Long-Term Effects of Teachers: Evidence from a Random Assignment of Teachers to Students

NBER Summer Institute
Education Program

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23 July 2020

Motivation

- Teacher quality measured by teacher value added (TVA) has been shown to affect students outcomes (Rockoff 2004, Kane and Staiger 2008, Hanusheck and Rivkin 2010, Chetty et al 2014 and 2017, Rothstein 2017).

- TVA methodology decomposes students' test scores into components attributed to student heterogeneity and to teacher's quality

- Concerns were raised whether TVA measures based on observational data are biased and so are their estimated effects (Rothstein, 2009, 2010; Baker et al., 2010, ; Koedel and Betts, 2011).
    - Students not randomly assigned to classrooms (Aaronson et al., 2017, Bacher-Hicks et al., 2017; Horvath, 2015; Paufler and Amrein-Beardsley, 2014; Jackson, 2014; Sass et al., 2012; Koedel and Betts, 2011; Rothstein, 2010, 2009)
    - Stability of TVA measures over time (Green et al., 2012; Darling-Hammond, 2015; Newton et al., 2010; Baker et al., 2010; Murnane et al., 2000).

Motivation

- If TVA measures may lack causal interpretation, can they be used for evaluation purposes, ex. recruitment, compensation etc.? (Koedel et al., 2015)
- In experimental settings TVA estimated effects were shown to be unbiased (Kane and Staiger 2008, Kane et al. 2013)
- Recent studies show that test-score value-added measures of teacher quality do not fully capture the impact of teachers on students since teaching ability is multidimensional. The non-test-score value-added measures include social, behavioral, and non-cognitive skills. For example, absences, suspensions, grades, and grade progression (Jackson forthcoming), behavior and non-cognitive skills (Petek and Pope 2019)
- Less evidence from a real-life context where matching of student-teacher is random
- Most evidence on TVA from primary and middle school, less about high school teachers
- Not much evidence from high stake exams.
- Less evidence on effect of TVA on choice of university field of study.

In this Paper

- Use an educational institutional setting where students and teachers are randomly assigned to classes.

- Avoid the issue of whether TVA measures are biased due to endogenous sorting/assignment based on potential outcomes of students and teachers.

- Measure TVA and estimate its effect based on:
  - Data from a sample of high schools in Greece
  - Use standardized national exams at 11th-12th
  - These are High stake exams because they are used for admission to universities and study programs in Greece
  - These exams and test scores span the whole high school curriculum

In this Paper

- We also estimate the effect of TVA on student attendance during the year
  - Attendance may proxy student motivation and other non cognitive skills

- Provide evidence on effect of TVA on several post-secondary outcomes:
  - Enrollment in post-secondary institution
  - Enrollment in university versus vocational schooling
  - Admission to a higher ranked university
  - Admission to a more preferred study program
  - Choice of field of study

- Heterogeneity of TVA effect: by student gender and ability, by teacher gender and teaching field

- TVA and exit and entry of teachers in relation to school quality.

Main Findings

- Students assigned to high-TVA teachers in high school have:
    - Higher test scores in national exams in 11th and 12th grade: 1 SD increase in TVA increase test scores by 0.2 SD.
    - Effect does not vary by teacher and student gender, nor by class size
    - Effect is larger in science and exact science subjects, lower in humanities/social science
    - Larger for HIGH ability students in science and exact science
    - Larger for LOW ability students in humanities and social science

- In US, Chetty et al 2014: 0.14 SD in math, 0.10 SD in English

- In Pakistan, Bau and Das 2020: 0.15 SD of average math, English, Urdu

Main Findings

- Students assigned to high-TVA teachers in high school are more likely to:
  - Pursue post-secondary education
  - Being admitted to higher ranked universities
  - Enroll in a more preferred study program
  - Choose a major related to a subject with higher TVA in high school
  - Higher average VA of teachers in the high school track increase the likelihood that a student will choose a track related subject as a university major

- Mechanism: higher TVA affect class attendance: it lowers school absences, excused and unexcused but mainly the latter:
  - 1 SD higher TVA reduces student absences by 4.2 hours, (mean per year= 52 hours)
  - Effect size seems small but perhaps it signal TVA effect on student motivation.

Additional Preliminary Results

- High VA teachers are more likely to exit from schools

- This average effect is completely due to the mobility dynamics of teachers in low performing schools

- In high performing schools teacher exit is unrelated to their value added

- These pattern is similar for female and male teachers and is robust to a variety of conditioning variables.

