Modeling Area-Level Health Rankings

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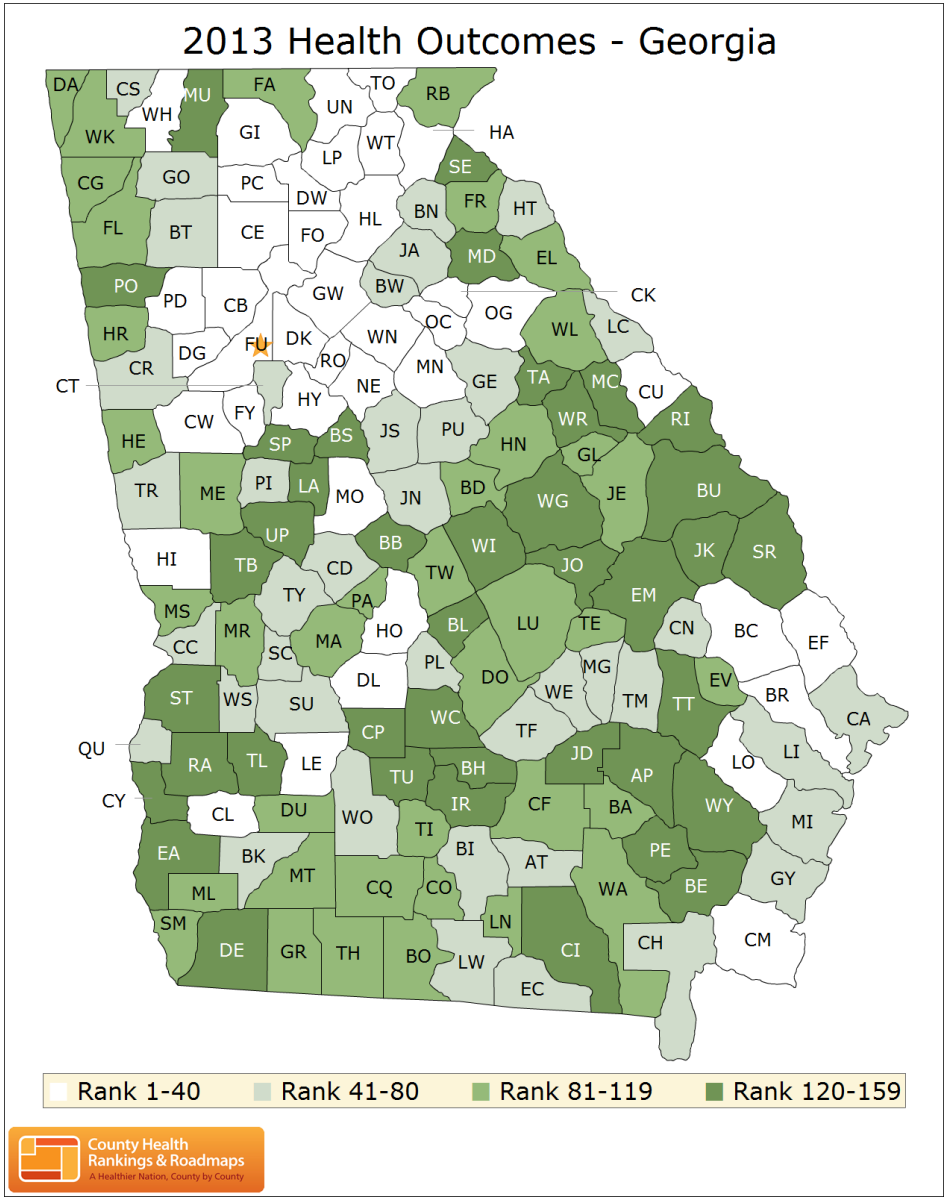
Overview

- Population Health measures
- UWPHI methods and ranks
- Our contribution
- Spatial factor analysis model
- Results
- Extensions

Population Health

- The goal is to rank areas based on health of the population
- The problem is that "health" is not observable directly
- There are two levels of population health measures available - state and county level
- Those are used to compare health levels across areas and to identify disadvantaged areas (mobilizing action vs. resource allocation)
- RWJF funded www.countyhealthrankings.org


2013 Health Outcomes - Georgia
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SM
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GR
TH
BO
LW
CI
CH
CM
EC
Rank 1-40
Rank 41-80
Rank 81-119
Rank 120-159
County Health Rankings & Roadmaps
A Healthier Nation, County by County

County Health Ranks

- We will only concentrate on "Mortality and Morbidity" ranks
- The variables used are county level averages of
  1. YPLL (2005-2007 NCHS)
  2. % reporting fair or poor health (2003-2009 BRFSS)
  3. # physically unhealthy days a month (2003-2009 BRFSS)
  4. # mentally unhealthy days a month (2003-2009 BRFSS)
  5. % low birth weight (2001-2007 NCHS)

UWPHI ranks

- Each variable j is standardized:

$$Z_{ij} = \frac{Y_{ij} - \mu_j}{St.d.(Y_{ij})}$$

- For each county an overall $Z - score$ is computed

$$Z_i = .5 * Z_{i1} + .1 * Z_{i2} + .1 * Z_{i3} + .1 * Z_{i4} + .2 * Z_{i5}$$

- Each county is assigned a rank based on its $Z - score$.
- $Z - scores$ are ranked and ranks are reported/mapped
- Example of maps

Potential Limitations

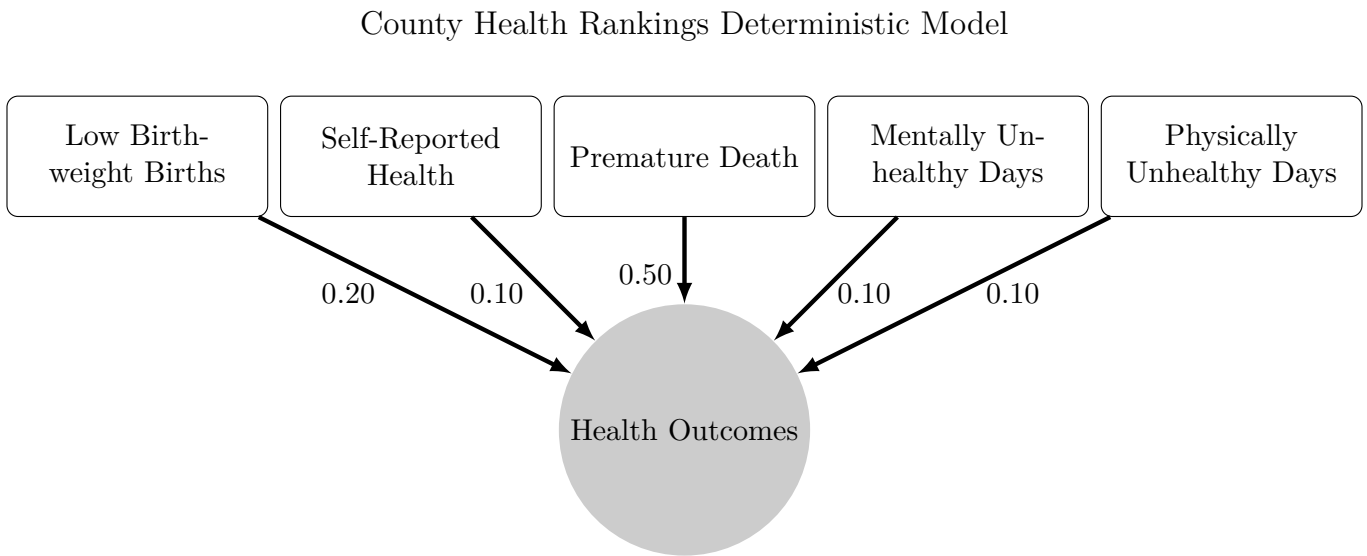
1. Add-hoc weights
2. No measure of uncertainty
3. County population sizes are not incorporated
4. Counties are assumed to be spatially independent

