.856	2.889 [0.106]	0.105

Interpretation:

- Flu
  - No clear urban–rural gradient (between states).
- Tdap
  - Positive, near-significant slope; could reflect between-state composition/policies.
- Why TWFE next
  - Between-state contrasts can be confounded → focus on within-state change.

Aim 2.3 — TWFE (State & Year FE; Clustered SE; Weighted)

Estimated coefficients (z-standardized uninsurance & NCHS)

Outcome	β1 Unins z	(SE)	β3 Unins×NCHS z	(SE)	Within R^2 / N
Flu	0.027	(0.622)	0.625	(0.434)	0.021 / 321
Tdap	6.530*	(2.431)	1.242	(1.314)	0.087 / 151

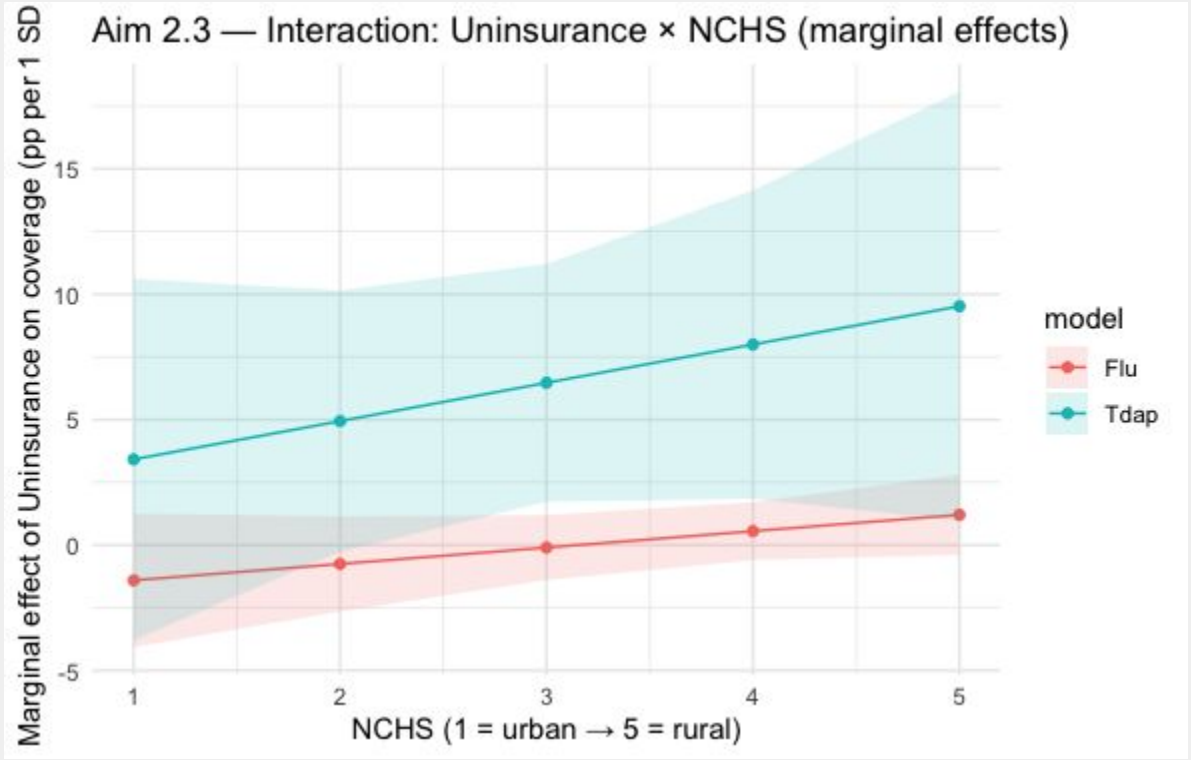
Notes

* $p<0.05$. Interaction is not statistically significant for either vaccine.