Institutional Setting

- Greek public high schools system
- A national law determines lexicographic assignment of students to classrooms within school
- Teachers are randomly assigned in schools to classrooms based on the subject they teach
  - The school Board oversees the process
  - Teachers are not likely assigned to the same class in two consecutive grades
  - Allowed to teach the same class at most twice during their tenure in school
- Students choose a track in 11th grade: classics, science, exact science
- Take multiple national exams in 11th (until 2005) and in 12th grades
  - Core subjects
  - Track subjects

Predicting Teacher Value Added

- We use the same estimators for value-added used in Kane and Staiger (2008) and Chetty et al. (2014). In a nutshell, the construction of this estimator involves three steps:
  - mRegress test scores A_{ijt} on X_{it}
  - Compute test score residuals adjusting for observables
  - Estimate the best linear predictor of mean test score residuals in classrooms in year t based on mean test score residuals in prior/later years
  - Use the coefficients of the best linear predictor to predict each teacher's VA in year t
  - Because prior/later test scores are a noisy signal of teacher quality the VA estimate is shrunk toward the sample mean ($=0$) to reduce mean-squared error

- In our setting, this prediction measures the expected causal effect of teacher j on students' scores in year t, because teachers and students are sorted randomly.

Teacher Value Added

- Details:
    - TVA based on mean test scores in teacher's prior/future classes
    - Sample include only teachers with classes in same grade in two years
    - Accounts for differences in class size, multiple classrooms per year
    - We observe multiple teachers teaching the same student, in same grade, school, and year.
    - TVA computed uniquely within course-grade-year. Multiple classrooms per teacher

- We do not observe teachers teaching in different schools, therefore we cannot include in TVA models school fixed effects.

- Kane et al. (2013), Kane and Staiger (2008), Chetty et al (2014a) show that TVA models without school and student fixed effects produce estimates of TVA with very little bias.

- Moreover, randomization of teachers and students occurs in our setting within schools, like an experiment, therefore it provides unbiased estimation of TVA variation.

Teacher Value Added

- We compute TVA for 936 course-grade-year cells.

- 341 classrooms and 50,000 stacked student level observations.

- We scale TVA in units of student test score standard deviations

Data

- 21 schools, 2003-2011, over 400 teachers, 341 classrooms.

- Students data from schools' administrative files:
  - Student Unique id, national exams test scores in 11th-12th grade, school exams test scores in 10th grade, gender, year of birth, high school track, absenteeism records in 11th-12th grade.

- Ministry of Education data
  - Enrollment in all post-secondary institutions, name of institution, field of study, quality rank of the department where enrolled, student's applications institutions/department.

- Teachers data obtained from schools' administrative files :
  - Employment record
  - Teaching assignment by class/grade/subject/course by year
  - Gender, teaching load (number of classes) as a proxy for experience.

Descriptive Statistics

Summary Statistics for Sample Used to Estimate Teacher Value-Added, 2003-2005

	Obs.	Mean	Std. Dev.	Min.	Max.
Student Characteristics					
Gender (1=Female)	49,678	0.56	0.50	0	1
Prior Score (std)	49,678	-0.03	1.00	-6.53	3.14
Age	49,668	17.33	0.82	16	42
No. of Subjects per Student	49,678	17.32	4.23	3	22
Study Track					
Classics	49,678	0.351	0.477	0	1
Science	49,678	0.234	0.423	0	1
Exact Science	49,678	0.415	0.493	0	1
Class Characteristics					
Class size	49,678	20.60	6.27	1	37

Summary Statistics for Sample Used to Estimate Teacher Value-Added, 2003-2005

	Obs.	Mean	Std. Dev.	Min.	Max.
Teacher Characteristics					
Teacher VA (2003-2005)	936	-0.07	0.63	-2.90	2.73
Teacher VA for Female Teachers	450	-0.05	0.64	-2.90	2.03
Teacher VA for Male Teachers	486	-0.09	0.61	-1.95	2.73
Gender (1=Female)	936	0.48	0.50	0	1
Experience (based on Previous Workload)	936	9.96	6.36	1	42

Summary Statistics for Sample Used to Estimate Teacher Value-Added, 2003-2005

	Obs.	Mean	Std. Dev.	Min.	Max.
Students Outcomes					
High School					
Test Score (std)	49,678	-0.11	1.01	-3.56	2.86
High School Graduation GPA (std)	49,678	0.00	1.00	-2.50	2.27
University Enrollment					
Secondary Schooling (0/1)	49,678	0.81	0.39	0	1
Academic University Vs Technical School (0/1)	40,196	0.48	0.50	0	1
Post-Secondary Admission Score	40,196	0.00	1.00	-2.28	2.51
Post-Secondary Degree Quality 1 (Rank 1-100)	40,196	49.66	28.94	0	99.95
Post-Secondary Degree Quality 2 (Rank 1-100)	40,196	40.14	23.41	0	82.18
Rank of Attending Institution on Degree Preference	40,196	10.86	13.84	1	140