Our contribution

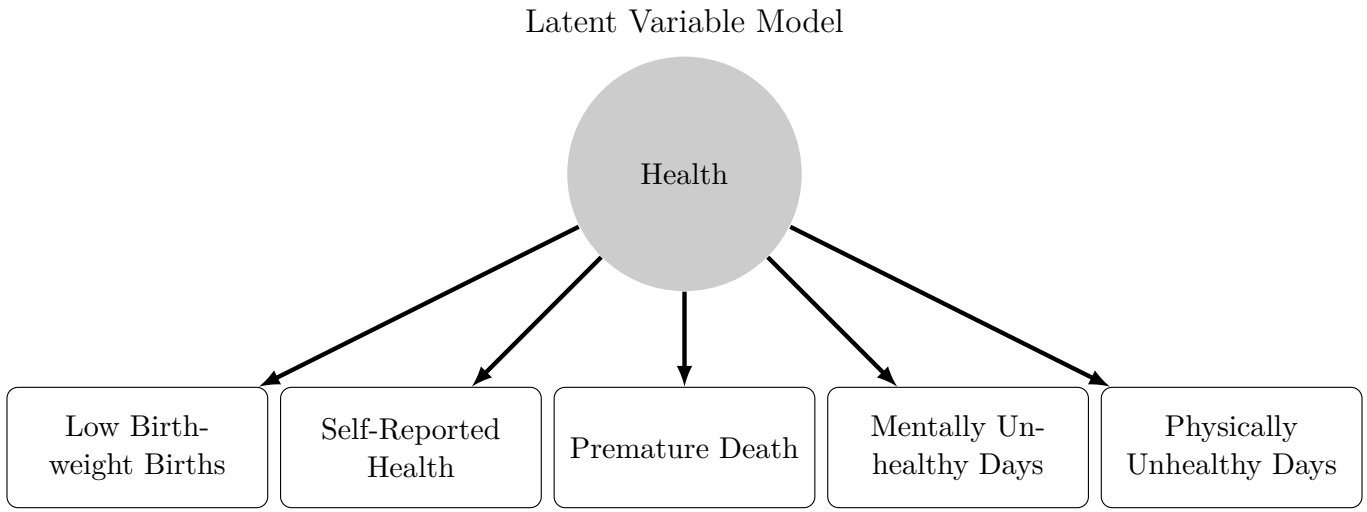
We propose to use Hogan and Tchernis (2004) spatial factor analysis model

1. Data-dependent weights
2. Results can be summarized using distribution of county ranks (representation of uncertainty)
3. County population sizes are incorporated into the variance of both factors and errors
4. Incorporated spatial correlation of factor scores

UWPHI Framework



Our Framework



Proposed Model - step 1

$$
\begin{aligned}
Y_{ij} &= \mu_j + \lambda_j \delta_i + e_{ij} \\
\\
\mu_j &= E(Y_{ij}) \\
&= \text{average of variable across areas} \\
\\
\delta_i &\sim N(0,1) \\
&= \text{latent county health level for area } i \\
\\
\lambda_j &= \text{factor loading} \\
&= Cov(Y_{ij}, \delta_i) \\
\\
e_{ij} &\sim N(0, \sigma_j^2) \\
&= \text{unexplained error}
\end{aligned}
$$

Proposed Model - compact form

Level I. Within-area variation

$$Y_i|\delta_i \sim N(\mu + \lambda\delta_i, \Sigma), \sigma_{jk} = 0 \ \forall \ j \neq k$$

or in stacked form

$$Y|\delta \sim N(\mu + \Lambda\delta, I_n \otimes \Sigma)$$

Level II. Between-area variation

$$\delta \sim N(0, I_n)$$

Requires normality and fixed variance for identification

Proposed Model - steps 2 and 3

Step 2: Incorporating population sizes:

$$M = diag\{m_i\}$$

m_i is population of county i

$$\begin{aligned} Y|\delta &\sim N(\mu + \Lambda\delta, M^{-1} \otimes \Sigma) \\ \delta &\sim N(0, M^{-1}) \end{aligned}$$

Step 3: Incorporating spatial correlation:

$$\begin{aligned} Y|\delta &\sim N(\mu + \Lambda\delta, M^{-1} \otimes \Sigma) \\ \delta &\sim N(0, M^{-1/2}\Psi M^{-1/2}) \end{aligned}$$

Implication: $E(\delta_i|Y)$ may depend on variables from other counties - spatial smoothing.

Spatial Correlation

- We work with the Conditional Autoregressive (CAR) specificion (Besag, 1974; Sun et al., 1999)

$$\begin{aligned} \delta_i | \{\delta_j : j \in R_i\} &\sim N\Big(\sum_{j \in R_i} \beta_{ij} \delta_j, v/\alpha_i \Big), \\ \text{or marginally} & \\ \delta &\sim N(0, (I - \omega R)^{-1}) \end{aligned}$$

- where $\beta_{ij} = \omega$, and $v/\alpha_i = 1$,
- $R_{ij} = 1$ if a county j is adjacent to county i and $R_{ii} = 0$.
- Thus $\Psi = (I - \omega R)^{-1}$ is a full matrix inducing the correlation between variables between counties.

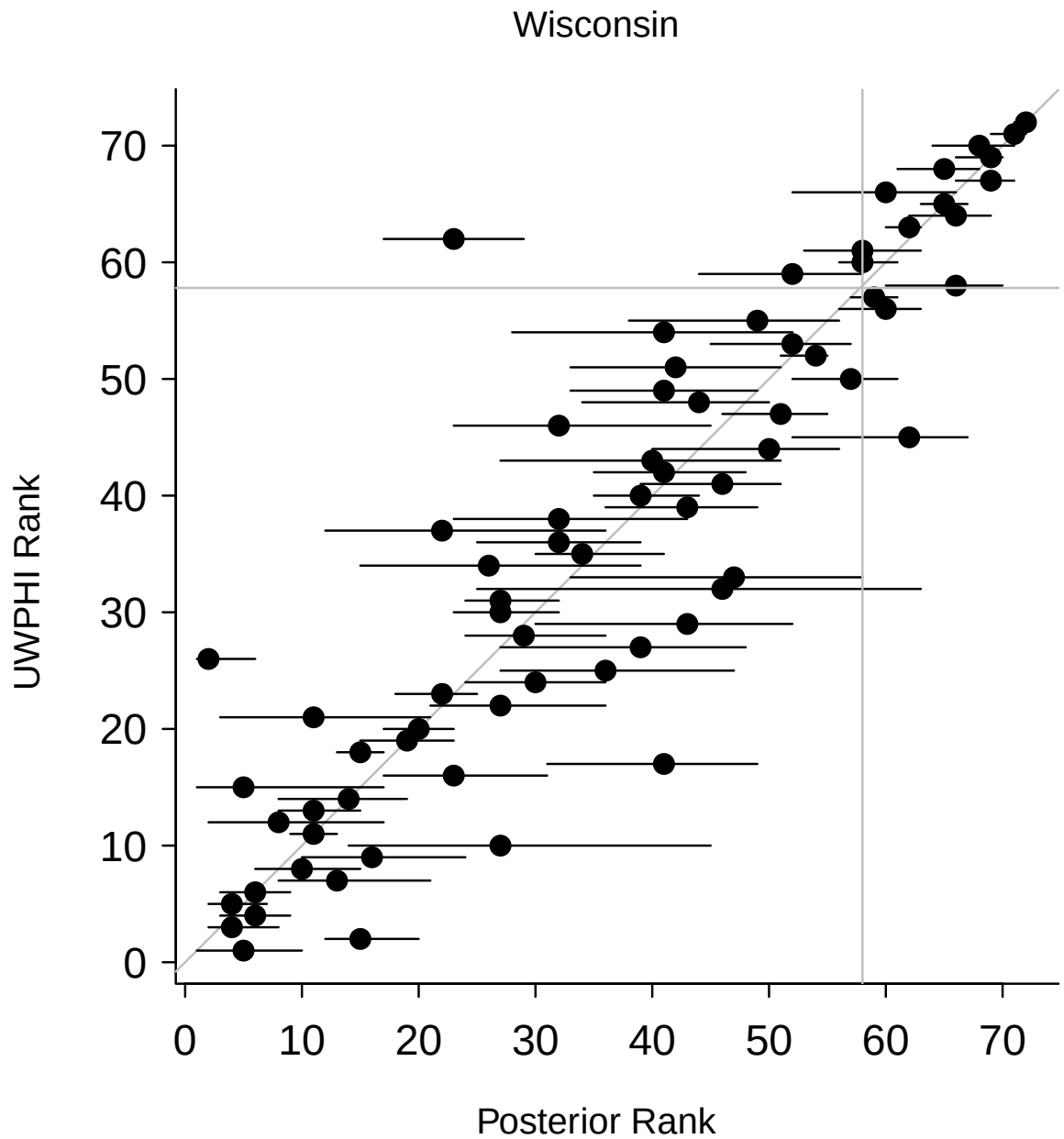
Estimation

- The model is estimated using MH within Gibbs Sampler, separately for each state
- We obtain 5,000 draws from the posterior distribution of parameters
- At each iteration we rank the draws of posterior mean of factor scores which produces a draw from the posterior distribution of county ranks
- In addition, we can compute probability that each county is in a certain range, e.g. top quintile of ranks (the worst health)

