The Effects of Performance Pay Bonuses for Top Teachers on Student Test Scores

Josh Hollinger

2/6/20

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Motivation

If teacher quality matters, how can teacher quality be increased, particularly in "high-need" schools?

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- Can performance pay (rewarding value-added) incentivize teachers to improve?

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 The literature in the US thus far suggests maybe not. (Springer et al. 2010, Fryer 2013)

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- One way forward: identify design flaws empirically
 - Evidence of reasons for weak incentives
 - Evidence of response where incentives should be stronger (Imberman and Lovenheim 2015)

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- Common feature: performance threshold
 - Could be too low or too high
 - Generally set high
 - Strongest incentive for "marginal" teachers

Do teachers predicted to have a better chance of attaining a performance bonus improve their students' test scores more?

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Evaluates effect of teacher performance pay on student test scores in 21 "high-need" elementary schools in North Carolina

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 Predicts probability of teachers attaining the value-added required to receive bonus Evaluates effect of teacher performance pay on student test scores in 21 "high-need" elementary schools in North Carolina

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- Predicts probability of teachers attaining the value-added required to receive bonus
- Investigates if teachers with higher probability of bonus respond more to incentive

No evidence of overall effect: perhaps positive math, negative reading

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 No evidence of better results for teachers with higher probability of bonus (some contrary)

- No evidence of overall effect: perhaps positive math, negative reading
- No evidence of better results for teachers with higher probability of bonus (some contrary)
 - Single-year VA estimates are quite noisy
 - Do teachers have any idea how changing their effort changes their VA?

- Are teachers already motivated?
- Should we focus more on the bottom of the distribution?



Effects of performance pay in education



- Effects of performance pay in education
 - Group-based: Often found positive effects in international settings (Lavy 2002; Glewwe et al. 2003) and no effects in the US (Fryer 2013; Goodman and Turner 2013)

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Non-linear incentives

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- Non-linear incentives
 - Sales commissions and executive compensation: Oyer (1998), Larkin (2014)

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Brehm et al. (2017): closest to my paper

Outline of This Paper

- Theoretical Framework
- Performance Pay Programs
- Data
- Policy Evaluation
- Predicting Bonus Probability
- Effects by Bonus Probability

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- Robustness
- Conclusion

- Principal-agent model: employ teacher to teach a student
- Output is test score *y*, teacher effort *t* unobserved:

$$y = t + \epsilon$$

- ϵ distributed N(0, σ^2)
- Without performance pay, teacher chooses $t = \overline{t}$
- Quadratic cost of additional effort:

$$f(t) = c(t - \bar{t})^2$$

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• Offer bonus b if test score exceeds a threshold y^T

• Wage is
$$w = s + b * 1(y > y^T)$$

• Teacher's utility is
$$U = w - c(t - \overline{t})^2$$

Teacher maximizes with t:

$$b[1-\Phi(y^{T}-t)]-c(t-\bar{t})^{2}$$

First order condition:

$$b\phi(y^T-t)=c(t-\overline{t})$$

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What happens if target is set too high?



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More within reach: higher marginal return to effort

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 Teacher Incentive Fund gave money to districts to implement teacher incentives in high-need schools

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- Two large districts in NC (Charlotte-Mecklenburg and Guilford) received grants to implement performance pay in a subset of their schools deemed high-need

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- Charlotte-Mecklenburg's VA bonuses started in 2010, Guilford in 2007
- Bonuses based on individual teacher's VA in a given year: had to exceed a VA threshold set relative to all teachers of the same grade in the district
 - Charlotte-Mecklenburg: \$2500 if above 70th percentile in the district
 - Guilford: \$2000 if 1 SD above district mean, \$6000 if 1.5 SD above

Recruitment incentives

 Guilford: teachers with VA 2 SD below the mean 2 years in a row were moved to a different school in the district

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Principals could also earn performance bonuses

- North Carolina Education Research Data Center
- All 3rd-5th grade students in NC 2000-2011
- Students' end-of-grade test scores, demographic characteristics
- Identifiers allow tracking students and teachers over time and linking students to teachers and schools
- Student-teacher link defined by the teacher administering test
 - Student's classroom teacher unless absent
 - Keep only teachers known to be teaching math/reading in the right grade

Estimate fixed-effect for each teacher:

$$y_{icsjt} = \theta y_{ics,t-1} + \beta X_{it} + \gamma Z_{ct} + \delta S_{st} + \mu_j + \epsilon_{icsjt}$$

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i=student, c=class, s=school, j=teacher, t=year

- Estimated separately for each year
- Multilevel hierarchical linear model (mixed model)
- Random coefficients for teacher and school
- Two lags of math and reading

$$y_{icsjt} = \theta y_{ics,t-1} + \beta X_{it} + \gamma Z_{ct} + \delta S_{st} + \mu_j + \mu_s + \epsilon_{icsjt}$$

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i=student, c=class, s=school, j=teacher, t=year
Value-added

- I use the list of controls used in the policies and a mixed model to match how VA is calculated for bonuses
- Highly correlated with more basic FE model (0.905)
- Don't observe who actually gets bonuses, but estimate from VA and threshold rules

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Estimate about 17% of eligible teachers get bonus

Summary Statistics

Summary Statistics					
	North Carolina	Performance Pay Schools			
VARIABLES	mean	mean			
	(SD)	(SD)			
Student Characteristics					
Math Score	0.057	-0.459			
	(0.983)	(0.959)			
Reading Score	0.051	-0.510			
6	(0.981)	(0.984)			
White	0.603	0.114			
	(0.489)	(0.318)			
Black	0.263	0.725			
	(0.440)	(0.446)			
Hispanic	0.067	0.081			
	(0.251)	(0.273)			
Female	0.495	0.503			
	(0.500)	(0.500)			
Economically Disadvantaged	0.451	0.822			
	(0.498)	(0.383)			
Exceptional	0 114	0.142			
	(0.317)	(0.349)			
Limited English	0.0248	0.0414			
0	(0.156)	(0.199)			
	(,	(1)			
Teacher Characteristics					
Experience	12.51	9.198			
	(9.587)	(9.067)			
White	0.865	0.602			
	(0.341)	(0.490)			
Black	0.119	0.385			
	(0.324)	(0.487)			
Female	0.925	0.902			
	(0.263)	(0.297)			
VA	-0.00298	-0.0238			
	(1.016)	(1.061)			
Observations	1,633,497	16,035			