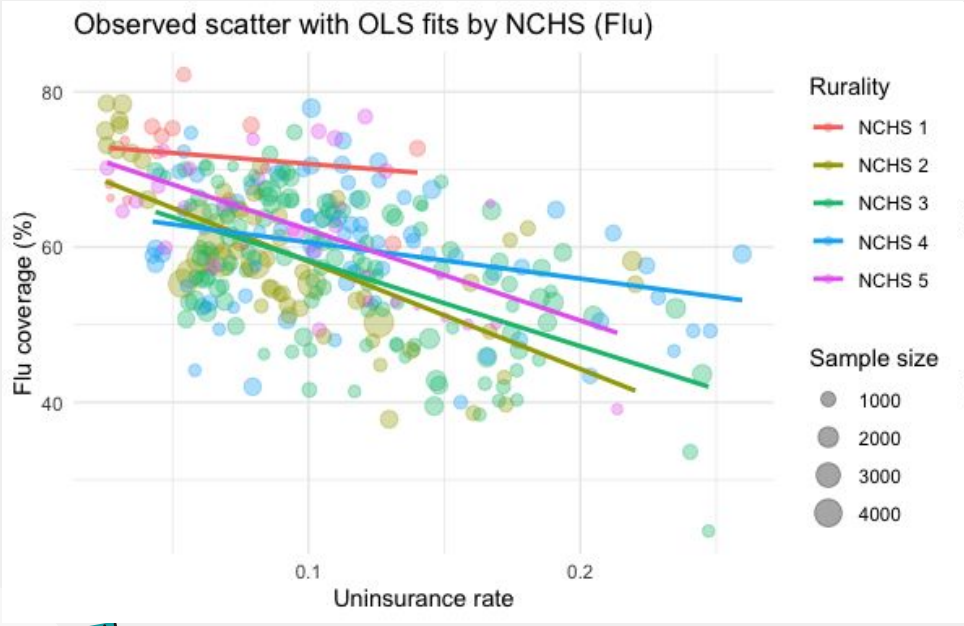
Interpretation:

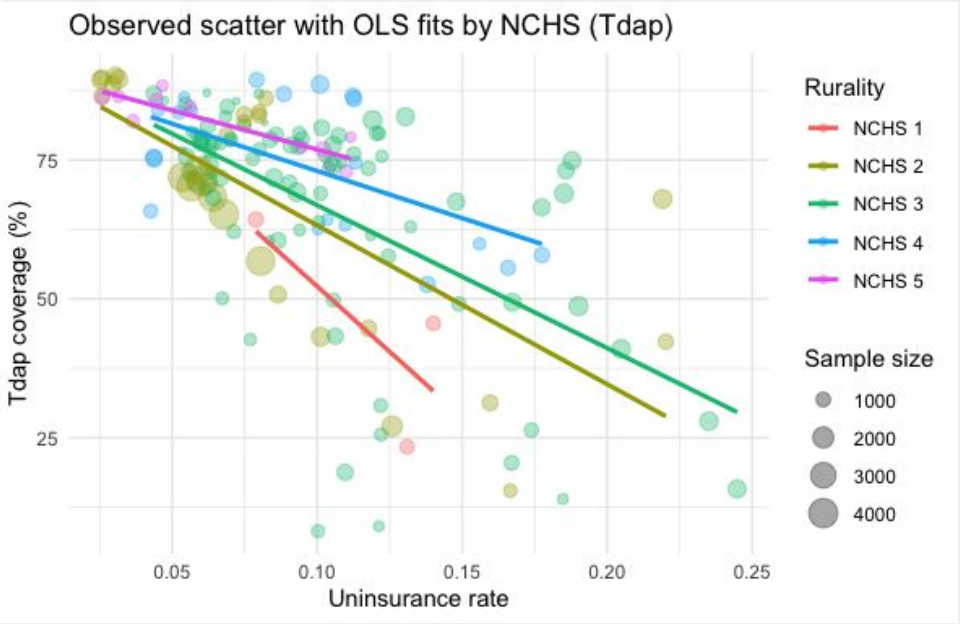
- Flu
  - No detectable within-state association with uninsurance.
- Tdap
  - Higher uninsurance associated with higher coverage (std. units).
  - Unins×NCHS moderation is visually suggestive but imprecise.