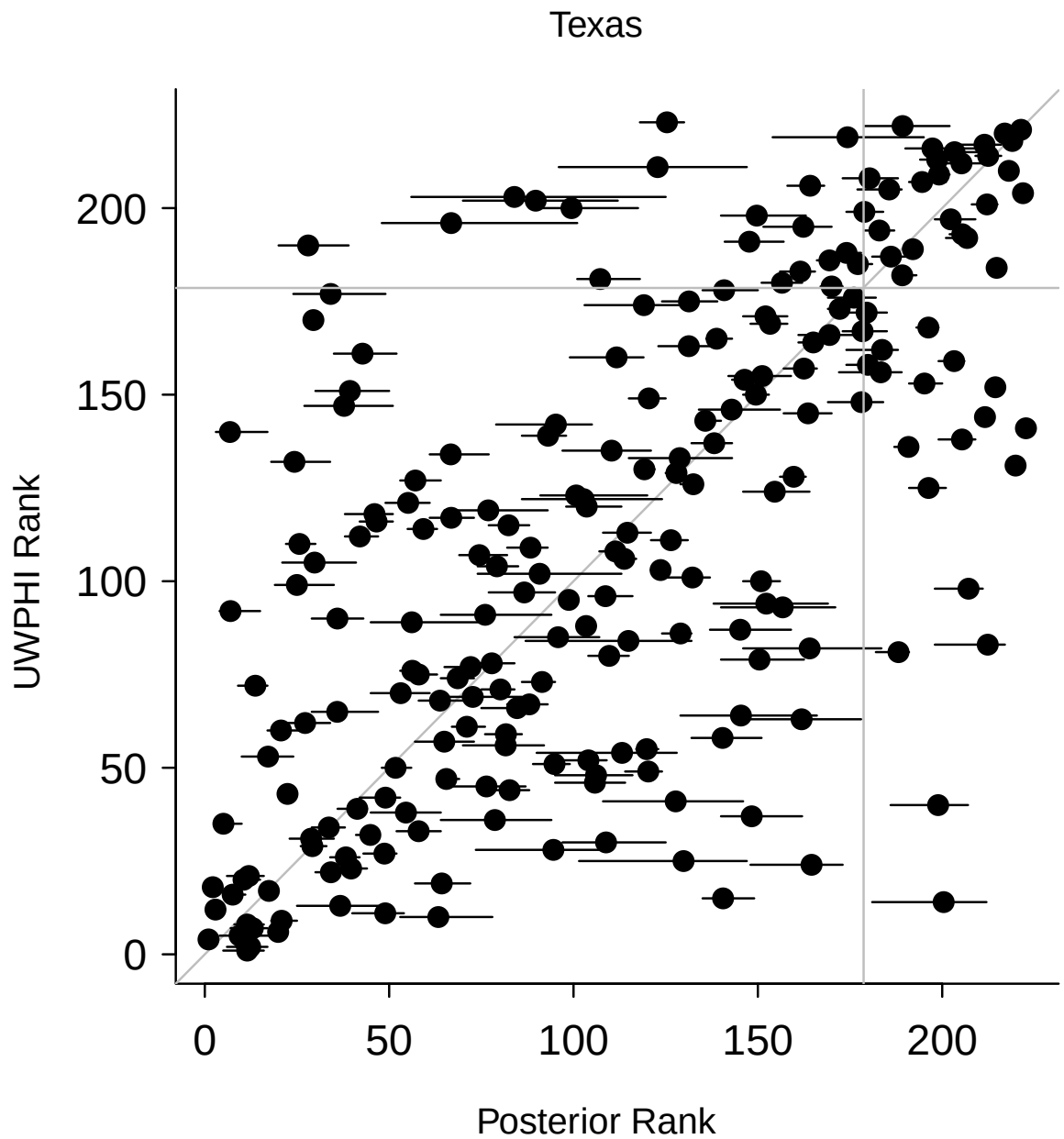
Data

- We use data from WI and TX
- WI has been researched in a number of contexts and has less missing data (only 2 observations out of 72 counties)
- TX is a larger state, but has a lot of missing data (out of 254 counties 31 are not ranked by UWPHI, and 116 of remaining counties have at least one missing observation)
- For easier comparison we will OLS predictions for missing observations (CHR uses means), but later we will incorporate missing data imputation