Distribution of TVA Measure
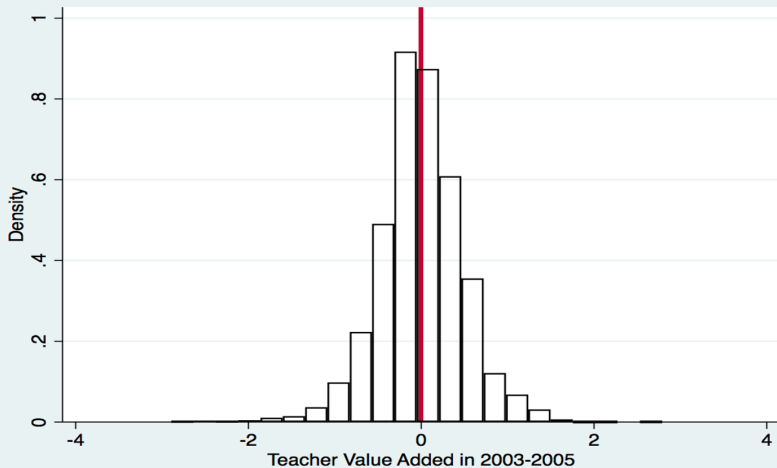
Distribution of TVA Measure
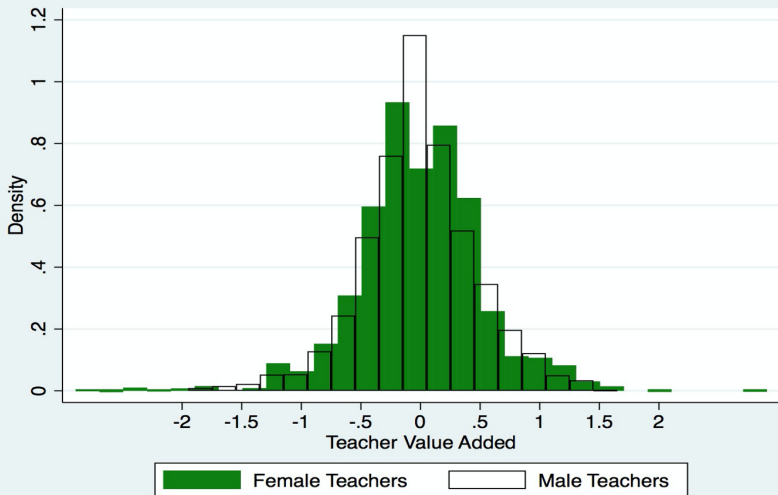
WITHIN-TEACHER CORRELATIONS BETWEEN TEACHER VALUE ADDED MEASURED IN DIFFERENT GRADES AND TIME PERIODS

	Panel A		
	Teacher VA in 2003		
	11th Grade (1)	12th Grade (2)	Average of 11th and 12th Grade (3)
Teacher VA in			
2004			
$\quad 11^{th}$ Grade	0.737 (0.036)***		
$\quad 12^{th}$ Grade		0.778 (0.043)***	
$\quad$ Average of $\quad 11^{th}$ and 12th Grade			0.878 (0.025)***
Controls	✓	✓	✓
N	131	117	48

Evidence on Random Assignment of Students and Teachers

Since students are randomly assigned to classrooms and classroom are randomly assigned to teachers, we would not expect a relationship between teachers' characteristics and value-added estimates and the characteristics of their students.

BALANCING TEST OF STUDENTS PRE-ASSIGNMENT CHARACTERISTICS ON TEACHER CHARACTERISTICS, 2003-2005,

	Student Characteristics				
	GPA in 10th Grade (1)	Mathematics in 10th Grade (2)	English in 10th Grade (3)	Gender (=1 Female) (4)	Age (5)
Teacher Characteristics					
Gender (=1 Female)	0.006	0.003	0.002	-0.003	-0.001
	(0.007)	(0.006)	(0.006)	(0.002)	(0.002)
N	40,548	40,548	36,323	42,732	42,732
Value Added$_t$	0.005	0.004	0.001	0.000	-0.004
	(0.008)	(0.007)	(0.008)	(0.003)	(0.003)
N	40,548	40,548	36,323	42,732	42,732
Value Added$_{t-1}$	0.010	0.008	0.006	0.001	-0.002
	(0.007)	(0.007)	(0.006)	(0.004)	(0.006)
N	32,712	32,712	29,310	34,572	34,572
Experience	0.0004	0.0004	0.0002	0.00006	0.0001
	(0.0003)	(0.0002)	(0.0003)	(0.0002)	(0.0001)
N	40,548	40,548	36,323	42,732	42,732

ADDITIONAL BALANCING TEST OF TEACHER CHARACTERISTICS ON STUDENTS PRE-ASSIGNMENT CHARACTERISTICS

|	Teacher Characteristics			
	Gender (=1 if Female)	Value Added$_t$	Value Added$_t - 1$	Experience
Student Characteristics				
GPA in 10th Grade	0.005	-0.001	0.001	-0.017
	(0.003)	(0.003)	(0.004)	(0.045)
Mathematics in 10th Grade	-0.002	0.003	0.001	0.046
	(0.003)	(0.003)	(0.004)	(0.056)
English in 10th Grade	-0.001	-0.001	-0.000	-0.001
	(0.001)	(0.001)	(0.001)	(0.016)
Gender (=1 if Female)	-0.002	-0.000	0.001	0.006
	(0.002)	(0.002)	(0.002)	(0.043)
Age	0.000	-0.000	0.001	0.026
	(0.001)	(0.001)	(0.002)	(0.022)
N	36,323	36,323	29,310	36,323
F-test for Joint Significance	0.04	0.02	0.77	1.29
P-value of F test	0.845	0.880	0.383	0.261

