Applying propensity score methods to multilevel settings with individual *and* cluster level interventions

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Overview

- Propensity score application under complex multilevel settings
- Two interventions implemented at different levels
- Dealing with multiple potential outcomes
- Separating individual- and cluster-level intervention effects

UC Outreach Program (UCOP)

- Purpose : Make more educationally disadvantaged secondary students to pursue post-secondary education
- Joint Multilevel design, 2-stage selection :
  - Low-performing schools are first selected as UC partner schools.
  - In partner schools, academically promising but economically disadvantaged students are selected to receive EAOP
- School-centered collaborations focus on teacher training and curriculum development (Partner-school program).
- Student-centered services include academic enrichment, information dissemination and motivation (Early Academic Outreach Program)

Questions

- Causal effect of partner school program
- Causal effect of student centered intervention
- Causal effect of overall outreach program
- Conditions for successful schools (between-school variation in intervention effectiveness)

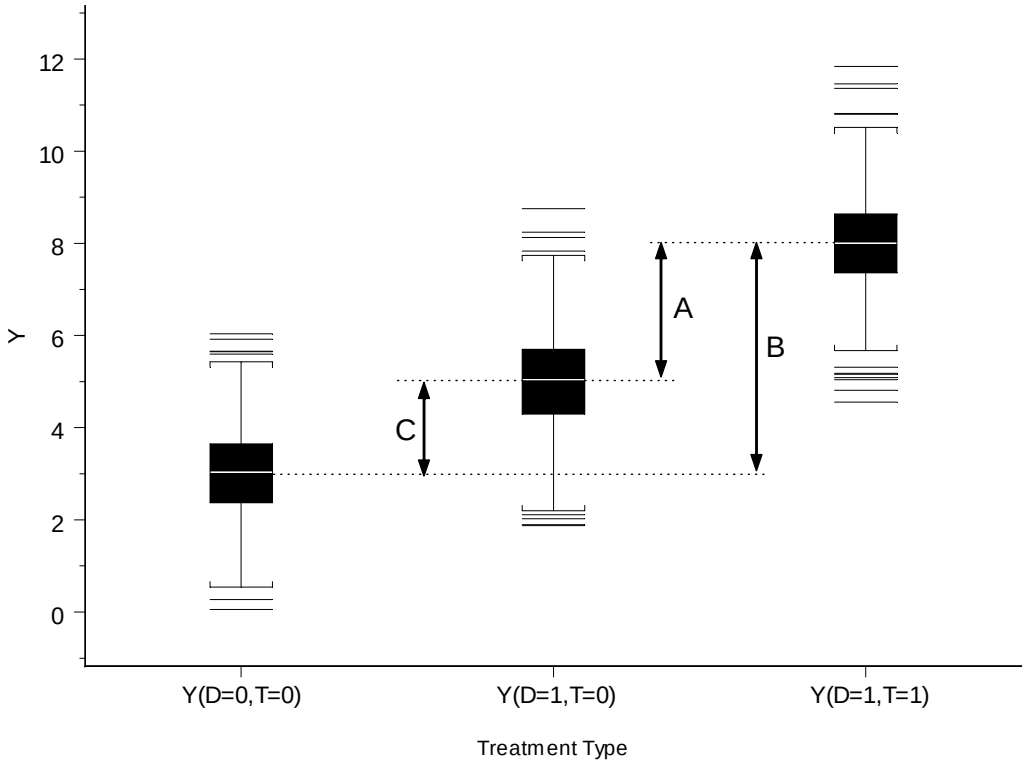
UCOP : Pretreatment differences

	Non-Partner Schools (N=19)	Partner Schools (N=29)		
		Total	Non-EAOP	EAOP
Number of students	6029	17324	15863	1461
% AG eligible at 12th grade	0.16	0.12	0.08	0.51
% Minority	0.67	0.85	0.85	0.86
% Receive free lunch	0.50	0.67	0.66	0.74
Average 9th grade GPA	2.48	2.39	2.29	3.42
School API	579.79	522.72		
Average Household Income	39.05	38.01		