UWPHI and Posterior Ranks - Wisconsin



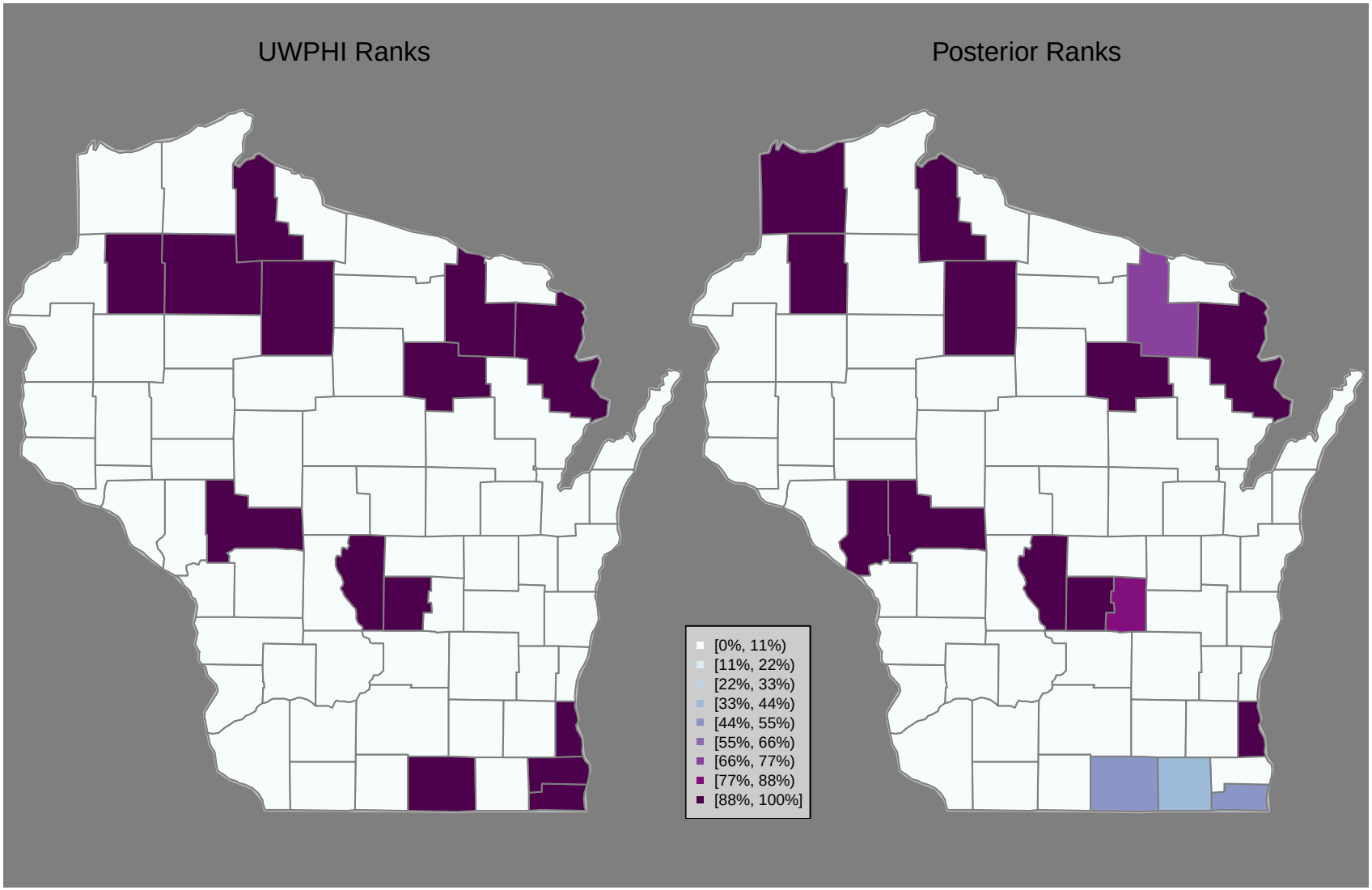
UWPHI and Posterior Ranks - Texas



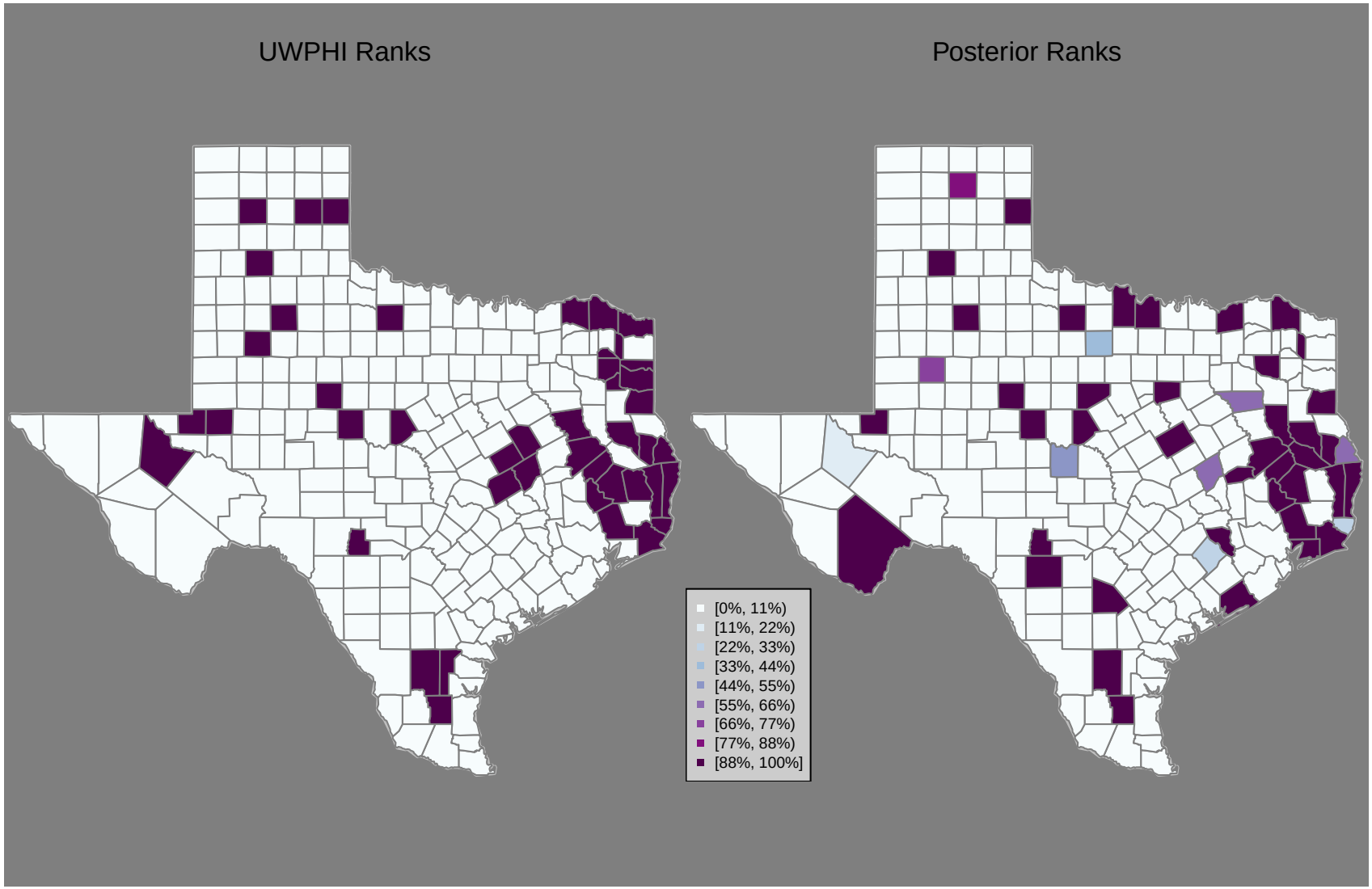
Weights and Squarred Correlations

	UWPHI		Texas		Wisconsin
	w	ρ^2	95% CI	ρ^2	95% CI
Premature Death	0.50	0.14	(0.09,0.19)	0.27	(0.17,0.38)
Health Status	0.10	0.24	(0.20,0.29)	0.21	(0.12,0.30)
Phys. Unhealthy Days	0.10	0.41	(0.34,0.48)	0.21	(0.11,0.31)
Ment. Unhealthy Days	0.10	0.15	(0.10,0.20)	0.17	(0.08,0.25)
Low Birthweight Births	0.20	0.06	(0.02,0.10)	0.15	(0.05,0.24)

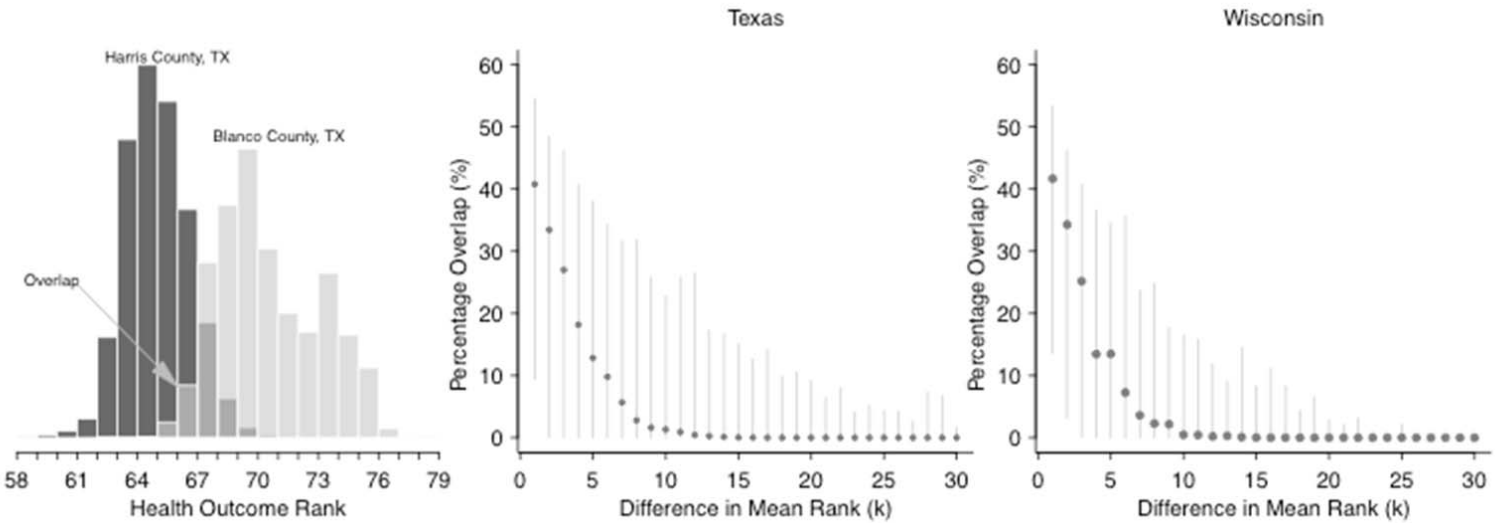
Maps of Probability of Being in the Top Quintile