Marginal Effects: Uninsurance × NCHS

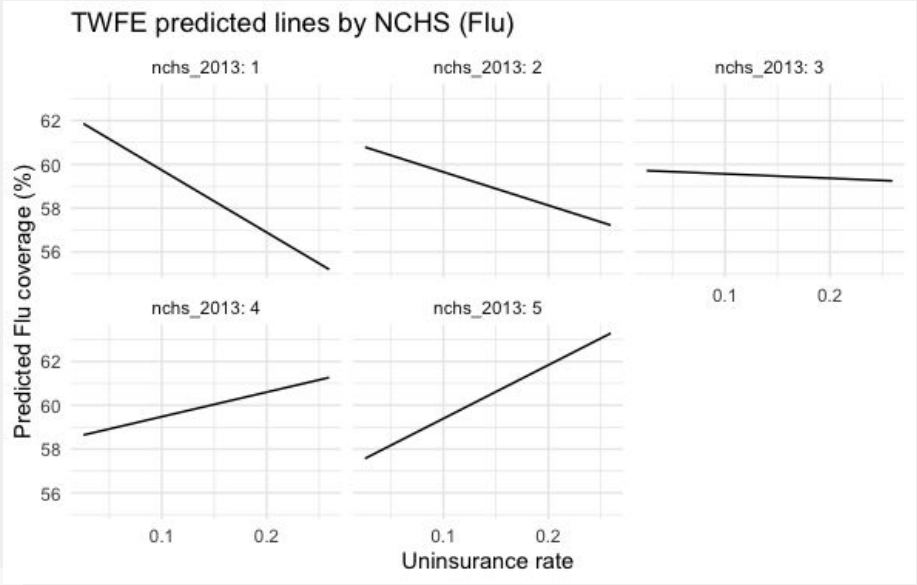


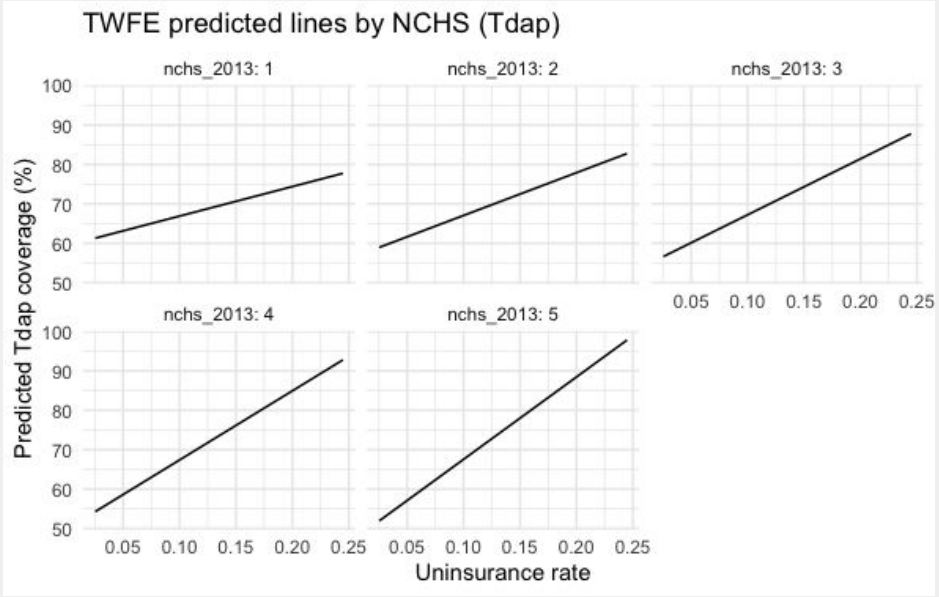
Observed Scatter Plot (Flu & Tdap)





TWFE Predicted Lines by NCHS (Flu & Tdap)





Summary and takeaways

Key Findings

- Maternal vaccination coverage improved from 2013–2022, especially for Tdap.
- States with higher insurance coverage consistently achieved higher vaccination rates.
- Coverage disparities remain by age and race: younger and Black, Non-Hispanic women are still least likely to be vaccinated.
- Across states, higher uninsurance is linked to lower vaccination, especially for Tdap and in rural areas.
- Within states, influenza shows little change, while Tdap responds more strongly to improvements in insurance access.

Limitations

- Some Tdap data missingness reduces precision.
- State-level analysis may mask within-state differences.
- The rurality index (NCHS) is time-invariant and may not capture recent local changes.

Summary and takeaways

Implications

- **Progress toward equity is visible but still incomplete.**
- Expanding insurance coverage and targeted outreach, especially for rural, younger, and underinsured populations are key to closing gaps.
- Ongoing monitoring is needed to ensure every pregnant woman has equal access to vaccination.

Overall

- **Achieving maternal immunization equity in the U.S. depends on improving insurance access and reducing sociodemographic and geographic barriers.**

Thanks