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Empirical Framework

 Difference-in-differences: student is "treated" if their school has performance pay in that year, "ever treated" if their school has performance pay at some time in the panel

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 Difference-in-differences: student is "treated" if their school has performance pay in that year, "ever treated" if their school has performance pay at some time in the panel

$$y_{isgt} = \theta treated_{st} + \Gamma ever_treated_s + \beta X_{it} + \delta_{gt} + \epsilon_{isgt}$$

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$$y_{isgt} = \theta treated_{st} + \Gamma ever_treated_s + \beta X_{it} + \delta_{gt} + \epsilon_{isgt}$$

 Identifying assumption: no year- and treatment-group-specific shocks besides performance pay

Performance Pay Effects - Math

Effect of Performance Pay Programs on Math Scores				
	(1)	(2)	(3)	(4)
Treated	0.0536* (0.0280)	0.000125 (0.0306)	0.0523 (0.0325)	0.0437 (0.0386)
Observations	1,658,694	1,658,507	1,658,693	1,658,425
R-squared	0.695	0.735	0.702	0.738
Student controls	YES	YES	YES	YES
Year-by-grade FE	YES	YES	YES	YES
Teacher FE		YES		
Teacher-by-School FE				YES
School FE			YES	
Pobust standard arrors	in parantha			

Kobust standard errors in parentheses *** p < 0.01, ** p < 0.05, * p < 0.1Standard errors are clustered at the school level.

Performance Pay Effects - Reading

Effect of Performance Pay on Reading Scores						
	(1) (2)					
Treated	-0.0130 (0.0126)	-0.0751*** (0.0274)	-0.0119 (0.0147)	-0.0644* (0.0369)		
Observations	1,658,694	1,658,507	1,658,693	1,658,425		
R-squared	0.669	0.689	0.673	0.692		
Student controls	YES	YES	YES	YES		
Year-by-grade FE	YES	YES	YES	YES		
Teacher FE		YES				
Teacher-by-School FE				YES		
School FE			YES			
Robust standard errors	in norenthes	200				

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Performance Pay Effects - Math - Class controls

Effect of Performance Pay on Math Scores						
	(1) (2) (3) (4)					
Treated	0.0646** (0.0290)	0.00493 (0.0310)	0.0613* (0.0338)	0.0474 (0.0389)		
Observations	1,658,694	1,658,507	1,658,693	1,658,425		
R-squared	0.696	0.735	0.703	0.738		
Student controls	YES	YES	YES	YES		
Class controls	YES	YES	YES	YES		
Year-by-grade FE	YES	YES	YES	YES		
Teacher FE		YES				
Teacher-by-School FE				YES		
School FE			YES			

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Performance Pay Effects - Reading - Class controls

Effect of Performance Pay on Reading Scores						
	(1)	(1) (2) (3)				
Treated	-0.00313 (0.0123)	-0.0733*** (0.0272)	-0.00778 (0.0145)	-0.0638* (0.0363)		
Observations	1,658,694	1,658,507	1,658,693	1,658,425		
R-squared	0.670	0.689	0.673	0.692		
Student controls	YES	YES	YES	YES		
Class controls	YES	YES	YES	YES		
Year-by-grade FE	YES	YES	YES	YES		
Teacher FE		YES				
Teacher-by-School FE				YES		
School FE			YES			

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

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 Predict each teacher's probability of attaining a bonus (1 SD above their district mean VA)

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 Treated teacher-years are excluded from regressions, then their VA is predicted by coefficients on rest of sample

- Predict each teacher's probability of attaining a bonus (1 SD above their district mean VA)
- Treated teacher-years are excluded from regressions, then their VA is predicted by coefficients on rest of sample
- What do teachers know?
 - Past VA (and if above 1 SD in the past)
 - Class characteristics
 - Teacher characteristics
 - All of the above
 - Average test scores in the past
 - Average test score gains
 - What if they think bonus is based on test score levels or gains?

Linear Probability Model using Past VA:

$$VA_{jt} = \sum_{y=1}^{5} [\beta_{1y} 1 (VA_{j,t-y} > 1SD) + \beta_{2y} VA_{j,t-y} + \beta_{3y} VA_{j,t-y}^{2}] + \epsilon_{jt}$$

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Linear Probability Model using Past VA:

$$VA_{jt} = \sum_{y=1}^{5} [\beta_{1y} 1 (VA_{j,t-y} > 1SD) + \beta_{2y} VA_{j,t-y} + \beta_{3y} VA_{j,t-y}^{2}] + \epsilon_{jt}$$

- Include indicators for missing lags
- Can add class and teacher characteristics, C_{jt} and T_{jt}
- Also, instead of VA, can use lags of average test scores / gains to predict VA

Linear Probability Model using Past VA:

$$VA_{jt} = \sum_{y=1}^{5} [\beta_{1y} 1 (VA_{j,t-y} > 1SD) + \beta_{2y} VA_{j,t-y} + \beta_{3y} VA_{j,t-y}^{2}] + \epsilon_{jt}$$

- Include indicators for missing lags
- Can add class and teacher characteristics, C_{jt} and T_{jt}
- Also, instead of VA, can use lags of average test scores / gains to predict VA Lastly, can predict probability of getting bonus if it were defined by test score levels / gains