Maps of Probability of Being in the Top Quintile



How Far Apart to be Different

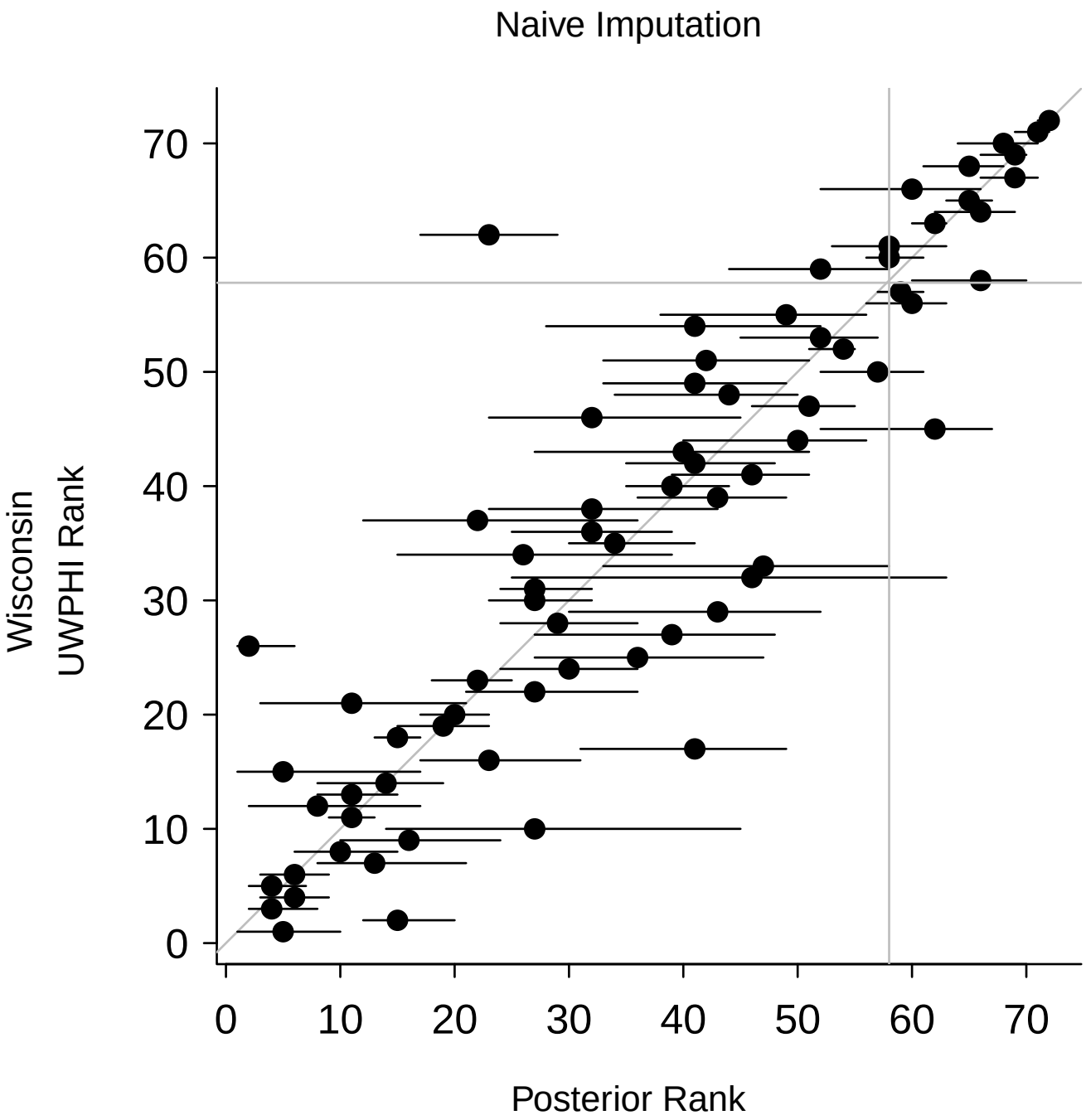


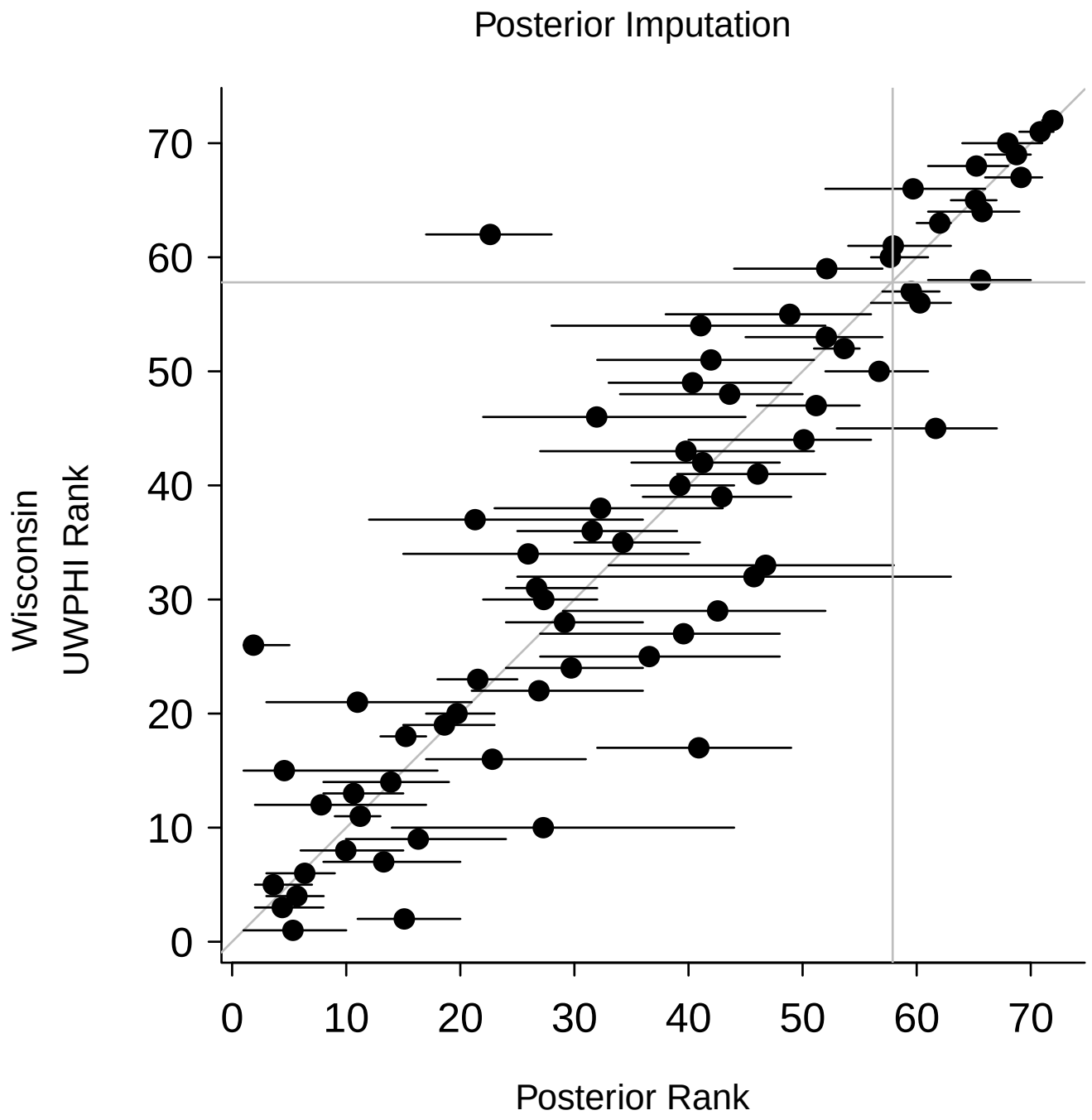
Dealing with Missing Data

- So far we used naive predictions of missing data and did not incorporate the uncertainty of prediction
- Our method extends to predicting missing data in one simple step
- Conditional on parameters, the distribution of the missing data is given by the model

$$\begin{aligned} Y_{ij}^{miss} &= \mu_j + \lambda_j \delta_i + e_{ij}, \\ e_{ij} &\sim N(0, \sigma_j^2) \end{aligned}$$

- We rerun the model for all counties used so far as well as a subset of counties with at most one variable missing.


Naive Imputation
Wisconsin
UWPHI Rank
Posterior Rank
0
10
20
30
40
50
60
70


Posterior Imputation
Wisconsin
UWPHI Rank
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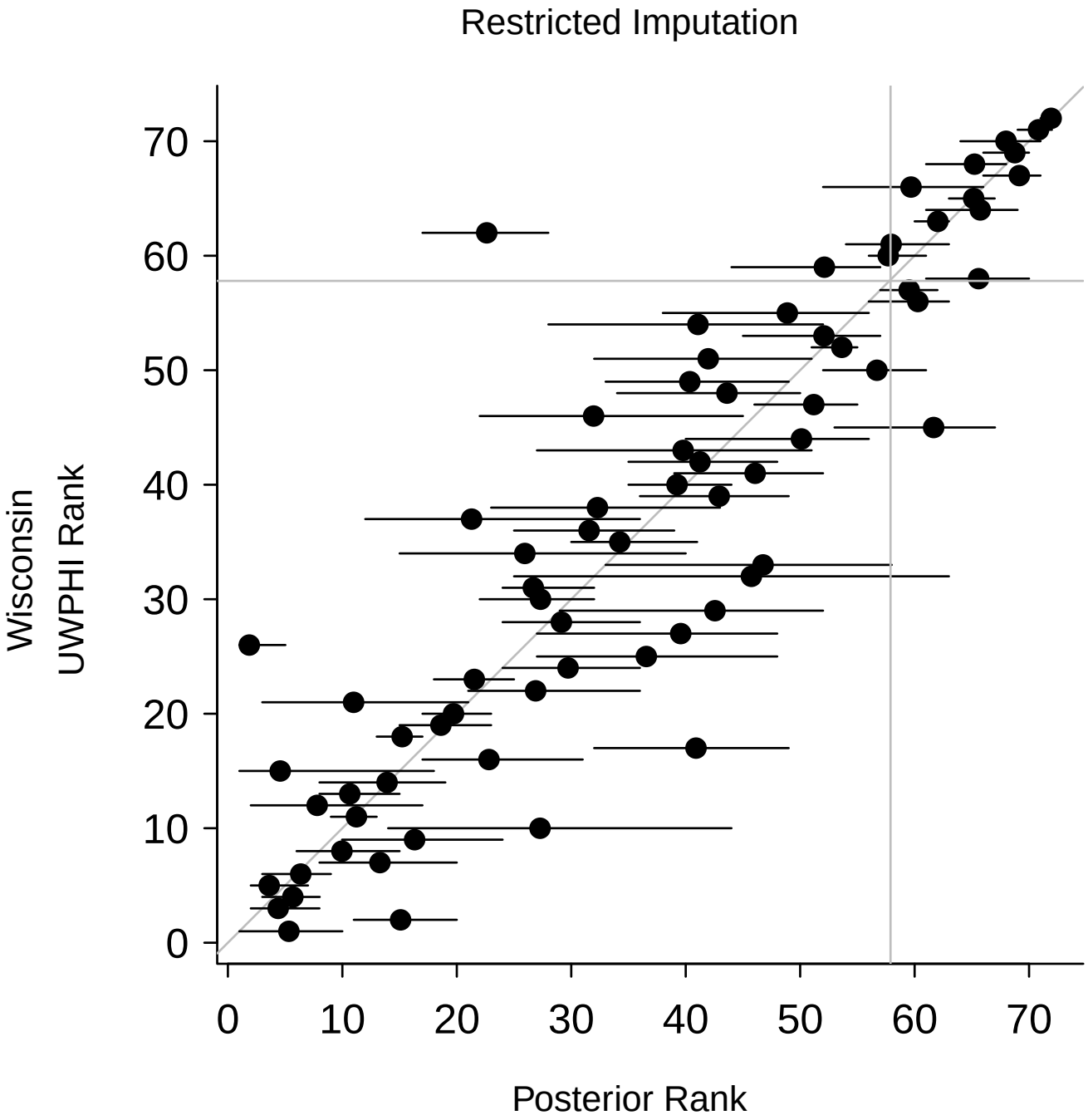
Posterior Rank