BALANCING TEST OF STUDENTS PRE-ASSIGNMENT CHARACTERISTICS ON TEACHER CHARACTERISTICS, 2003-2005, TRACK CLASSES ONLY

	Student Characteristics				
	GPA in 10th Grade (1)	Mathematics in 10th Grade (2)	English in 10th Grade (3)	Gender (=1 Female) (4)	Age (5)
Teacher Characteristics					
Gender (=1 Female)	0.026	0.024	0.014	0.003	0.000
	(0.017)	(0.015)	(0.014)	(0.007)	(0.006)
N	12,058	12,058	10,814	12,909	12,909
Value Added$_t$	0.014	0.015	0.014	0.007	0.001
	(0.023)	(0.021)	(0.016)	(0.009)	(0.009)
N	12,058	12,058	10,814	12,909	12,909
Value Added$_{t-1}$	0.033	0.021	0.015	0.014	0.006
	(0.024)	(0.022)	(0.019)	(0.011)	(0.018)
N	9,664	9,664	8,674	10,392	10,392
Experience	0.002	0.001	0.000	-0.000	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)
N	12,058	12,058	10,814	12,909	12,909

ADDITIONAL BALANCING TEST OF TEACHER CHARACTERISTICS ON STUDENTS PRE-ASSIGNMENT CHARACTERISTICS, TRACK CLASSES ONLY

	Teacher Characteristics			
	Gender (=1 if Female)	Value Added$_t$	Value Added$_t - 1$	Experience
Student Characteristics				
GPA in 10th Grade	0.003	-0.003	0.005	0.049
	(0.005)	(0.005)	(0.005)	(0.077)
Mathematics in 10th Grade	0.006	0.006	-0.001	0.039
	(0.005)	(0.005)	(0.004)	(0.073)
English in 10th Grade	-0.001	0.001	-0.001	-0.023
	(0.002)	(0.002)	(0.002)	(0.033)
Gender (=1 if Female)	0.002	0.002	0.003	-0.079
	(0.006)	(0.004)	(0.004)	(0.114)
Age	0.001	0.001	0.003	0.014
	(0.004)	(0.004)	(0.006)	(0.071)
N	10,814	10,814	8,674	10,814
F-test for Joint Significance	1.66	0.41	0.55	0.48
P-value of F test	0.162	0.840	0.739	0.789

Figure 2:
CORRELATION OF TEACHER VALUE ADDED ON TEST SCORES
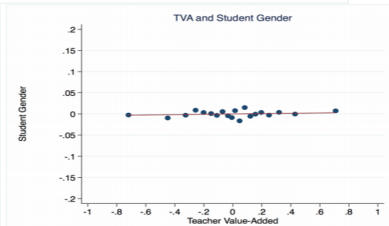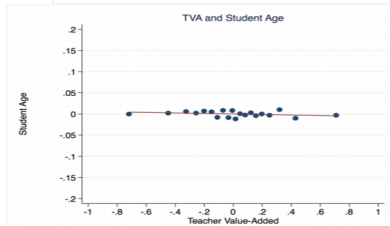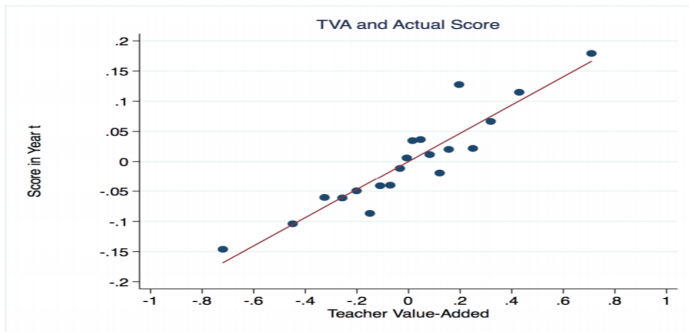
Effect of TVA on Test Scores and Post-Secondary Outcomes

- We estimate the following equation:

$$\text{Outcome}_{iscgtp} = \alpha_u + \lambda X_{i,s,c,t} + \beta X_{j,s,c,t} + \delta \text{TeacherVA}_{jsctp} + \zeta \text{PriorTS}_{i,s,c,t,p} + U_t + \xi_g + \psi_c + \chi_p + \epsilon_{i,s,c,g,t,p}$$

- Outcome_{iscgtp}: outcome of student i, at school s and class c, assigned to teacher j, in subject p and year t
- $X_{i,s,c,t}$- student gender and age
- $X_{j,s,c,t}$- teacher gender and experience based on prior workload
- $\text{PriorTS}_{i,s,c,t,p}$- student i prior test score in school s, class c, time t and subject p
- ξ_g- grade fixed effect
- ψ_c- class fixed effect
- U_t- year fixed effect
- χ_p - subject fixed effect
- $\delta \text{TeacherVA}_{jsctp}$: measure of a teacher's j quality measured by his/her value added in subject p, school s, class c, and year t. The TVA is scaled in units of student test score standard deviations.