Predicting Probability of Bonus - Regression Results

Past VA variables 1(Bonus) Teacher 1(Bonus) Class 1(Bonus) Lag Bonus 0.0681*** (0.00721) No experience (0.00721) -0.0694*** (0.00033) Class size (0.000229) -0.0113*** (0.000229) Lag VA 0.0672*** (0.00212) 1-3 yens exp. (0.00419) -0.0140*** Male (0.00237) -0.00263*** Lag VA 0.0145*** (0.0022) 4-9 years exp. (0.00370) -0.0122*** Age (0.00378) -0.0326 Lag 2 VA 0.0339*** (0.00225) 1-24 year exp. (0.00348) -0.00220 (0.00376) Limited English (0.00366) -0.00544 Lag 2 VA ² 0.00899*** (0.0025) Licensing exam (0.00161) 0.00751*** Disadvantaged (0.00533) -0.00564 Lag 3 VA 0.0158*** Male 0.00161 Ist year -0.00228*** Lag 3 VA 0.0169*** Male 0.00161 Ist year -0.0028*** Lag 4 VA ² 0.00262 Multi-race -0.0638* Lag Math -0.0129*** Lag 4 VA ² 0.00262 Multi-race -0.0638*** Lag Times OS -0.0333** Lag 5 VA ²			Predicting Probab	ility of Bonus		
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Past VA variables	1(Bonus)	Teacher	1(Bonus)	Class	1(Bonus)
Constant Constant Constant Constant Constant Constant Lag VA 0.067211 1-3 years exp. -0.0140*** Male -0.0263*** Lag VA ² 0.0145*** 4-9 years exp. -0.01221*** Male -0.00263*** Lag VA ² 0.0145*** 4-9 years exp. -0.0122*** Age 0.00196 Lag 2 Bonus 0.0673*** 10-24 year exp. -0.0220 Limited English -0.0226 Lag 2 VA 0.039*** >25 years exp. - Exceptional 0.00445 (0.0028) (0.00270) (0.00161) Reserventional 0.00584 (0.00271) (0.00409) (0.0153) (0.00578) (0.00578) Lag 3 Bonus 0.0347*** Certified 0.00316 Repeat -0.00534 (0.00271) (0.00409) (0.0151) Lag XA ² 0.00499 (0.00475) Lag 3 VA ² 0.00491** Black -0.0561** Lag Math -0.0199*** Lag 4 VA ² 0.00282 Multi-race (0.0327)	Lag Bonus	0.0681***	No experience	-0.0694***	Class size	-0.00113***
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Eug Donus	(0.00721)	no experience	(0.00538)	CIUSS SILC	(0.000229)
(0.00212) (0.00419) (0.00419) (0.0081) Lag VA ² 0.0145*** 4-9 years exp. -0.0122*** Age (0.00578) Lag 2 Bonus 0.0673*** 10-24 year exp. -0.00220 Limited English -0.0236 Lag 2 VA 0.039*** >25 years exp. - Exceptional 0.00445 Lag 2 VA 0.039*** >25 years exp. - Exceptional 0.00445 Lag 2 VA 0.039*** >25 years exp. - Exceptional 0.00445 Lag 3 VA 0.0058** Licensing exam 0.00751*** Disadvantaged -0.00584 Lag 3 VA 0.0168*** Male 0.00161 Ist year -0.022**** Lag 3 VA 0.058*** Male 0.00161 Ist year -0.022**** Lag 4 VA ² 0.00295 (0.0327) (0.00453) (0.00453) Lag 4 VA ² 0.00262 Multi-race -0.0638**** Lag Days ISS -0.032*** Lag 5 VA 0.0145*** (0.0327) (0.00743) (0.0377)	Lag VA	0.0672***	1-3 years exp	-0.0140***	Male	-0.0263***
Lag VA ² 0.015*** 4.9 years exp. -0.0121*** Age 0.00106 Lag 2 Bonus 0.0673*** 10-24 year exp. -0.00220 Limited English (0.00576) Lag 2 Bonus 0.0673*** 10-24 year exp. -0.00220 Limited English (0.0153) Lag 2 VA 0.0339*** >25 years exp. - Exceptional 0.00455 Lag 3 Long 0.00899** Licensing exam 0.00751*** Disadvantaged 0.00087) Lag 3 Bonus 0.0347*** Certified 0.00160 (0.00278) (0.00278) Lag 3 VA 0.0158** Certified 0.00161 154 year -0.0228* Lag 3 VA 0.00411 (0.00425) (0.00475) Lag Math -0.0199** Lag 3 VA 0.00411* (0.00425) Lag Math -0.0199*** (0.00425) Lag 4 VA 0.0151** (0.0226) Lag Reading 0.0165** (0.00282 Multi-race -0.038** Lag Absences -0.000530 Lag 4 VA 0.015*** (0.0226)		(0.00212))	(0.00419)		(0.00881)
(0.00122) (0.00370) (0.00370) (0.00376) Lag 2 Bonus 0.0673*** 10-24 year exp. -0.00220 Limited English -0.0036 Lag 2 VA 0.0339*** >25 years exp. - Exceptional 0.00445 Lag 2 VA 0.0329*** >25 years exp. - Exceptional 0.00445 Lag 2 VA2 0.0089*** Licensing exam 0.00751*** Disadvantaged -0.00534 Lag 3 VA 0.0089*** Licensing exam 0.00161 Repeat -0.00533 Lag 3 VA2 0.0089*** Male 0.00161 Ist year -0.0228*** (0.0011) (0.00271) (0.00491) (0.00575) Lag Reading 0.0057** Lag 4 VA2 0.00595** (0.00261) Lag Reading 0.0057** (0.00433) Lag 4 VA2 0.00282 Multi-race -0.0638* Lag Abaye (0.00433) (0.0043) Lag 5 VA2 0.00425** (0.0327) (0.00743) (0.0374) (0.0374) Lag 5 VA2 0.0145*** (0.0249) <t< td=""><td>Lag VA²</td><td>0.0145***</td><td>4-9 years exp</td><td>-0.0121***</td><td>Age</td><td>0.00196</td></t<>	Lag VA ²	0.0145***	4-9 years exp	-0.0121***	Age	0.00196