Restricted Imputation
Wisconsin
UWPHI Rank
0
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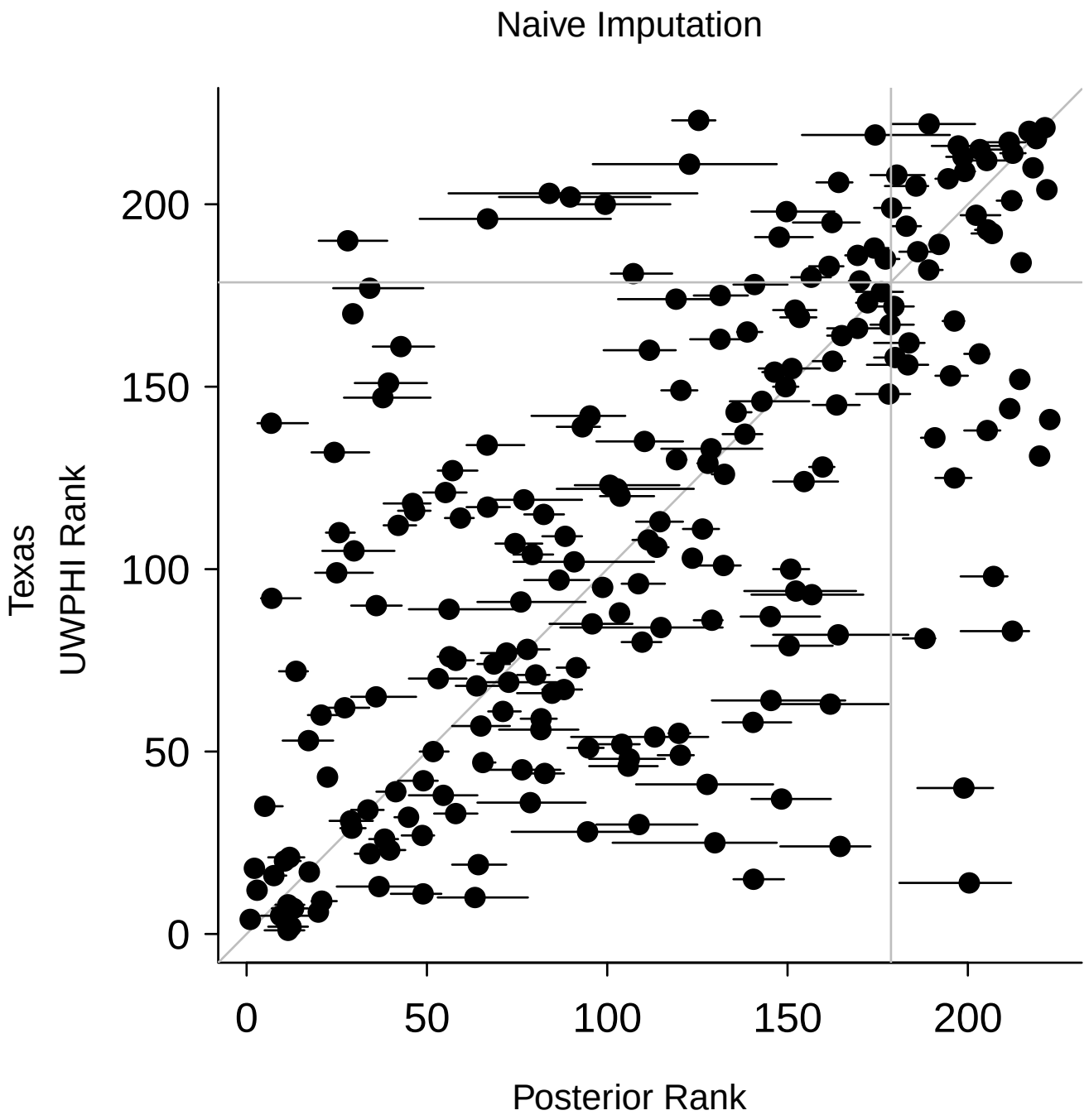
Posterior Rank


Naive Imputation
Texas
UWPHI Rank
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100
150
200
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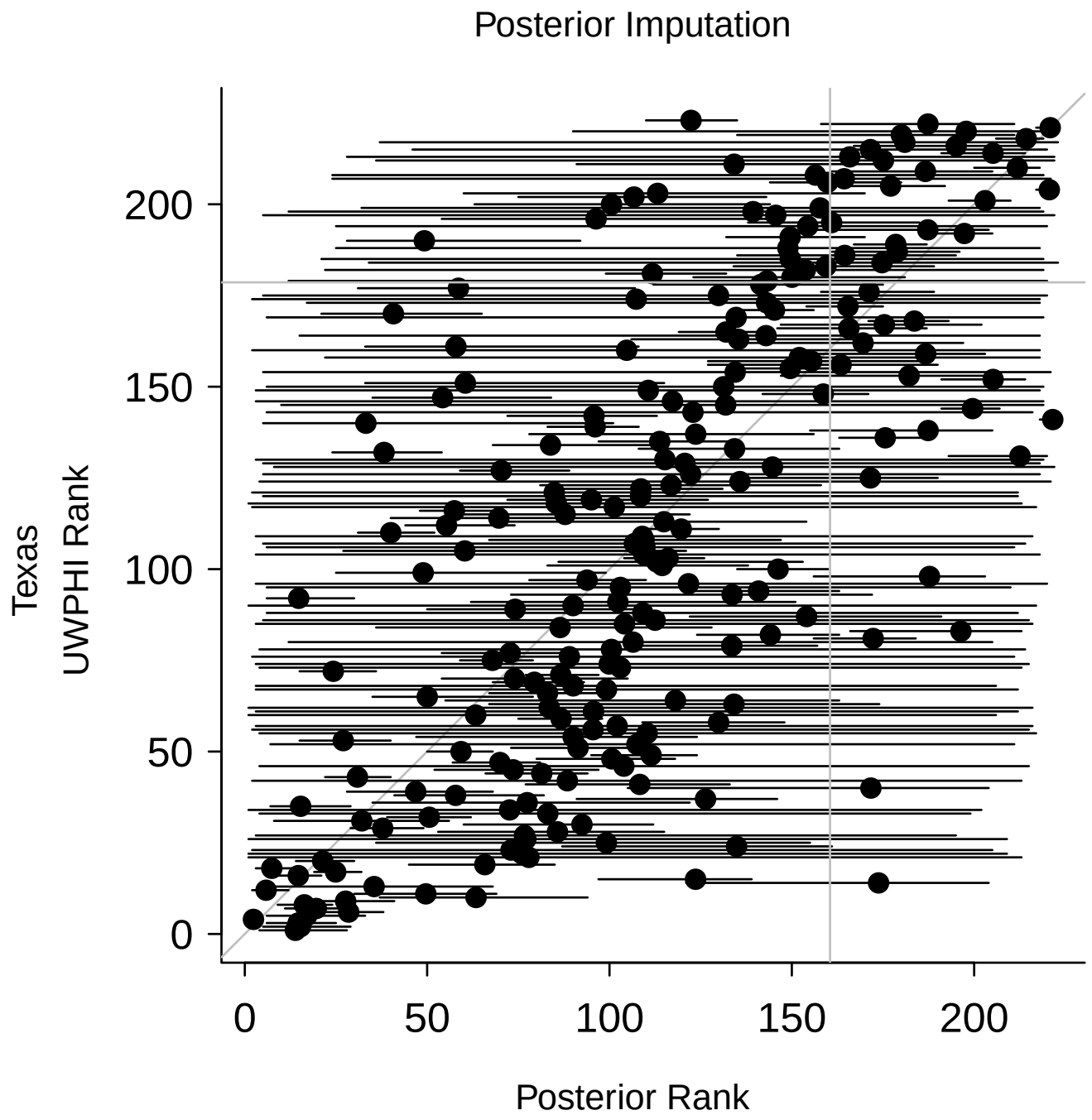
100
150
200
Posterior Rank


