The Impact of Computer-Based Tutorials on High School Math Proficiency

Federal Reserve Bank of Dallas: Intent vs. Impact

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Background & Motivation

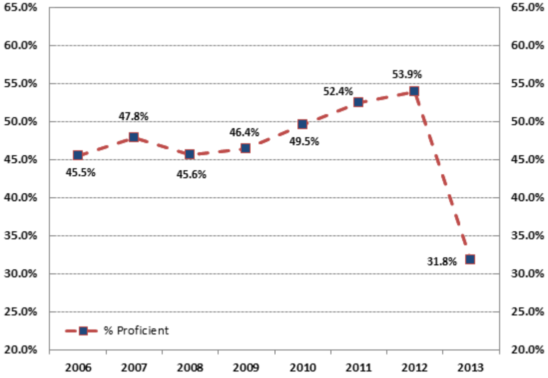
- Benefits of mathematical skills are widely documented in the economics and education literature
  - Success in higher education (Duncan & Magnuson 2013)
  - Labor market outcomes (Heckman et al. 2006)
  - Financial literacy skills (Lusardi et al. 2010)
  - Broad economic growth (Hanushek et al. 2008)

Background & Motivation

- Even in light of these benefits, math proficiency levels remain low amongst U.S. high school students
  - 2005 $\rightarrow$ 23% proficient
  - 2009 $\rightarrow$ 26% proficient
  - 2013 $\rightarrow$ 26% proficient

Background & Motivation

- Specifically in Clark County, NV (math proficiency for 10th graders)



Source: Clark Country School District

Background & Motivation

- Over the 2005/06 school year, the Clark County School District (CCSD) provided access to the *Succeed in Math*® (SCIM) computer-based tutorial to high school students
- The tutorial was made available prior to taking the state math proficiency exam over the 2006/07 school year

Research Question: Did the computer-based tutorial have any impact on increasing math proficiency rates over the 2006/07 school year?

Literature on Computer-Aided Tutorials

- The majority of existing work focuses on computer-based tutorials as effective instructional methods *in* the classroom *during school hours*
  - Results are mixed as measured by increasing standardized test scores (Campuzano et al. 2009; WWC Intervention Report, Dept. of Education 2013; Kulik & Fletcher 2015)
- Lai et al. (2015) implement an RCT in Beijing looking at computer-assisted learning in an *out of school hours* context
  - Found positive and statistically significant results on standardized math scores
- We further contribute to the literature by evaluating students who interacted with computer-aided tutorials as a complement to traditional, in classroom instruction

Data

- Data provided by CCSD covering the 2006/2007 school year for 10th and 11th graders
  - Sample restricted to those who only took the exam once
  - Treatment group restricted to individuals who spent a positive amount of time in the tutorial
    - ★ 2,989 students selected into the treatment, but were deemed proficient at the onset and asked *not* to continue (more on this)
- Final sample size: 16,219
  - 15,360 10th graders
  - 859 11th graders
- Information on treatment uptake, indicator for proficiency on the state math exam, and *some* observable student/household characteristics

Data

Table 1: Summary Statistics

	Full Sample		Tutorial Participants		Non-Tutorial Participants	
Variable	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Proficient on State Math Exam (1 = proficient)	0.515	0.500	0.561	0.497	0.512	0.500
White (1 = yes)	0.406	0.491	0.401	0.490	0.406	0.491
Black (1 = yes)	0.139	0.346	0.157	0.364	0.138	0.344
Hispanic (1 = yes)	0.340	0.474	0.300	0.458	0.342	0.474
Gender (1 = female)	0.515	0.499	0.615	0.486	0.509	0.500
Proficient in English (1 = yes)	0.770	0.500	0.786	0.410	0.769	0.421
English Language Learner (1 = yes)	0.091	0.288	0.069	0.254	0.092	0.289
Gifted and Talented (1 = yes)	0.142	0.349	0.098	0.298	0.145	0.352
10th Grader (1 = yes)	0.947	0.224	0.772	0.420	0.957	0.202

Note: N = 16,219 for the full sample; of this, 908 are tutorial participants and 15,311 are non-participants.

Some Problems

- Observable characteristics that we would like to have are not available
  - HH income, parental education, HH structure, etc.
  - Model will be underidentified
- Non-random selection into the treatment group along the dimension of unobservable characteristics
- Given the above, the CIA assumption fails $\longrightarrow$ estimating causal effects becomes difficult
  - Typically rely on IV methods $\longrightarrow$ requires a valid exclusion restriction
  - A valid instrument is not available in this case

Empirical Methods

- Minimum-Biased approach (MB) proposed by Millimet & Tchernis (JAE, 2013); coded in Stata (see McCarthy et al. 2014; - *bmte -)*
  - Extension of Hirano & Imbens (2001) Inverse Probability Weighted (IPW) estimator
  - When the CIA holds, IPW yields an unbiased estimates of the treatment effects; estimates are biased when CIA fails
- MB estimator trims the estimation sample using observations with a propensity score in some neighborhood around the BMPS, P^*
  - Bias is minimized at the expense of changing the parameter being estimated
  - Needs to be interpreted with respect to the value of P^* (which may be uninteresting)