THE EFFECT OF TEACHER VALUE ADDED ON HIGH SCHOOL AND UNIVERSITY OUTCOMES, 2003-2005

	Panel A: High School Outcomes				
	Subject Specific National Score 11th Grade	Subject Specific National Score 12th Grade	Subject Specific National Score, Stacked 11th + 12th Grades	National Exams Average Test Scores	Post-Secondary Admission Score
	(1)	(2)	(3)	(4)	(5)
Teacher VA	0.199	0.209	0.205	0.118	0.295
	(0.026)***	(0.036)***	(0.021)***	(0.053)**	(0.114)**
Observations	23,566	19,144	42,731	2,870	2,322
Student Characteristics	-	-	-	✓	✓
Teacher Characteristics	✓	✓	✓	✓	✓
Previous Year Test Scores	✓	✓	✓	✓	✓
Grade FE	-	-	✓	-	-
Year FE	✓	✓	✓	✓	✓
School FE	-	-	-	✓	✓
Track FE	-	-	✓	✓	✓
Subject FE	✓	✓	✓	-	-
Class FE	✓	✓	✓	-	-
Student FE	✓	✓	✓	-	-

THE EFFECT OF TEACHER VALUE ADDED ON HIGH SCHOOL AND UNIVERSITY OUTCOMES, 2003-2011

	Panel A: High School Outcomes				
	Subject Specific National Score 11th Grade	Subject Specific National Score 12th Grade	Subject Specific National Score, Stacked 11th + 12th Grades	National Exams Average Test Scores	Post-Secondary Admission Score
	(1)	(2)	(3)	(4)	(5)
Teacher VA		0.243 (0.025)***		0.223 (0.072)***	0.184 (0.073)**
Observations		31,909		4,075	3,335
Student Characteristics	-	-	-	✓	✓
Teacher Characteristics	✓	✓	✓	✓	✓
Previous Year Test Scores	✓	✓	✓	✓	✓
Grade FE	-	-	✓	-	-
Year FE	✓	✓	✓	✓	✓
School FE	-	-	-	✓	✓
Track FE	-	-	✓	✓	✓
Subject FE	✓	✓	✓	-	-
Class FE	✓	✓	✓	-	-
Student FE	✓	✓	✓	-	-

THE EFFECT OF TEACHER VALUE ADDED ON HIGH SCHOOL AND UNIVERSITY OUTCOMES, 2003-2005

	Panel B: University Outcomes				
	Post-Secondary Institution Quality 1	Post-Secondary Institution Quality 2	Rank of Attending Institution on Degree Preference	Academic University Vs Technical School	Enrollment in Post-Secondary Schooling (0/1)
	(1)	(2)	(3)	(4)	(5)
Teacher VA	7.949	7.329	4.200	0.052	0.220
	(3.659)***	(3.257)**	(1.687)**	(0.076)	(0.047)***
Observations	2,322	2,322	2,322	2,322	2,870
Student Characteristics	✓	✓	✓	✓	✓
Teacher Characteristics	✓	✓	✓	✓	✓
Previous Year Test Scores	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓
School FE	✓	✓	✓	✓	✓
Track FE	✓	✓	✓	✓	✓

	Panel B: University Outcomes				
	Post-Secondary Institution Quality 1	Post-Secondary Institution Quality 2	Rank of Attending Institution on Degree Preference	Academic University Vs Technical School	Enrollment in Post-Secondary Schooling (0/1)
	(1)	(2)	(3)	(4)	(5)
Teacher VA	7.225	6.619	2.715	0.115	0.114
	(2.080)***	(2.091)***	(1.069)**	(0.043)***	(0.028)***
Observations	3,335	3,335	3,335	3,335	4,075
Student Characteristics	✓	✓	✓	✓	✓
Teacher Characteristics	✓	✓	✓	✓	✓
Previous Year Test Scores	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓
School FE	✓	✓	✓	✓	✓
Track FE	✓	✓	✓	✓	✓

Effect Size of TVA on Post-Secondary Schooling

- Using our estimate based on 2003-2011 study period, 1 SD increase in TVA in 12th grade raises the probability of post-secondary schooling by 12 percent.

- Chetty, Friedman and Rockoff, 2014 II, based on TVA in grades 4-8, find that 1 SD improvement in TVA in a single grade raises the probability of college attendance at age 20 by 2.2 percent.