Lag 2 Bonus 0.0673*** 10-24 year exp 0.00220 Limited English 0.0036 (0.00769) ->25 years exp Exceptional 0.00445 (0.0089)*** - Exceptional 0.00445 (0.0089)*** Licensing exam 0.00751*** Disadvantaged 0.00584 (0.00895)*** Licensing exam 0.00751*** Disadvantaged 0.00584 (0.00895)*** Certified 0.00316 Repeat -0.00538 (0.00885) (0.00409) (0.0189) Lag 3 VA 0.0158*** Male 0.00161 St year -0.0228*** (0.00271) (0.00401) (0.00257) (0.00271) (0.00401) Lag Math -0.0199*** (0.00161) (0.00251) (0.00453) (0.00327) Lag 4 VA 0.0156*** Hispanic -0.0561** Lag Math -0.0199*** (0.00161) (0.02651) Lag Reading 0.0105** (0.00327) (0.00445) Lag 4 VA 0.0156*** Am. Indian -0.0302 Lag Absences -0.006653 (0.00453) (0.00453) Lag 5 VA 0.0145**** (0.00128 Lag 5 VA 0.0145*** (0.0014) Lag 5 VA 0.0164*** (0.0014) Lag 5 VA 0.0164*** (0.0014) Lag 5 VA 0.0164*** (0.0014) Lag 5 VA 0.0164*** (0.00282 Multi-race -0.0808** Lag Days ISS -0.0332** (0.0037) Lag 6 Math -0.0302 Lag Absences -0.006653 (0.00465) (0.0031) Lag 7 Wa 0.0154*** (0.0014) Lag 5 VA 0.0145*** (0.0014) Lag 5 VA 0.0145*** (0.0014) Lag 5 VA 0.0145*** (0.0025) Lag 6 VA 0.0164*** (0.0025) Lag 6 VA 0.0164*** (0.0025) Lag 7 Wa 0.0250* (0.0327) AlG math 0.0256* (0.0159) Constant 0.184*** Observations 102.395 R-squared 0.099		(0.00122)		(0.00370)		(0.00578)
(0.00769) 25 years exp. - Exceptional (0.0133) Lag 2 VA (0.0325) Licensing exam 0.0751*** Disadvantaged -0.00584 Lag 2 VA ² (0.00225) (0.00150) (0.00150) (0.00578) Licensing exam 0.0751*** Disadvantaged -0.00584 Lag 3 Bonus 0.0347*** Certified 0.0316 Repeat -0.00533 Lag 3 VA 0.0189*** Male 0.01011 Ist year -0.0228*** Lag 3 VA 0.0189*** Male 0.01011 Ist year -0.0228*** Lag 4 Bonus 0.0305*** Hispanic -0.0638* Lag Reading 0.0105** Lag 4 Bonus 0.0395*** Hispanic -0.0638* Lag Reading 0.000453) Lag 4 VA ² 0.00222 Multi-race -0.0688*** Lag Days ISS -0.0332** Lag 5 VA ² 0.0145*** (0.0327) Lag Times ISS 0.0397) (0.0377) Lag 5 VA ² 0.0145*** (0.0249) Lag Times ISS 0.0397)	Lag 2 Bonus	0.0673***	10-24 year exp.	-0.00220	Limited English	-0.0236
Lag 2 VA 0.039*** >25 years exp. - Exceptional 0.00445 Lag 2 VA ² 0.00899*** Licensing exam 0.0751*** Disadvantage (0.00807) Lag 3 Bonus 0.0347*** Certified 0.00160 (0.0025) (0.00268) Lag 3 Bonus 0.0347*** Certified 0.00161 Repeat -0.0533 Lag 3 VA ² 0.004855 (0.00409) (0.0189) (0.00271) Lag 3 VA ² 0.00411 (0.00271) (0.0041) (0.00475) Lag 4 VA 0.00161 1st year -0.0199*** (0.00445) Lag 4 VA 0.0159** Am. Indian -0.0322 Lag Reading 0.004453 Lag 4 VA 0.0159** Am. Indian -0.0302 Lag Absences -0.00653 Lag 5 Bonus 0.02282 Multi-race -0.0308*** Lag Days ISS -0.032** Lag 5 VA ² 0.002041** White -0.0471* Lag Days OSS -0.030* Lag 5 VA ² -0.000448 Lag Times ISS 0.0395** (0.		(0.00769)		(0.00348)		(0.0153)
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Lag 2 VA	0.0339***	>25 years exp.	-	Exceptional	0.00445
Lag 2 VA ² 0.00594** Licensing exam 0.00751*** Disadvantaged 0.00584 (0.0058) (0.0058) (0.0058) (0.0058) (0.0058) (0.00685) (0.00409) (0.00160) (0.00161) (0.00161) (0.00161) (0.0075) (0.00271) (0.00401) (0.00251) (0.00251) (0.00475) (0.00251) (0.00447** (0.00595) (0.00251) (0.00447** (0.00595) (0.00251) (0.00447** (0.00595) (0.00287) (0.00453) (0.00282) (0.00282) (0.00282) (0.00281) (0.00281) (0.00282) (0.00281) (0.00281) (0.00245) (0.00441** (0.00281) (0.00281) (0.00282) (0.00281 (0.00281) (0.00281 (0.00281) (0.00281) (0.00281) (0.00281) (0.00281) (0.00281) (0.00282 (0.00281 (0.00281) (0.00281) (0.00281) (0.00281) (0.00281) (0.00281) (0.00281) (0.00281) (0.00281) (0.00281 (0.00281) (0.00281) (0.00281) (0.00281) (0.00281) (0.00281) (0.00281 (0.00281) (0.00281) (0.00281) (0.00281) (0.00281) (0.00281) (0.00281) (0.00281) (0.00281) (0.00281) (0.00281) (0.00281) (0.00281) (0.00281) (0.00281)	-	(0.00225)				(0.00807)
(0.0135) (0.00160) (0.0028) Lag 3 Bonus 0.0387*** Certified 0.00316 Repeat -0.00533 Lag 3 VA 0.0188*** Male 0.00161 1st year -0.0228*** (0.00805) (0.00409) (0.00409) (0.0151) 1st year -0.0228*** (1.00271) (0.00401) (0.00575) (0.00575) (0.00475) Lag 3 VA ² 0.00441*** Black -0.028*** (0.00475) (0.00161) (0.00161) Lag Reading 0.0105*** (0.00425) Lag 4 Bonus 0.0395*** Hispanic -0.0638* Lag Reading 0.0105** (0.00280) (0.00320) (0.00430) (0.00436) (0.00436) (0.00446) Lag 4 VA ² 0.00282 Multi-race -0.0380*** Lag Days ISS -0.0332** (0.00147) (0.0147) (0.0249) (0.0037) (0.0276) (0.0037) Lag 5 VA 0.0145*** White -0.0471* Lag Days ISS -0.030** (0.00245) (0.	Lag 2 VA ²	0.00899***	Licensing exam	0.00751***	Disadvantaged	-0.00584