Challenges

- Treatment settings defined by combinations of two indicators (D_j: school , T_{ij}: individual)
- Not a perfect crossed multilevel design
  - (D_j=0, T_{ij}=1) cannot be defined
- Three potential outcomes leads to three causal effects
  - Appropriate propensity scores are not estimable for all causal questions

Causal effects with three potential outcomes



- A: $Y(D_j=1, T_{ij}=1) - Y(D_j=1, T_{ij}=0)$
  Individual level intervention effect
- B: $Y(D_j=1, T_{ij}=1) - Y(D_j=0, T_{ij}=0)$
  Individual and cluster level intervention effect
- C: $Y(D_j=1, T_{ij}=0) - Y(D_j=0, T_{ij}=0)$
  Cluster level intervention effect

Intervention effect A :
Effect of EAOP in Partner Schools

- Y(D=1,T=1) vs. Y(D=1,T=0)
- Student level intervention effect only
- May be biased under intervention (EAOP) diffusion (underestimation)
- Proper propensity score : prob(T=1|D=1)
- A Crossed multilevel design -> students may have different propensity score depending on schools they are attending
- Within school matching

Intervention effect B : Effect of partner school program and individual intervention

- Y(D=1,T=1) vs. Y(D=0,T=0)
- Student-level plus school-level intervention effect
- Proper propensity score : p(T=1,D=1)=p(T=1|D=1)*p(D=1)
- p(T=1|D=1) is not estimable for students in non-partner schools: out-of-sample extrapolation or direct matching?
- Matching based on student characteristics and inverse-probability weighting at school level

Intervention effect C : Effect of partner school program for those who did not receive EAOP

- Y(D=1,T=0) vs. Y(D=0,T=0)
- School-level intervention effect only, possibly biased under the presence of EAOP effect diffusion (overestimation)
- Proper propensity score : $p(T=0,D=1)=(1-p(T=1|D=1))*p(D=1)$
- $p(T=1|D=1)$ is not estimable for students in non-partner schools: out-of-sample extrapolation or direct matching?
- Matching based on student characteristics and inverse-probability weighting at school level

Achieving balance across three treatment settings

- Estimate p(T=1|D=1) for partner school students
- In each partner school, match EAOP recipients with non-EAOP (within school matching)
- p(T=1|D=1) cannot be estimated for non-partner school students -> direct matching with EAOP recipients
- Partner school and non partner schools are still different -> Estimate p(D=1) for each school and use inverse-probability weighting

RIS Propensity Model for p(T=1|D=1)

$$logit(EAOP = 1) = \beta_{0j} + \sum_{p=1}^{P} \beta_{pj} X_{pij},$$

$$\beta_{pj} = \gamma_{p0} + \sum_{q=1}^{Q} \gamma_{pq} W_{qj} + u_{pj}, \quad for \ p = 0,1,\cdots,P.$$

- More chances for students with high academic performance, lower SES and URM
- Slopes as well as intercepts vary significantly across schools
- Between-level interaction (e.g., URM's are more likely to receive EAOP in schools with high API)
- Matching based on estimated propensity score within each school

Effect A: Checking the balance after matching

$$X_{ij} = \beta_{0j} + \beta_{1j}(EAOP)_{ij} + r_{ij}, \quad r_{ij} \sim N(0, \sigma^2)$$

$$\beta_{0j} = \gamma_{00} + u_{0j}, \quad \beta_{1j} = \gamma_{10} + u_{1j},$$

$$\begin{pmatrix} u_{0j} \\ u_{1j} \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \tau_{00} & \tau_{01} \\ \tau_{10} & \tau_{11} \end{pmatrix}\right)$$

Variable	γ_{10}	**SD** ($\sqrt{\tau_{11}}$)
Hispanic	**0.022**	**0.007**
GPA9	**-0.008**	**0.005**

School-level propensity model for inverse-probability weighting (p(D=1)) : Effect B and C

- Propensity score model suggests that large schools and low performing schools are more likely to be partner schools
- With matched student sample, p(D=1) is used for inverse-probability weighting at school level

	Partner	Non-Partner	Before Adjustment		After Adjustment	
			Diff.	Sig.	Diff.	Sig.
Total Enrollment	3425.31	2267.63	1157.68	0.00	18.30	0.93
School API	522.72	579.79	-57.07	0.04	9.96	0.74
Std/Teacher Ratio	24.47	22.93	1.55	0.11	0.38	0.75
% Minority	0.81	0.69	0.12	0.04	-0.02	0.81
Average 9th Grade GPA	2.40	2.52	-0.12	0.03	0.00	0.99