Robustness Checks: Changes in Controls and Specification

ROBUSTNESS OF MAIN RESULTS: THE EFFECT OF TEACHER VA ON HIGH SCHOOL AND UNI-VERSITY OUTCOMES, CONTROLS ADDED GRADUALLY TO THE BENCHMARK SPECIFICATION, 2003-2005

	(1)	(2)	(3)	(4)
	Panel A: Subject-Specific Test Scores			
Subject Specific Score, Stacked (11th and 12th)	0.239	0.239	0.229	0.205
	(0.024)***	(0.024)***	(0.025)***	(0.021)***
Observations	42,734	42,734	42,732	42,731
Baseline Controls FE (Year, Subject, Grade, School)	✓	✓	✓	✓
Student Characteristics & Previous Year Test Scores	✓	✓	✓	✓
Teacher Characteristics	X	✓	✓	✓
Class FE	X	X	✓	✓
Student FE	X	X	X	✓

MAIN ESTIMATES WITH ADDITIONAL CONTROLS AND ALTERNATIVE INTERACTIONS BETWEEN THE VARIOUS FIXED EFFECTS, 2003-2005

	Subject-Specific Test Scores, Stacked 11th and 12th Grades					
	(1)	(2)	(3)	(4)	(5)	(6)
Teacher VA	0.205	0.209	0.204	0.205	0.208	0.212
	(0.021)***	(0.024)***	(0.022)***	(0.020)***	(0.020)***	(0.020)***
Observations	42,731	39,282	42,712	42,733	42,733	42,733
Controls as in Table 5, column 3, Panel A	Yes	Yes	Yes	Yes		
Class FE × Student FE × Grade FE		Yes				
Grade FE × Student FE × Year FE			Yes			
Controls as in Table 5, column 3, Panel A, but replace class FE with school FE				Yes	Yes	Yes
Core Subjects Indicator					Yes	
Grade FE x School FE x Year FE						Yes

Mechanism: School Attendance

RELATIONSHIP BETWEEN TEACHER VALUE ADDED AND STUDENT CLASS ATTENDANCE

	Total Absences			Excused Absences			Unexcused Absences		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Teacher VA	-2.986	-3.783	-4.304	-0.047	-1.080	-1.624	-3.939***	-3.704***	-3.681***
	(2.821)	(2.824)	(2.811)	(2.172)	(2.167)	(2.206)	(1.338)	(1.322)	(1.294)
Observations	2,412	2,412	2,412	2,412	2,412	2,412	2,412	2,412	2,412
School x Grade FE x Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Track FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
GPA 10th grade	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Absences 10th grade	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Student Characteristics	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Teacher Characteristics & Class-Cohort Characteristics	No	No	Yes	No	No	Yes	No	No	Yes
Mean Y	52.04	52.04	52.04	25.12	25.12	25.12	26.92	26.92	26.92
St. Dev Y	34.66	34.66	34.66	23.81	23.81	23.81	16.62	16.62	16.62

TVA Effect on Choice of College Major

THE EFFECT OF TEACHER VA IN CLOSEST SUBJECT ON STUDENTS PROBABILITY TO STUDY A UNIVERSITY DEPARTMENT THAT IS THE NATURAL FOLLOW-UP OF SCHOOL TRACK FOR FULL SAMPLE AND BY GENDER

	Indicator if Choice of Department is a Natural Follow-up of School Track		
	(1)	(2)	(3)
Full Sample	0.097	0.096	0.096
	(0.040)***	(0.040)***	(0.040)***
Observations	1,943	1,943	1,943
Females	0.078	0.080	0.081
	(0.052)	(0.052)	(0.052)
Observations	1,079	1,079	1,079
Males	0.095	0.092	0.096
	(0.063)	(0.063)	(0.063)
Observations	864	864	864
School FE	✓	✓	✓
Previous Year Test Scores	✓	✓	✓
Year FE	✓	✓	✓
Track FE	✓	✓	✓
Student Characteristics		✓	✓
Average Teacher Characteristics		✓	✓
Average Class Size			✓

THE EFFECT OF TEACHER VALUE ADDED IN CLOSEST SUBJECT ON
CHOICE OF UNIVERSITY DEPARTMENT FOR FULL SAMPLE AND BY GENDER

	Indicator for the Choice of Department at the University Level		
	(1)	(2)	(3)
Full Sample	0.026	0.026	0.025
	(0.009)***	(0.009)***	(0.009)***
Observations	16,895	16,895	16,895
Females	0.021	0.020	0.019
	(0.012)*	(0.012)*	(0.012)
Observations	8,855	8,855	8,855
Males	0.034	0.034	0.034
	(0.015)**	(0.015)**	(0.015)**
Observations	8,040	8,040	8,040
School FE	✓	✓	✓
Previous Year Test Scores	✓	✓	✓
Year FE	✓	✓	✓
Track FE	✓	✓	✓
Student Characteristics		✓	✓
Average Teacher Characteristics		✓	✓
Average Class Size			✓