Lag 3 Bonus 0.034*** Certified 0.00316 Repeat 0.00533 (0.00885) (0.0040) (0.0189) (0.0087) (0.0040) (0.0189) (0.0071) (0.0040) (0.0047) (0.0071) (0.0040) (0.0057) (0.0071) (0.0071) (0.0047) (0.0011) (0.0011) (0.0051) (0.0057) (0.0011) (0.0011) (0.0051) (0.0047) (0.0012) (0.0011) (0.0051) (0.0057) (0.0057) (0.0057) (0.0057) (0.00453) (0.0057) (0.0014) (0.0327) (0.00465) (0.00465) (0.0014) (0.0211) (0.0249) (0.00473) (0.0014) (0.0211) (0.0147) (0.0113) (0.0249) (0.0073) (0.0073) (0.0050) (0.0057) (0.00366) (0.0057) (0.0057) (0.0050) (0.0050) (0.0057) (0.0050) (0.0057) (0.0057) (0.0050) (0.0057) (0.0057) (0.0057) (0.0050) (0.0057) (0.0057) (0.0050) (0.0057) (0.0050) (0.0057) (0.0050) (0.0057) (0.0054) (0.0050) (0.0057) (0.0054) (0.0059) (-	(0.00135)	0	(0.00160)		(0.00528)
(0.00865) (0.00409) (0.0189) Lag 3 VA 0.0158*** Male 0.00161 15 tyear 0.02271 Lag 3 VA ² 0.0041*** Male 0.00561** Lag Math -0.023*** Lag 3 VA ² 0.0041*** Black -0.0561** Lag Math -0.0199*** Lag 4 Bonus 0.0395*** Hispanic -0.0563* Lag Reading 0.0106** Lag 4 VA 0.0150*** (0.00327) (0.00425) (0.00453) Lag 4 VA 0.0150*** (0.0261) (0.0264) (0.00443) Lag 4 VA 0.0150*** (0.0262) (0.00463) (0.00446) Lag 4 VA 0.0252 Multi-race -0.080*** Lag Days ISS -0.032** Lag 5 VA 0.041*** White -0.0471* Lag Days OSS -0.0130* Lag 5 VA 0.045*** (0.0249) Lag Times ISS 0.0580 (0.0205) (0.0226) Lag Times OSS 0.0500** (0.0227) Lag 5 VA ² -0.000448 Lag Times OSS 0.0500** <td>Lag 3 Bonus</td> <td>0.0347***</td> <td>Certified</td> <td>0.00316</td> <td>Repeat</td> <td>-0.00533</td>	Lag 3 Bonus	0.0347***	Certified	0.00316	Repeat	-0.00533
Lag 3 VA 0.0158*** Male 0.00161 1st year 0.0228*** (0.00271) (0.0041) (0.00401) (0.00471) (0.00575) Lag 3 VA ² 0.00441*** Black 0.0561** Lag Math 0.0199*** (0.0013) (0.0251) (0.00453) (0.00453) (0.00453) (0.00453) (0.00453) (0.00453) (0.00453) (0.00453) (0.00453) (0.00453) (0.00453) (0.00453) (0.00453) (0.00453) (0.00453) (0.00463) (0.00327) Lag 4 VA ² 0.00222 Multi-race 0.0880*** Lag Days 1S5 -0.032** (0.0014) (0.0311) (0.0447) (0.0312) (0.0147) (0.0113) (0.0249) (0.0147) (1.00366) (0.0366) (0.0366) (0.0367) (0.0377) Lag 5 VA ² -0.000448 Lag Times 1S5 0.0580 (0.00366) (0.0327) Lag 5 VA ² -0.000448 Lag Times 0S5 0.0580* (0.0215) (0.0205) AlG math 0.0256* (0.0154) AlG reading -0.0368** (0.0159) Constant 0.184*** Observations 102.395 R-squared 0.099		(0.00885)		(0.00409)		(0.0189)
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Lag 3 VA	0.0158***	Male	0.00161	1st year	-0.0228***
Lag 3 VA ² 0 00441*** Black 0.0551** Lag Math 0.0109*** (0.00161) (0.0251) (0.00425) (0.00425) (0.00425) (0.00425) (0.0095) (0.0327) (0.00453) (0.00453) (0.00453) (0.00453) (0.00453) (0.00453) (0.00453) (0.00262) Multi-race 0.0880*** Lag Days ISS 0.0032** (0.00164) (0.0131) (0.0147) Lag 5 Bonus 0.0241** White -0.0471* Lag Days OSS 0.0130* (0.0113) (0.0249) (0.0147) Lag 5 VA ² 0.00366) (0.0269) (0.00763) (0.00366) (0.0276) (0.0377) Lag 5 VA ² 0.00366 (0.0046) (0.0276) (0.00366) (0.0327) Lag 5 VA ² 0.00366 (0.0056) (0.0377) Lag 5 VA ² 0.00048 (0.0377) (0.0154) Lag 5 VA ² 0.00048 (0.0377) (0.0154) AIG math 0.0256* (0.0159) Constant 0.184*** Observations 102.395 R-squared 0.099	•	(0.00271)		(0.00401)		(0.00575)
(0.00161) (0.0251) (0.00425) Lag 4 Bonus 0.0395*** Hispanic -0.0538* Lag Reading (0.00453) Lag 4 VA 0.0150*** Am. Indian -0.0302 Lag Absences -0.000653 Lag 4 VA 0.0150*** Am. Indian -0.0302 Lag Absences -0.000653 Lag 4 VA 0.00262 Multi-race -0.0808*** Lag Days ISS -0.032** Lag 5 Bonus 0.0241** White -0.0471* Lag Days ISS -0.0330* Lag 5 VA 0.0145**** (0.0246) Lag Times ISS 0.0580 Lag 5 VA 0.0445*** (0.0256) (0.0371) (0.0257) Lag 5 VA ² -0.000443 Lag Times ISS 0.0580* (0.0257) Lag 5 VA ² -0.000443 Lag Times OSS 0.0527* (0.0126) AlG math 0.184*** Observations 102.395 R-squared 0.0368* Constant 0.184*** Observations 102.395 R-squared 0.0368* <td>Lag 3 VA²</td> <td>0.00441***</td> <td>Black</td> <td>-0.0561**</td> <td>Lag Math</td> <td>-0.0199***</td>	Lag 3 VA ²	0.00441***	Black	-0.0561**	Lag Math	-0.0199***
Lag 4 Bonus 0.395*** Hispanic -0.0638* Lag Reading 0.0105** (0.00965) (0.00975) (0.00453) (0.00453) (0.00453) (0.004543) (0.004543) (0.004543) (0.004543) (0.004543) (0.004545) (0.004545) (0.004545) (0.004545) (0.004545) (0.004545) (0.004545) (0.004545) (0.004545) (0.004545) (0.004545) (0.004545) (0.004545) (0.00147) (0.0113) (0.0311) (0.0249) (0.01337) (0.01337) (0.0113) (0.0249) (0.0073) (0.03057) (0.00356) (0.03057) (0.03057) (0.03057) (0.00454) (0.00255) (0.00256) (0.00256) (0.00256) (0.00560) (0.02565) (0.02565) (0.02565) (0.02565) (0.02565) (0.02565) (0.0159)	•	(0.00161)		(0.0251)		(0.00425)