Posterior Imputation
Texas
UWPHI Rank
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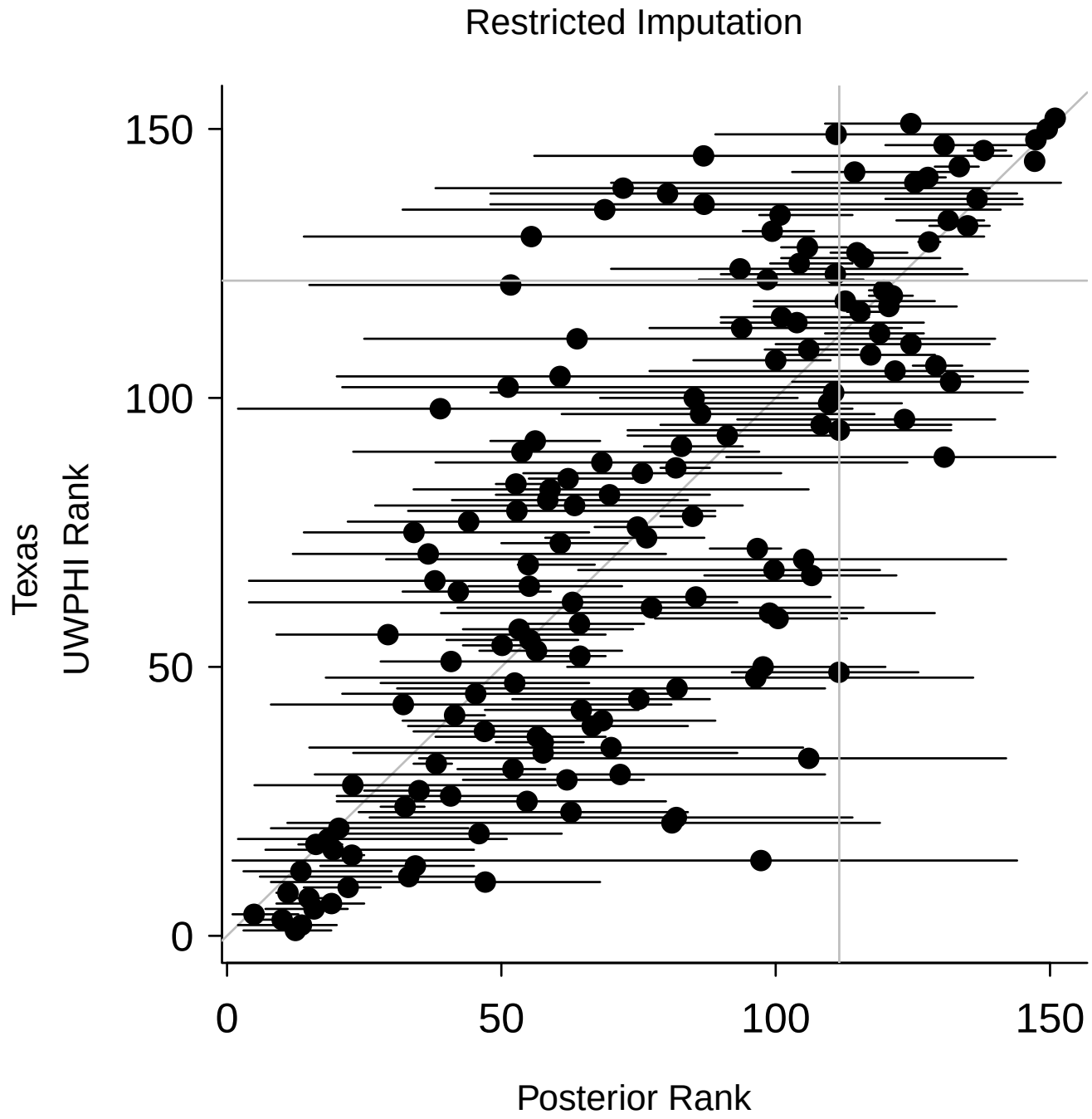
Posterior Rank


