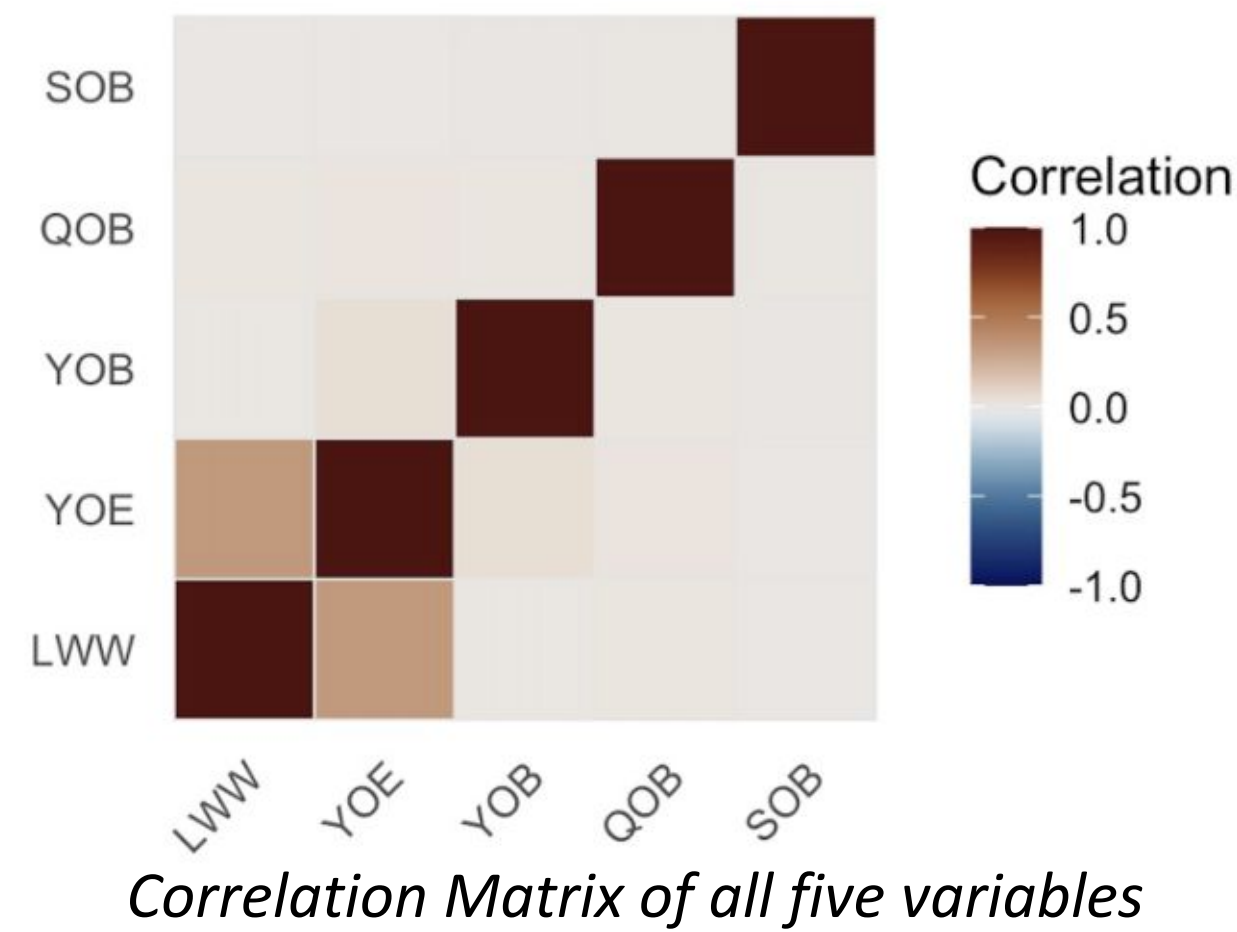


BACKGROUND

This project examines the causal effect of education on earnings using variation in U.S. compulsory schooling laws, which differ across states and determine when students can legally start or leave school. Children born earlier in the year reach the legal dropout age (16 or 17) earlier, being exposed to less education than the ones born later in the year. Assuming that the Quarter of Birth (**QOB**) is random (debatable), it can be adopted as an Instrumental Variable (IV) to estimate the causal effect of Years of Education (**YOE**) on income while controlling confounding from other variables such as State of Birth (**SOB**).