Empirical Methods

- In our case, the model is underidentified and treatment equation exhibits homoskedasticity (fail to reject null of homoskedasticity at conventional levels)
  - Millimet & Tchernis (2013) → MB-EE estimator (where EE denotes Edgeworth expansion)
- Estimate the model for full sample and for various demographic groups
- Re-estimate the model coding those who selected into the treatment, but asked not to continue, as the control group
  - These students were asked *not* to continue given exogenous proficiency standards set by the state
  - Control and treatment groups may be more homogeneous across unobservables

Results

Full sample

Table 2a: Impact of Math Tutorial, Full Sample

	ATE	ATT
IPW	0.118	0.121
	[0.089, 0.145]	[0.095, 0.147]
MB - EE		
θ = 0.05	0.114	0.131
	[0.057, 0.186]	[0.078, 0.169]
θ = 0.25	0.139	0.131
	[0.086, 0.182]	[0.097, 0.168]
P* - EE	0.188	0.250
	[0.020, 0.654]	[0.094, 0.438]

Note: Treatment is defined as spending any positive amount of time in the tutorial module; 95% empirical confidence intervals in brackets obtained using 250 bootstrap repetitions.

Results

Minority students compared to white students

Table 2b: Impact of Math Tutorial, Minority Students

	ATE	ATT
IPW	0.147	0.143
	[0.101, 0.191]	[0.101, 0.181]
MB - EE		
θ = 0.05	0.091	0.101
	[0.011, 0.223]	[0.007, 0.184]
θ = 0.25	0.173	0.170
	[0.065, 0.245]	[0.100, 0.215]
P* - EE	0.188	0.222
	[0.020, 0.861]	[0.094, 0.466]

Note: Treatment is defined as spending any positive amount of time in the tutorial module; 95% empirical confidence intervals in brackets obtained using 250 bootstrap repetitions.

Table 2c: Impact of Math Tutorial, White Students

	ATE	ATT
IPW	0.044	0.069
	[0.006, 0.086]	[0.027, 0.113]
MB - EE		
θ = 0.05	0.073	0.092
	[-0.095, 0.132]	[0.026, 0.154]
θ = 0.25	0.073	0.092
	[-0.003, 0.130]	[0.027, 0.151]
P* - EE	0.259	0.343
	[0.020, 0.886]	[0.071, 0.679]

Note: Treatment is defined as spending any positive amount of time in the tutorial module; 95% empirical confidence intervals in brackets obtained using 250 bootstrap repetitions.

Results

Female students compared to male students

Table 2d: Impact of Math Tutorial, Female Students

	ATE	ATT
IPW	0.132	0.122
	[0.085, 0.167]	[0.081, 0.153]
MB - EE		
θ = 0.05	0.326	0.09
	[0.036, 0.389]	[0.017, 0.172]
θ = 0.25	0.135	0.111
	[0.087, 0.182]	[0.079, 0.18]
P* - EE	0.020	0.766
	[0.020, 0.506]	[0.289, 0.859]

Note: Treatment is defined as spending any positive amount of time in the tutorial module; 95% empirical confidence intervals in brackets obtained using 250 bootstrap repetitions.

Table 2e: Impact of Math Tutorial, Male Students

	ATE	ATT
IPW	0.104	0.118
	[0.052, 0.147]	[0.071, 0.163]
MB - EE		
θ = 0.05	0.114	0.126
	[-0.043, 0.171]	[0.075, 0.183]
θ = 0.25	0.113	0.126
	[0.062, 0.164]	[0.079, 0.179]
P* - EE	0.828	0.718
	[0.020, 0.886]	[0.228, 0.793]

Note: Treatment is defined as spending any positive amount of time in the tutorial module; 95% empirical confidence intervals in brackets obtained using 250 bootstrap repetitions.

Results

"Treatment" subsample

Table 3: Impact of Math Tutorial, "Treatment" Subsample

	ATE	ATT
IPW	0.052	0.056
	[0.024, 0.080]	[0.027, 0.084]
MB - EE		
θ = 0.05	0.024	0.024
	[-0.072, 0.144]	[-0.043, 0.137]
θ = 0.25	0.071	0.071
	[0.015, 0.117]	[0.020, 0.114]
P* - EE	0.925	0.514
	[0.032, 0.979]	[0.411, 0.809]

Note: Control group is now defined as those students who selected into treatment, but were asked not to continue; treatment is still defined as spending any positive amount of time in the tutorial module; 95% empirical confidence intervals in brackets obtained using 250 bootstrap repetitions.

In Summary

- Conditional of having a relatively mid to high rank in the estimated propensity score distribution of participation in the SCIM tutorial, we find evidence of a statistically positive causal effect for the average $10^{th}/11^{th}$ grader in CCSD
- Assuming these impacts can be applied across the entire distribution of estimated propensity scores and are in fact causal:
  - 1,849 (1,151) additional $10^{th}/11^{th}$ grade students would have passed the state proficiency exam over the 2006/2007 school year
  - 119 (64) students in the treatment group would *not* have passed the state proficiency exam had they not participated over the 2006/2007 school year

In Summary

- Some evidence of a greater impact for minorities and females
  - Note, these comparisons need to be made cautiously since P^* differs across groups
  - Parameter being estimated changes
- Supports findings of Lai et al. (2015) in that positive impacts seem to exist when computer-aided tutorials are viewed as complements

THANK YOU