Restricted Imputation
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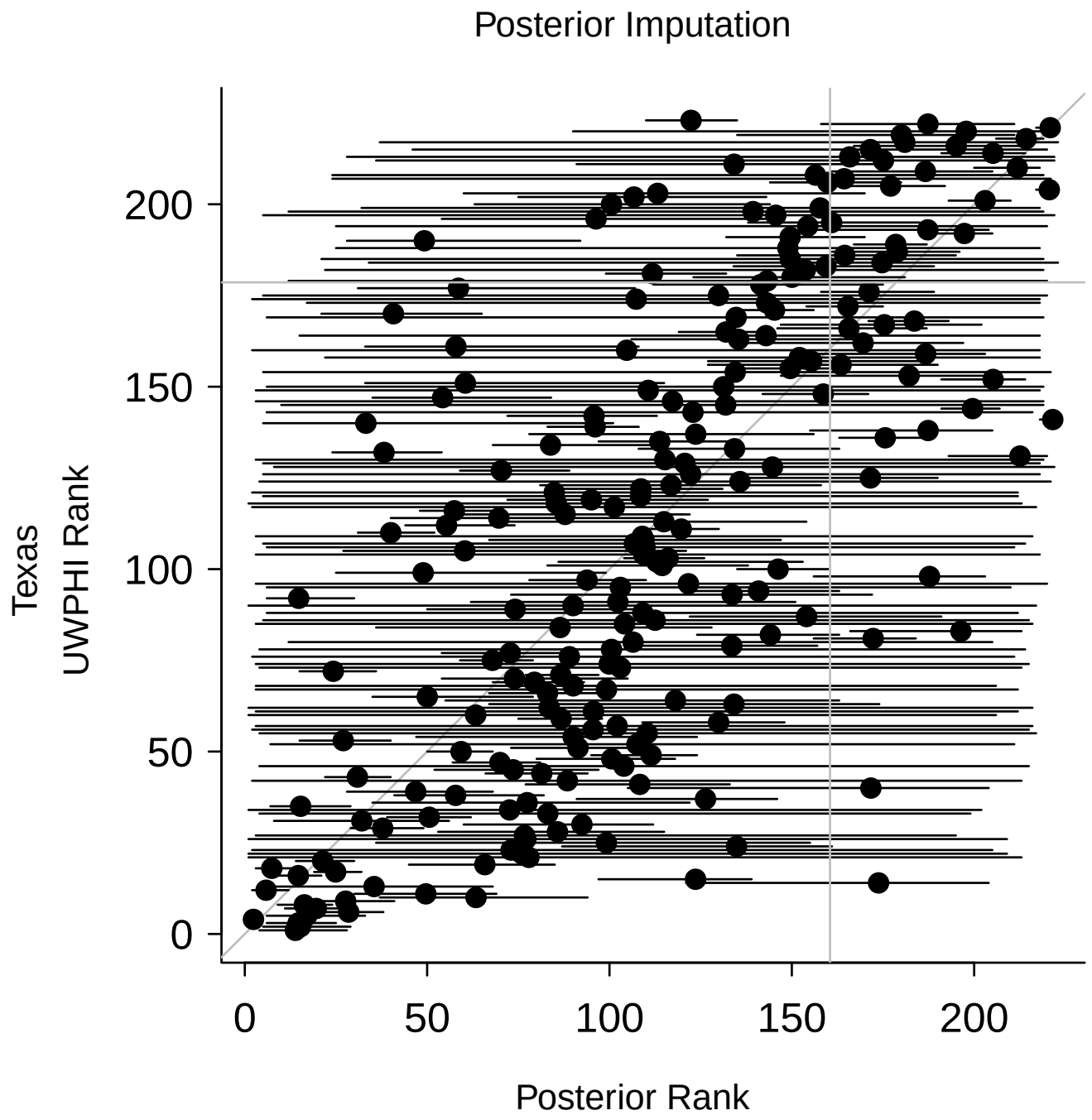
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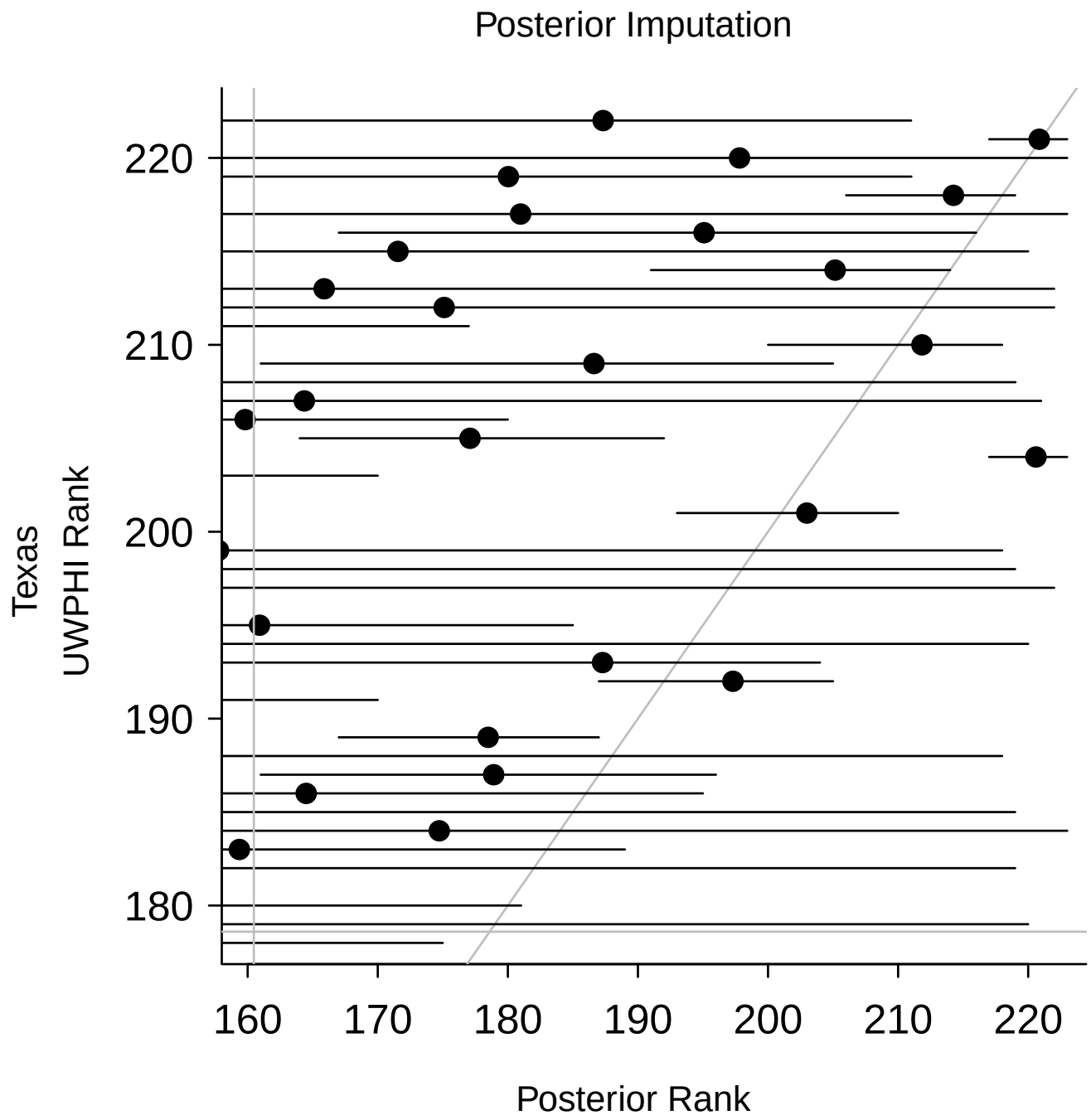
Posterior Imputation
Texas
UWPHI Rank
220
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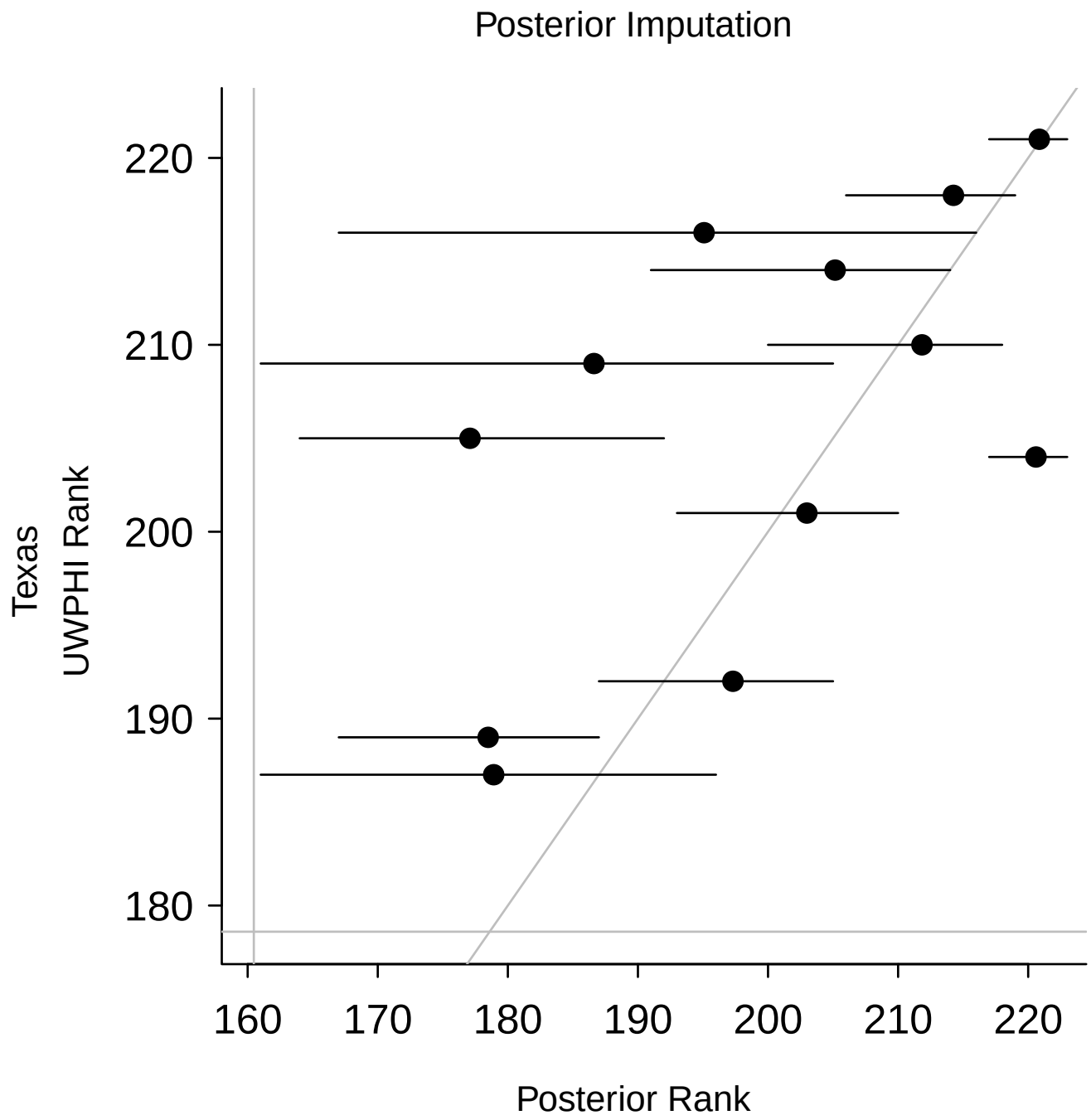
Posterior Rank


Posterior Imputation
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Posterior Rank

Conclusions

- Same data can lead to different rankings
- While there is a lot of agreement in WI we contribute in terms of uncertainty
- In TX we agree on fewer counties
- However, even in TX after accounting for missing data imputation there are a few counties we agree on
- These methods can be used for many other applications

Future Work

- Add other variables - multiple factors
- Should the model be estimated for the entire country or state by state?
- Other applications: quality of cancer care, hospital quality, county childhood obesity rates, etc.
- Investigate reliability of rankings (in the spirit of Arndt et al., 2013)
- Run a horse race between methods

Thank you!