Heterogeneity by Student Ability and High School Track

HETEROGENEITY OF TEACHER VA BY STUDENT PREVIOUS YEAR TEST SCORES

	(1)	(2)	(3)
Teacher TV × Student Previous Year Test Scores	0.016	0.017	0.040
	(0.013)	(0.014)	(0.014)***
Teacher VA	0.238	0.229	0.205
	(0.024)***	(0.025)***	(0.021)***
Student Previous Year Test Scores	0.671	0.666	0.196
	(0.010)***	(0.010)***	(0.010)***
Subject FE	✓	✓	✓
Track FE	✓	✓	✓
Grade FE	✓	✓	✓
Year FE	✓	✓	✓
Class FE	X	✓	✓
Student FE	X	X	✓
Observations	42,734	42,732	42,731

THE EFFECT OF TEACHER VALUE ADDED ON HIGH SCHOOL OUTCOMES BY STUDENT GENDER

	Subject Specific National Score 11th Grade		Subject Specific National Score 12th Grade		Subject Specific National Score, Stacked 11th + 12th Grades	
	(1) Males	(2) Females	(3) Males	(4) Females	(5) Males	(6) Females
Teacher VA	0.214 (0.032)***	0.193 (0.035)***	0.157 (0.042)***	0.258 (0.044)***	0.208 (0.025)***	0.204 (0.027)***
Observations	10,229	13,326	8,530	10,609	18,777	23,950
Teacher Characteristics	✓	✓	✓	✓	✓	✓
Previous Year Test Scores	✓	✓	✓	✓	✓	✓
Grade FE.	-	-	-	-	✓	✓
Year FE.	✓	✓	✓	✓	✓	✓
Track FE.	-	-	-	-	✓	✓
Subject FE.	✓	✓	✓	✓	✓	✓
Class FE.	✓	✓	✓	✓	✓	✓
Student FE	✓	✓	✓	✓	✓	✓

	Subject Specific National Scores 11th Grade		Subject Specific National Scores 12th Grade		Subject Specific National Scores, Stacked 11th + 12th Grades	
	(1) Males	(2) Females	(3) Males	(4) Females	(5) Males	(6) Females
Teacher VA	0.196 $(0.041)^{***}$	0.227 $(0.052)^{***}$	0.248 $(0.059)^{***}$	0.172 $(0.050)^{***}$	0.196 $(0.026)^{***}$	0.191 $(0.037)^{***}$
Observations	12,349	10,780	8,605	10,076	21,316	21,228
Teacher Characteristics	✓	✓	✓	✓	✓	✓
Previous Year Test Scores	✓	✓	✓	✓	✓	✓
Grade FE.	-	-	-	-	✓	✓
Year FE.	✓	✓	✓	✓	✓	✓
Track FE.	-	-	-	-	✓	✓
Subject FE.	✓	✓	✓	✓	✓	✓
Class FE.	✓	✓	✓	✓	✓	✓
Student FE	✓	✓	✓	✓	✓	✓

Heterogeneity by Student Ability and High School Track

- TVA effect on core subjects does not vary by student track
- TVA effect on classics track subjects is higher for LOW ability students.
- TVA effect on science/exact science subjects is higher for HIGH ability students.

THE EFFECT OF TEACHER VALUE ADDED ON TEST SCORES BY TYPE OF SUBJECTS (CORE OR TRACK)

	Classics Core (1)	Science Core (2)	Exact Science Core (3)	Classics Track (4)	Science Track (5)	Exact Science Track (6)
Teacher VA	0.131 (0.048)***	0.122 (0.029)***	0.103 (0.035)***	0.097 (0.051)*	0.116 (0.042)***	0.223 (0.066)***
Observations	11,631	16,392	6,659	5,605	3,484	5,521
Teacher Characteristics	✓	✓	✓	✓	✓	✓
Previous Year Test Scores	✓	✓	✓	✓	✓	✓
Grade FE.	✓	✓	✓	✓	✓	✓
Year FE.	✓	✓	✓	✓	✓	✓
Track FE.	✓	✓	✓	-	-	-
Subject FE.	✓	✓	✓	✓	✓	✓
Class FE.	✓	✓	✓	✓	✓	✓
Student FE	✓	✓	✓	✓	✓	✓

HETEROGENEITY OF TEACHER TA BY STUDENT PREVIOUS YEAR TEST SCORES AND TYPE OF SUBJECTS

	Classics Core (1)	Science Core (2)	Exact Science Core (3)	Classics Track (4)	Science Track (5)	Exact Science Track (6)
Teacher TV × Student Previous Year Test Scores	-0.009	0.053	0.018	-0.052	0.059	0.066
	(0.020)	(0.020)***	(0.041)	(0.026)**	(0.032)*	(0.060)
Teacher VA	0.143	0.128	0.124	0.069	0.173	0.239
	(0.047)***	(0.029)***	(0.036)***	(0.058)	(0.064)***	(0.066)***
Student Previous Year Test Scores	0.075	0.023	-0.284	-0.093	0.024	0.003
	(0.018)***	(0.012)*	(0.026)***	(0.020)***	(0.025)	(0.019)