Effect A: The Effect of EAOP on A-G Eligibility

Modeling Potential Outcomes

$$\eta_{ij}^{0} = \gamma + u_{j}$$

$$\eta_{ij}^{1} = \gamma + u_{j} + \delta_{T} + u_{j,\delta_T}$$

Translation into random effects model

$$\eta_{ij} = \beta_{0j} + \beta_{1j}(EAOP)_{ij} + \gamma_{20}(logit(p))_{ij},$$

$$\beta_{0j} = \gamma_{00} + u_{0j}, \quad \beta_{1j} = \gamma_{10} + u_{1j},$$

Effect A : Y(D=1, T=1) – Y(D=1, T=0)
EAOP recipients vs. non recipients in partner schools

	Mean	SD	95% interval	
Adjusted average probability of being A-G eligible				
Non-EAOP	**0.242**	**0.037**	**(0.172,**	**0.320)**
EAOP	**0.436**	**0.033**	**(0.370,**	**0.502)**
Difference	**0.194**	**0.031**	**(0.131,**	**0.255)**
Odds ratio	**2.478**	**0.411**	**(1.785,**	**3.401)**
Between school variation	**Mean**	**2.5%**	**Median**	**97.5%**
A-G eligibility under control (τ_{00})	**0.953**	**0.423**	**0.877**	**1.926**
EAOP effect on eligibility (τ_{11})	**0.133**	**0.011**	**0.112**	**0.377**

Effect A: Summary

- Under RIS selection process, omitting random effects in propensity score leads to misleading match
- Assignment to EAOP improves students' chance to be A-G eligible by about 19 % point on average (2.4 times increased odds)
- EAOP effect tends to increase in schools serving more free lunch students

Effect B and C: Potential outcomes models and treatment effect estimation with HM

- Modeling Potential Outcomes

$$\eta_{ij}^{0} = \gamma_{00} + u_{j.C}$$

$$\eta_{ij}^{1} = \gamma_{00} + \delta + u_{j.C} + u_{j.\delta}$$

- Translation into random effects model

$$\eta_{ij} = \beta_{0j} + \sum_{k=1}^{K} \gamma_{k0} X_{kij},$$

$$\beta_{0j} = \gamma_{00} + \gamma_{10}(PARTNER)_j + u_{0j}$$

Effect B : Y(D=1, T=1) – Y(D=0, T=0)

EAOP recipients vs. non-partner school students

	Mean	SD	95% interval
Adjusted average probability of being A-G eligible			
Non-partner school students	**0.240**	**0.024**	**(0.195, 0.288)**
Partner school, EAOP	**0.398**	**0.029**	**(0.340, 0.454)**
Difference	**0.158**	**0.037**	**(0.085, 0.230)**
Odds ratio	**2.135**		**(1.487, 2.974)**

Effect C : Y(D=1, T=0) - Y(D=0, T=0)
EAOP non-recipients vs. non-partner school students

	Mean	SD	95% interval
Adjusted average probability of being A-G eligible			
Non-partner school students	**0.248**	**0.027**	**(0.197, 0.304)**
Partner school, Non-EAOP	**0.217**	**0.022**	**(0.175, 0.263)**
Difference	**-0.031**	**0.034**	**(-0.099, 0.036)**
Odds ratio	**0.854**		**(0.578, 1.225)**

Effect B and C : Summary

- Attending partner schools *and* receiving EAOP services increase students' A-G eligibility about 15% when compared to non-partner school attendance
- Simply attending partner schools but not receiving EAOP services does not affect students' eligibility compared to attending non-partner schools.
- Non-significant estimate of effect C implies no EAOP effect diffusion

Implications

- Methodology for addressing various causal questions that can arise in multilevel settings
- Attending to selection process informs administrative decisions: For whom we need to increase access? Where to put more resources?
- Studying variation in treatment effects is important for decisions regarding revision / improvement of program.
- Principal stratification can be a tool to identify subgroups of subjects for whom the treatment is needed most