DATA

- Source: 1980 U.S. Census 5% (PUMS)
- 329,509 U.S.-born(1930–1949) men
- Variables: Log Weekly Wage (**LWW**), Years of Education (**YOE**), Quarter of Birth (**QOB**), Year/State of Birth (**YOB/SOB**)
- 5 variables were selected (among 27) to focus on the core IV design
- Identification relies on **QOB as an instrument**



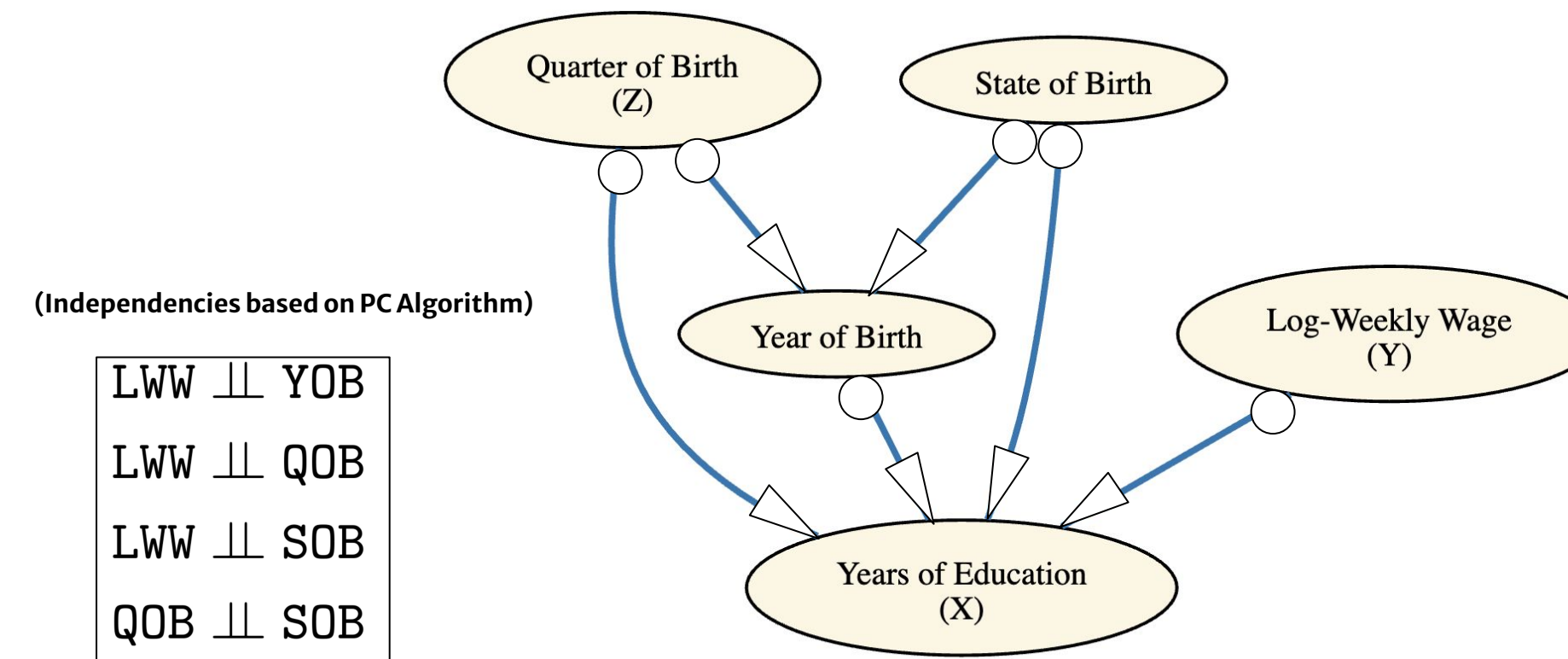
METHODS & RESULTS

Two-Stage Least Squares (TSLS)