(0.00995) (0.0327) (0.00433) Lag 4 VA 0.0150*** Am. Indian -0.0302 Lag Absences -0.000653 Lag 4 VA2 0.00282 Multi-race -0.0809*** Lag Days ISS -0.032*** Lag 5 Bonus 0.0211*** White -0.0471* Lag Days ISS -0.030** Lag 5 KA 0.0147*** (0.0246) (0.027*) Lag Days ISS -0.030** Lag 5 VA 0.0145**** (0.0266) (0.027*) Lag Times ISS 0.0850 Lag 5 VA ² -0.000448 Lag Times OSS 0.090*** (0.0226*) Lag 5 VA ² -0.000448 Lag Times OSS 0.0526* (0.0225) AlG math 0.0256* (0.0357) (0.0159) (0.0511) Constant 0.184*** Observations 102.395 R-squared 0.099	Lag 4 Bonus	0.0395***	Hispanic	-0.0638*	Lag Reading	0.0105**
Lag 4 VA 0.0150*** Am. Indian -0.0302 Lag Absences -0.000653 (0.0038) (0.0286) (0.0286) (0.00466) (0.00466) Lag 4 VA ² 0.00282 Multi-race -0.080*** Lag Days ISS -0.033** (0.0147) (0.01311) White -0.0471* Lag Days OSS -0.030** (0.0147) (0.0147) (0.0249) Lag Times ISS 0.0310* (0.0145*** (0.0249) Lag Times ISS 0.0500* Lag 5 VA ² -0.000448 Lag Times OSS 0.0500* (0.0025) AIG math 0.0256* (0.0256)* Constant 0.184*** Observations 102.395 R-squared 0.099	•	(0.00995)		(0.0327)	• •	(0.00453)
(0.00328) (0.0266) (0.00466) Lag 4 VA ² 0.00282 Multi-race -0.0880*** Lag Days ISS -0.0332** (0.00184) (0.0311) (0.0311) (0.0147) (0.0130* (0.0147) Lag 5 Bonus 0.0241** White -0.0471* Lag Days ISS -0.0332** Lag 5 VA 0.0145*** (0.0241) (0.0274) Lag Times ISS 0.0380 Lag 5 VA 0.0145*** (0.0266) (0.0377) (0.0377) Lag 5 VA ² -0.000448 Lag Times ISS 0.0580* (0.0222) Lag 6 Mark 0.02256* 0.050** (0.0256) (0.0226) AIG math 0.0256* (0.0154) AIG reading -0.036** Constant 0.184*** Observations 102.395 R-squared 0.099	Lag 4 VA	0.0150***	Am. Indian	-0.0302	Lag Absences	-0.000653
Lag 4 VA ² 0.00282 Multi-race -0.0880*** Lag Days ISS -0.0331** (0.0014) (0.0311) (0.0311) (0.0147) Lag Days OSS -0.0330* Lag 5 Bonus 0.0241** White -0.0471* Lag Days OSS -0.030* Lag 5 VA 0.0145*** (0.0249) Lag Times ISS (0.0743) Lag 5 VA ² -0.00366) Lag Times ISS 0.0580 (0.0357) Lag 5 VA ² -0.00446 Lag Times OSS 0.0500* (0.0222) Lag 0.00205) AIG math 0.0256* (0.0154) Constant 0.184*** Observations 102.395 R-squared 0.099		(0.00328)		(0.0286)	•	(0.000466)
(0.00164) (0.0311) (0.0147) Lag 5 Bonus 0.0241** White -0.0471* Lag Days OSS -0.0130* Lag 5 VA 0.0145**** (0.0249) Lag Times ISS 0.0360 (0.0377) Lag 5 VA 0.0145**** (0.0387) (0.0387) (0.0229) (0.0222) Lag 5 VA ² -0.000448 Lag Times OSS 0.050** (0.0225) AIG math 0.0256* (0.0154) AIG reading -0.0368** Constant 0.184*** Observations 102.395 R-squared 0.099	Lag 4 VA ²	0.00282	Multi-race	-0.0880***	Lag Days ISS	-0.0332**
Lag 5 Bonus 0.0241** White -0.0471* Lag Days OSS -0.0130* (0.0113) (0.0249) Lag 5 VA 0.0145*** (0.0249) (0.0249) (0.00360) (0.0357) Lag 5 VA ² -0.000448 Lag Times OSS 0.0500** (0.0220) (0.0220) AIG math 0.0256* (0.0154) AIG reading -0.0368** Constant 0.184*** Observations 102.395 R-squared 0.099		(0.00184)		(0.0311)		(0.0147)
(0.0113) (0.0249) (0.0073) Lag 5 VA 0.0145*** Lag Times ISS 0.0580 (0.00366) (0.0377) (0.0222) (0.0222) Lag 5 VA ² -0.000448 Lag Times OSS 0.0500** (0.00205) AIG math 0.0256* (0.0154) (0.0154) AIG reading -0.0368** (0.0159) Constant 0.184*** Observations 102.395 R-squared 0.099	Lag 5 Bonus	0.0241**	White	-0.0471*	Lag Days OSS	-0.0130*
Lag 5 VA 0.0145*** Lag Times ISS 0.05800 (0.00366) (0.0357) (0.00266) (0.0327) (0.0022) AIG math 0.02256* (0.0154) AIG reading -0.0368** Constant 0.184*** Observations 102.395 R-squared 0.099	•	(0.0113)		(0.0249)	• •	(0.00743)
(0.00366) (0.0357) Lag 5 VA ² -0.000448 Lag Times OSS 0.0500** (0.00205) AIG math 0.0222) AIG math 0.0256* (0.0154) (0.0154) AIG reading -0.0368** (0.0159) Constant 0.184***	Lag 5 VA	0.0145***			Lag Times ISS	0.0580
Lag 5 VA ² -0.000448 Lag Times OSS 0.0500** (0.00205) AIG math 0.0225* (0.0154) AIG reading -0.0366** (0.0159) Constant 0.184*** Observations 102.395 R-squared 0.099	•	(0.00366)				(0.0357)
(0.00205) (0.0222) AIG math 0.0226* (0.0154) AIG reading -0.0368** (0.0159) Constant 0.184*** Observations 102.395 R-squared 0.099	Lag 5 VA ²	-0.000448			Lag Times OSS	0.0500**
AlG math 0.0256* (0.0154) AlG reading -0.0368** (0.0159) Constant 0.184*** Observations 102,395 R-squared 0.099	-	(0.00205)			•	(0.0222)
(0.0154) AIG reading -0.0368** (0.0159) Constant 0.184*** Observations 102,395 R-squared 0.099		. ,			AIG math	0.0256*
AlG reading -0.0368** (0.0159) Constant 0.184*** Observations 102,395 R-squared 0.099						(0.0154)
(0.0159) Constant 0.184*** Observations 102,395 R-squared 0.099					AIG reading	-0.0368**
Constant 0.184*** Observations 102,395 R-squared 0.099						(0.0159)
	Constant	0.184***	Observations	102,395	R-squared	0.099

