**Analysis Assignment (ITT / IV / Gain Scores / DiD / ANCOVA)**

Deadline for submission: *Monday, March 27*  
Max of *7pts*

**Background – Summer Math Camp Example: RCT with noncompliance**

In an effort to evaluate the effect of attending summer math camps on student math achievement, researchers randomly assigned/encouraged 1000 students to attend a math camp or an alternative (non-math related) camp of student’s choice. Since random assignment was performed at the student level across 50 schools rather than randomly assigning schools to the treatment conditions, the clustered data-structure (i.e., students nested within schools) does not need to be considered. However, if random assignment were blocked by schools, we would need to include the corresponding school fixed or random effects. But here we assume that randomization was implemented without blocking by school.

There was considerable non-compliance with the assigned treatment/control conditions. The causal graph shows the presumed data-generating process, including the observed variables. Researchers presumed that noncompliance was mostly driven by students’ (math) ability, their math anxiety, and their (dis)liking of math (summarized by the unobserved variable *A* in the graph).



The observed variables in the graph and data set (math\_camp\_RCT.csv) are:

**R** … randomization outcome (1 … summer math camp, 0 alternative summer camp)

**T** … treatment received (1 … math camp, 0 alternative camp)

**P** … math pretest measure (standardized with mean of 500 and SD of 100)

**SES** … socioeconomic status – standardized variable computed from unreliable   
 measurements of parents’ years of education (*E*\*) and income (*I*\*).   
 *E* and *I* are the true but unknown education and income variables that   
 affect the pretest and posttest.

**Y** … math posttest measure (standardized with mean of 500 and SD of 100)

If you use R, you can read the data using dat <- read.csv('math\_camp\_RCT.csv')

**Initial Data Analysis**

Before you estimate any treatment effects, check the following:

1. Did randomization (**R**) resulted in comparable (i.e. balanced) groups with respect to the baseline measures **P** and **SES**? That is, assess whether group means (and variances) of **P** and **SES** differ across the randomized groups. Also plot the distributions (histograms) by group.

It did, randomization (R) resulted in comparable groups with respect to the baseline measures P and SES. As can be seen in the following graphs, both distributions are very alike respect to the baseline measures.

Gráfico, Gráfico de líneas, Histograma

Descripción generada automáticamenteGráfico, Gráfico de líneas

Descripción generada automáticamente

1. What is the extend of noncompliance? What percentage of students in the treatment group did not show up, and how many students in the control group crossed over to the math camp condition?

The noncompliance rate is 22.6%, because there are 7 *always takers* and 219 *never takers*. Also, 219 (44%) of the students in the treatment group did not show up, and 7 (1.38%) students in the control group crossed over to the math camp condition (*always takers*).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | | Treatment received (T) | | Total |
| Alternative camp | Math camp |
| Randomization outcome (R) | Alternative camp | 497  (98.61%) | 7  (1.38%) | 504  (100%) |
| Math camp | 219  (44.15%) | 277  (55.84%) | 496  (100%) |

1. Did noncompliance result in imbalanced treatment and control groups (**T**) with respect to baseline distributions of **P** and **SES**? Do the same as in (a) but now use treatment received (**T**) instead of treatment assignment (**R**) as grouping variable.

More or less. As you can see from the graphs below, noncompliance regarding the treatment received resulted in imbalanced treatment and control groups with respect to the math pretest measure (P). However, it seems that SES balance is correct, according to the p-value.

Chart, histogram

Description automatically generated

**Estimate the Summer Math Camp Effect on Math Achievement**

Estimate *treatment effects* and corresponding *standard errors* using the following analyses:

1. Treatment-as-received analysis
2. Per-protocol analysis (i.e., analysis of the subgroup of participants who received the treatment/control condition as indicated by randomization, i.e., **R** = **T**)
3. Intent-to-treat analysis
4. Instrumental variable (IV) analysis   
   (using 2SLS and random assignment **R** as instrument)
5. Gain score analysis (with the *wide format* of the data)
6. Difference-in-Differences (DiD) analysis with
   1. Student fixed effects (fixed effects model) or
   2. Student random effects (random effects model)

(you need to transform the data into *long format*)

1. ANCOVA/regression analysis (with the pretest **P** as covariate)

For each analysis, decide whether you want to include additional covariates (i.e., **P** and/or **SES**). You should have a clear rationale for including additional covariates—either with regard to removing confounding bias or increasing efficiency (i.e., obtaining smaller standard errors).

**Write-up / Reporting**

Complete the two tables below and *explicitly highlight* the two analyses you find most credible for causal inference given the data. You may use any statistical analysis package of your choice.  
(Notes. With regard to gain scores / DiD, you only need to do/report one analysis, either from the gain score, fixed or random effects model (but you might try all of those analyses). Writing the model equations may be challenging, but just try it. In writing the equations use the variable names as give above. You don’t need to provide any R code or results from the Initial Data Analysis steps.)   
*Reading assignment*: Sections 7.4, 7.5 & 7.6 of Reichardt’s textbook (no write-up needed).

**Table 1. Causal Estimands, Assumptions, and Estimates**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Analysis** | **Causal Estimand** | **Causal Assumptions** (that must be met to identify the causal estimand) | **Assumpts. Met?** (yes/ maybe/ no) | **Estimate** (Standard Error) |
| (1) Treatment-  as-received | ATE | SUTVA No systematic noncompliance (i.e., no open confounding path between *T* and *Y*) | No | 94.88 (6.4) |
| (2) Per-protocol | ATE for per-prot. subpop. | SUTVA  No systematic noncompliance (i.e., no open confounding path between *T* and *Y*) | No | 76.2 (6.9) |
| (3) Intent-to-  Treat | ITT | SUTVA, no confounders | Yes | 16.6  (6.35) |
| (4) IV | CATE | SUTVA  Valid Instrument (Exclusion restriction, first-stage condition)  Monotonicity/ no-defiers assumption | Maybe | 28.42  (6.58) |
| (5) Gain Scores | ATT | SUTVA  Common Trend Assumption | Maybe | 25.86  (4.37) |
| (6) DiD | ATT | SUTVA  Common Trend Assumption | Maybe | 25.86  (4.37) |
| (7) ANCOVA/  regression | ATE | SUTVA  Linearity  Unconfoundedness  No systematic noncompliance | No | 46.24  (4.18) |

**Table 2. Model Equations**

|  |  |
| --- | --- |
| **Analysis** | **Model Equation1** |
| (1) Treatment-as-received | (with being the treatment effect) |
| (2) Per-protocol | for subpopulation with |
| (3) Intent-to-Treat |  |
| (4) IV (via 2SLS) | First stage: 🡪 T on R  Second stage: 🡪 Y on predicted values from the first stage) |
| (5) Gain Scores |  |
| (6) DiD |  |
| (7) ANCOVA/regression |  |