- **Assumptions:** OLS + Instrument relevance/Exclusion
- Stage 1: Ordinary Least Squares (OLS) of **YOE** on **QOB**
- Stage 2: OLS of **LWW** on estimates of **YOE** from 1
- Output: Point estimate of the Local Average Treatment Effect (LATE)

Results

- **OLS Slope:** 7%
(average increase in **LWW** for an additional **YOE**, with F-Stat of 36.036 (seemingly "strong"))
- **Local Average Treatment Effect (LATE):** 10.3%



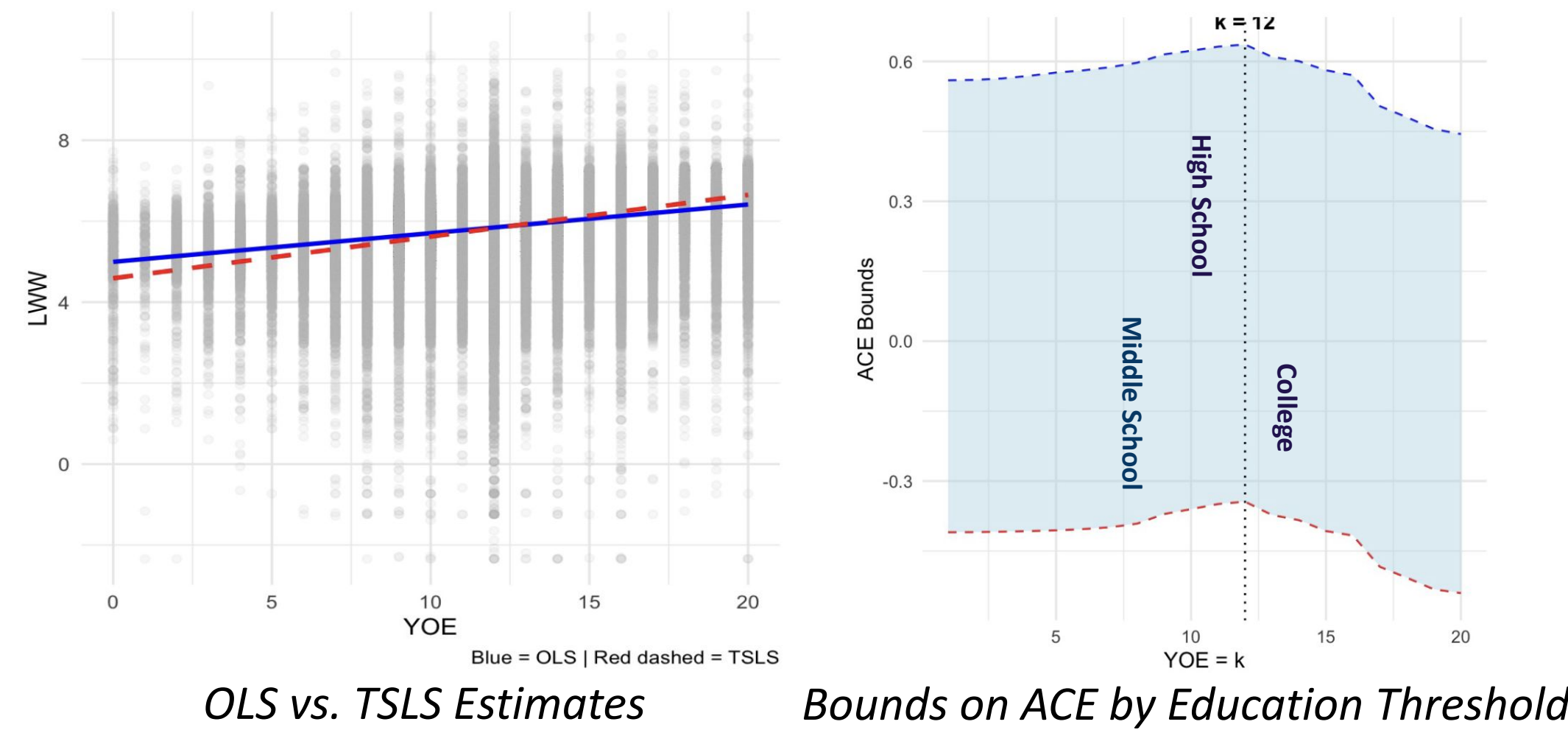
Partial Ancestral Graph (PAG) given by FCI Algorithm