R-squared of Predictions

Prediction Model

Full Model	9.85%
Past VA and Teacher variables	9.76%
Past VA variables	9.56%
Past Gains variables	7.37%
Past Levels variables	1.51%
Class variables	0.09%
Levels predicting levels	15.26%

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Testing for heterogeneous effects by bonus probability:

 $\begin{array}{l} \mathsf{y}_{ijsgt} = \theta_1 \mathit{Tr}_{st} + \theta_2 \mathit{Tr}_{st} \times \mathit{Prob}_{jt} + \Gamma_1 \mathit{Ev} \mathit{Tr}_s + \Gamma_2 \mathit{Ev} \mathit{Tr}_s \times \mathit{Prob}_{jt} + \\ \nu \mathit{Prob}_{jt} + \beta \mathit{X}_{it} + \delta_{gt} + \epsilon_{isgt} \end{array}$

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Effects by Probability of Bonus

Effect on Test Scores by Predicted Probability of Bonus				
	Math	Reading		
Specifications				
Linear				
Treated × Pr(Bonus)	-0.027	-0.273**		
	(0.144)	(0.109)		
Quadratia				
Quadratic Treated v Dr(Panus)	0.060	0 202		
Treated × Pr(Bollus)	(0.000	-0.302		
Treated v Dr(Panus)2	(0.211)	(0.203)		
Treated × Pr(Bollus)	-0.514	-0.010		
	(0.001)	(0.065)		
Above/Below Median				
Treated \times [Pr(Bonus) < 13.6%]	0.083**	0.043**		
	(0.0417)	(0.0214)		
Treated \times [Pr(Bonus) \ge 13.6%]	0.053**	-0.041**		
	(0.0313)	(0.0208)		
Temples				
Tracted of [De(Denors) < 10.79/]	0.001*	0.050		
Treated × [Pr(Bonus) < 10.7%]	(0.0426)	0.050		
Tracted \dots [10.7.9/ \leq Dr(Derms) \leq 17.29/]	(0.0420)	(0.0319)		
Treated \times [10.7 % \leq Pr(Bonus) $<$ 17.2%]	(0.069.)	0.000		
Treated [D.(Dame) > 17.0%]	(0.0420)	(0.0130)		
Treated × [Pr(Bonus) ≥ 17.2%]	(0.0345)	-0.025		
	(0.0345)	(0.0271)		
Observations	1,658,694	1,658,694		
Student controls	YES	YES		
Year-by-grade FE	YES	YES		