Heterogeneity by Class Size

- Effect of TVA does not vary by class size
- This results holds for female and male students

THE EFFECT OF TEACHER VALUE ADDED ON SUBSEQUENT PERFORMANCE BY CLASS SIZE AND TEACHER GENDER

	Outcome: Subsequent Subject-specific Performance (std)					
	Class Size>=21	Class Size<21	Class Size>=21	Class Size<21	Class Size>=21	Class Size<21
Teacher Gender:			Females	Females	Males	Males
	(1)	(2)	(3)	(4)	(5)	(6)
Teacher VA	0.211	0.188	0.184	0.169	0.236	0.179
	(0.031)***	(0.028)***	(0.034)***	(0.035)***	(0.068)***	(0.045)***
Observations	22,066	20,454	11,254	10,045	10,393	9,815
Teacher Characteristics	✓	✓	✓	✓	✓	✓
Previous Year Test Scores	✓	✓	✓	✓	✓	✓
Grade FE.	✓	✓	✓	✓	✓	✓
Year FE.	✓	✓	✓	✓	✓	✓
Track FE.	✓	✓	✓	✓	✓	✓
Subject FE.	✓	✓	✓	✓	✓	✓
Class FE.	✓	✓	✓	✓	✓	✓
Student FE	✓	✓	✓	✓	✓	✓

Conclusion

- We provide evidence on effect of TVA from a relatively less studied context - high school grades and high stakes exams.

- These TVA estimate reflect more structural education function parameters because there is less room to adjust other inputs and investments by end of high school.

- The evidence that higher TVA increase school attendance is important because it demonstrates that teaching quality may have effect on student non-cognitive skills, attendance perhaps reflects effect on motivation, importance of schooling for students.

Conclusion

- Improved school attendance is perhaps indirect evidence that TVA effect on test scores is more than teaching to the test, especially in context of high stake exams.

- Evidence is important for debate about early versus late childhood remedial interventions. End of high school intervention can be economically meaningful. Similar to Lavy and Schlosser (2011) and Lavy et al (forthcoming).

High Schools In Greece

- Centralized, run by the Ministry of Education, Research and Religious Affairs.

- Ministry determines curriculum, staffing and funding of schools.

- Teachers' salary based on seniority, level similar to public sector jobs with equivalent qualifications.

- Ministry places teachers in schools based on needs. Mobility between schools needs Ministry approval

Number and Proportion of Students Enrolled in Different University Studies by High School Track

			All	Not Enrolled	Enrolled in Universities	Human.	Science	Exact Science	Social Science	Vocational
			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2003-2005										
Track12	Classics	N.	1,095	274	464	423	2	36	198	357
		%	35	44	37	78	3	7	31	28
	Science	N.	866	60	515	49	75	276	171	291
		%	27	10	41	9	94	55	27	22
	Exact Science	N.	1,212	287	277	70	3	187	277	648
		%	38	46	22	13	4	38	43	50
	Total		3,173	621	1,256	542	80	499	646	1,296

Note: We report number of observations and proportion of students enrolled in different university studies by high school track. The proportions of students in each column add to one. Data for 2003-2005 are used.

Teacher Value Added

- We use the following baseline controls to compute TVA [similar to Chetty et al. (2014a) and Kane et al. (2008)]:
  - students' demographics (gender and age), student high-school track indicators, quadratic polynomials of a student's previous year test scores in the same subject, class size, school-level-grade enrolment, gender of the teacher, class and school-grade means of prior-year average GPA, average test scores in the same subjects, teacher's experience, and mean school's neighbourhood income.

- When a prior test score is missing (1.3% of our sample), we set it to 0 and include an indicator for missing data.

- We do not account for a drift when using 2003-2005 data.

- We drop students who have the same teacher in two consecutive grades (72 teachers).

Choice of University Major Regressions

- The dependent variable is a 0/1 indicator, 1 for the observed department of study and 0 for the other possible choices.

- We stack the possible post-secondary choices as the dependent variable for each student against the teachers' VA in each of the post-secondary choices of university studies as follows:

  History: TVA in history in the track, otherwise history in the core
  Mathematics: TVA in mathematics in the track, otherwise mathematics in the core
  Physics TVA in physics in the track, otherwise physics in the core
  Statistics: TVA in mathematics in the track, otherwise mathematics in the core
  Biology: TVA in biology, otherwise biology in the core
  Computer Science: : TVA in computer science in the track, otherwise math in the core
  Engineering: TVA in Physics and Bio in the track, otherwise Physics and Bio in the core
  Economics: TVA in economics, otherwise the average TVA in the track
  Business: TVA in business administration, otherwise the average TVA in the track
  Health-related (Medicine, Dentistry, Veterinary and Pharmacy): TVA in physics and mathematics in the track, otherwise physics and mathematics in the core
  Remaining Humanities department: TVA in the classics track, otherwise modern Greek and history in the core
  Remaining Exact Science departments: TVA in the exact science track, otherwise physics and mathematics in the core