Instrumental Variable (IV) Polytope Bounds

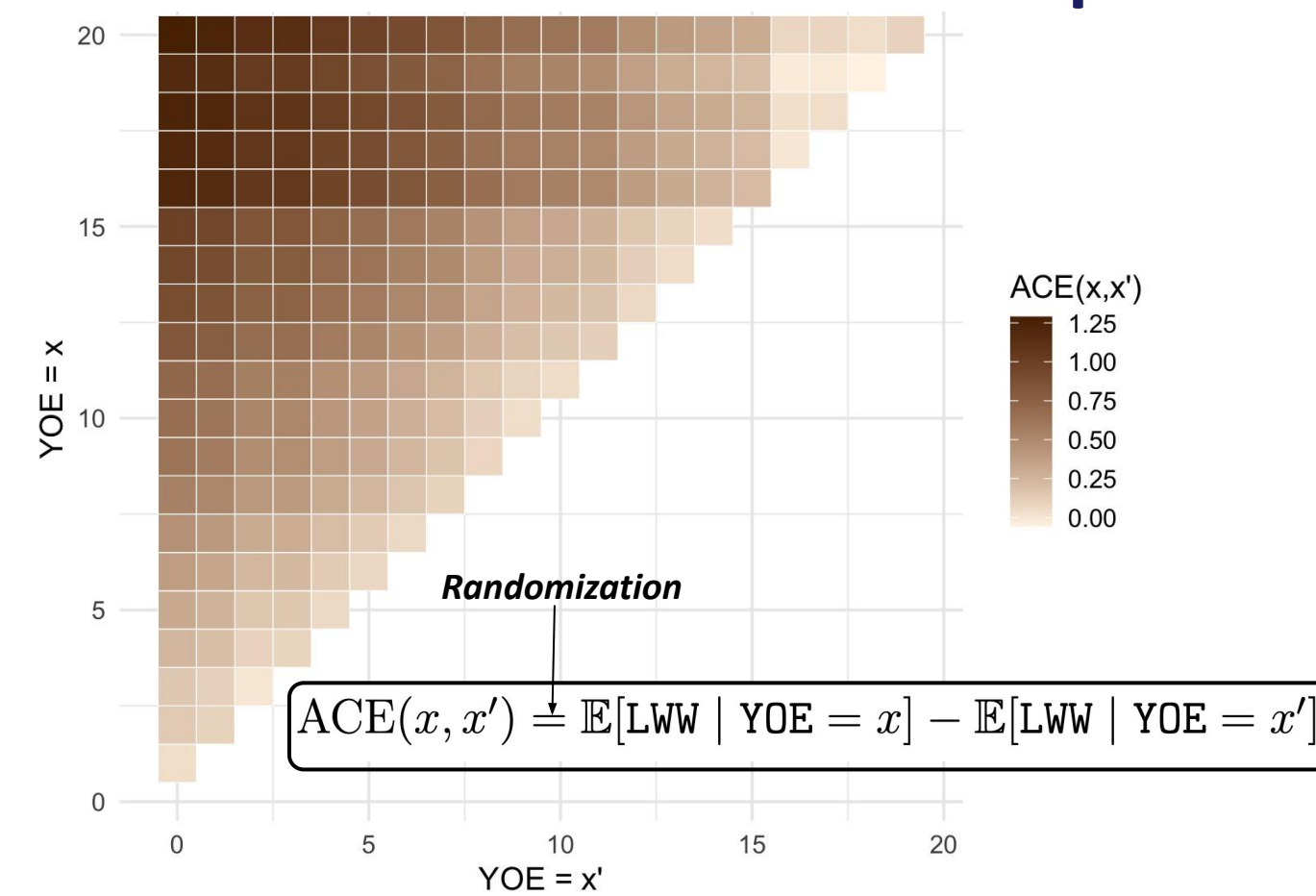
- **Restriction:** Need to Dichotomize **YOE** and **LWW**
 - $YOE \leftarrow \mathbf{1}\{YOE \geq k\}$
 - $LWW \leftarrow \mathbf{1}\{LWW \geq \text{median}(LWW)\}$
- **Assumptions:** Validity of the instrumental variable (IV) inequality constraints
- Output: Bounds on Average Causal Effects (ACE) computed from IV polytope bounds

Results

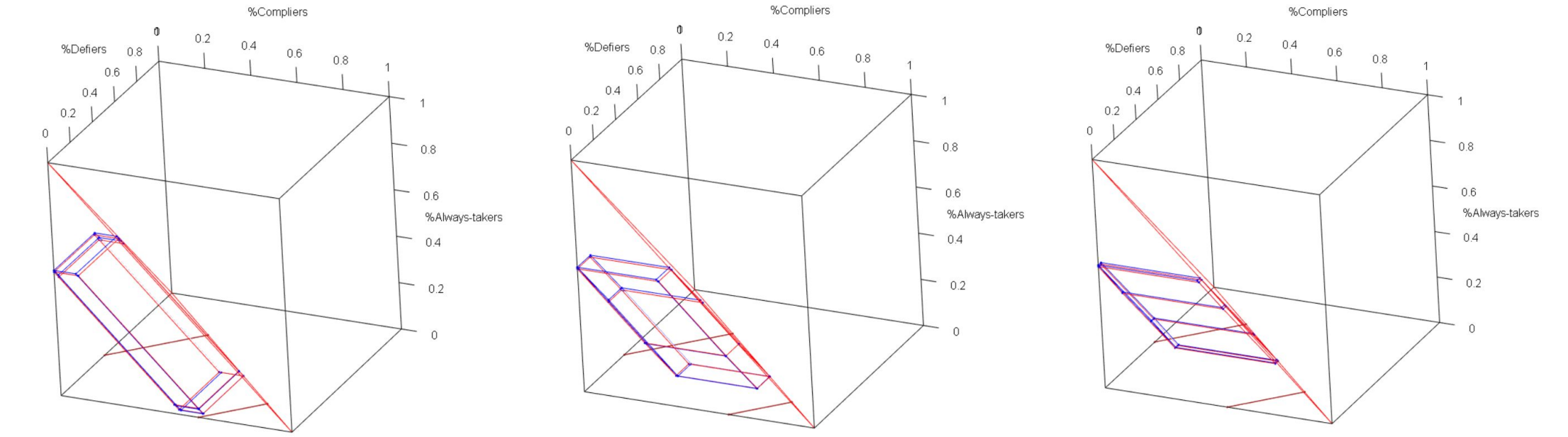
- **ALL bounds contain zero:** Cannot reject null of no causal effect - more uncertainty without parametric assumptions
- **k=12 (high school completion):** maximum positivity



Observation under randomization assumption



Polytopes of YOE, LWW, and QOB (Dichotomized)



Polytopes of k = 9

Polytopes of k = 12

Polytopes of k = 16

CONCLUSIONS

There is a stark contrast between the precise 2SLS point estimate of 10.3% and the wide bounds given by polytopes, which include zero and cannot even determine the sign of the average causal effect (ACE) without additional parametric assumptions.

Methodological Implications

- OLS overconfidence: F-stats alone insufficient for instrument evaluation
- TSLS Dependence Assumption: results heavily depend on linearity assumptions
- Honest uncertainty: ACE bounds show what data actually reveals

Contributions: PC Algorithm and FCI Algorithm Implementation, Parametric (OLS and TSLS) and Non-Parametric (Instrumental Variable Polytope) methods comparison

ACKNOWLEDGEMENTS

We thank Professor Thomas S. Richardson for the guidance and support.

Data: 1980 U.S. Census 5% Public Use Microdata Sample.

REFERENCES

- [1] J. D. Angrist and A. B. Krueger. Does compulsory school attendance affect schooling and earnings?. *The Quarterly Journal of Economics*,
- [2] J. Bound, D. A. Jaeger, and R. M. Baker. Problems with instrumental variables estimation when the correlation between the instruments and the endogenous explanatory variable is weak. *Journal of the American Statistical Association*,
- [3] T. S. Richardson and J. M. Robins. ACE Bounds; SEMs with Equilibrium Conditions. *Statistical Science*,
- [4] T. S. Richardson, Causal Modelling Lecture Slides and Lab Codes (2024), *University of Washington*