Using Test Score Gains

Effect on Test Scores by Predicted Probability of "Gains' Bonus				
	Math	Reading		
Specifications				
Linear				
Treated \times Pr(Bonus)	-0.078	-0.303*		
	(0.224)	(0.159)		
Quadratic				
Treated × Pr(Bonus)	-0.062	-0.240		
	(0.398)	(0.309)		
Treated \times Pr(Bonus) ²	-0.090	-0.304		
	(1.483)	(0.913)		
Above/Below Median				
Ireated \times [Pr(Bonus) < 13.4%]	0.076**	0.021		
	(0.0350)	(0.0147)		
Treated \times [Pr(Bonus) \ge 13.4%]	0.088***	-0.007		
	(0.0324)	(0.0226)		
Toroilos				
	0.007**	0.040		
Treated × [Pr(Bonus) < 11.5%]	0.097**	0.040		
T	(0.0468)	(0.0316)		
Treated \times [11.5 % \leq Pr(Bonus) $<$ 15.9%]	0.101***	0.037*		
T (D (D	(0.0377)	(0.0219)		
Treated \times [Pr(Bonus) \ge 15.9%]	0.032	-0.045*		
	(0.0351)	(0.0268)		
Observations	1 658 604	1 658 604		
Student controls	VES	VES		
Vear-by-grade FF	VES	VES		
ical-by-grade i E	163	163		

Using Test Score Levels

Effect on Test Scores by Predicted Probability of "Levels" Bonus				
	Math	Reading		
Specifications				
Linear				
Treated × Pr(Bonus)	-0.329	-0.536**		
	(0.342)	(0.222)		
Quadratic				
Treated × Pr(Bonus)	0.142	-0.382		
	(0.259)	(0.253)		
Treated \times Pr(Bonus) ²	2.397*	0.652		
	((1.239))	(1.322)		
Above/Below Median				
Treated × [Pr(Bonus) < 12.9%]	0.041	-0.006		
	(0.0327)	(0.0139)		
Treated \times [Pr(Bonus) \ge 12.9%]	0.145***	-0.013		
	(0.0429)	(0.0543)		
Tauailaa				
Terclies	0.007	0.004		
Ireated \times [Pr(Bonus) < 9.8%]	0.027	-0.004		
	(0.0338)	(0.0141)		
Ireated \times [9.8 % \leq Pr(Bonus) $<$ 14.3%]	0.106***	0.026		
	(0.0316)	(0.0304)		
Treated \times [Pr(Bonus) \ge 14.3%]	0.014	-0.098**		
	(0.0533)	(0.0436)		
Observations	1 659 604	1 659 604		
Cuservations	1,000,094	1,006,094		
Very her made EF	163	165		
rear-by-grade FE	15	TES		

Robustness

- Pre-trends: separately for each district
- Differential classroom composition in treatment group

Differential sorting of students into classrooms

Pre-Trends: Guilford Math



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Pre-Trends: Guilford Reading



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Pre-Trends: Charlotte-Mecklenburg Math



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Pre-Trends: Charlotte-Mecklenburg Math



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Pre-Trend Regression

Testing for Pre-trends in Math Scores								
	(1) (2) (3) (4)							
VARIABLES								
Ever-treated $ imes$ Time	0.00560	0.00430	0.0153	0.00883				
	(0.00458)	(0.00614)	(0.0106)	(0.0118)				
Observations	1,099,634	1,099,462	1,099,630	1,099,406				
R-squared	0.696	0.738	0.705	0.740				
Student controls	YES	YES	YES	YES				
Year-by-grade FE	YES	YES	YES	YES				
Teacher FE		YES						
Teacher-by-School FE				YES				
School FE			YES					
	• .1							

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Pre-Trend Regression

Testing for Pre-trends in Reading Scores					
	(1)	(2)	(3)	(4)	
VARIABLES					
Ever-treated $ imes$ Time	-0.00410	-0.00289	0.0111	0.00130	
	(0.00409)	(0.00566)	(0.00847)	(0.0106)	
Observations	1,099,634	1,099,462	1,099,630	1,099,406	
R-squared	0.696	0.738	0.705	0.740	
Student controls	YES	YES	YES	YES	
Year-by-grade FE	YES	YES	YES	YES	
Teacher FE		YES			
Teacher-by-School FE				YES	
School FE			YES		

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Classroom Characteristics

Characteristic	"Treatment Effect
Age	-0.092***
	(0.0202)
AIG math	-0.041**
	(0.0166)
AIG reading	-0.040**
	(0.0161)
Exceptional	-0.036***
	(0.0125)
First year in school	0.0349
	(0.0232)
Lag Days Absent	0.762***
-	(0.249)
Lag Days ISS	0.006
	(0.015)
Lag Days OSS	0.095***
	(0.0365)
Lag Times ISS	0.008
Lag Times OSS	(0.0142)
	0.033***
	(0.0125)
Lag Math	-0.011
	(0.0526)
Lag Reading	-0.094*
	(0.0535)
Limited English	0.000
	(0.00981)
Economically Disadvantaged	0.016
	(0.0183)
Male	-0.004
Repeat grade	(0.0139)
	-0.006***
	(0.00208)

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Sorting Students into Classrooms

Testing for Sorting to Teachers within Schools	
Characteristic	Treatment effect on SI
Age	-0.096
	(0.103)
AIG math	-0.013
	(0.0140)
AIG reading	-0.014
	(0.0130)
Exceptional	-0.036**
	(0.0176)
First year in school	0.079**
	(0.0365)
Lag Days Absent	6.360***
	(0.585)
Lag Days ISS	0.874***
	(0.0469)
Lag Days OSS	0.953***
	(0.0513)
Lag Times ISS	0.874***
Lag Times OSS	(0.0469)
	0.882***
	(0.0380)
Lag Math	0.028
	(0.0641)
Lag Reading	-0.080
	(0.0722)
Limited English	0.011
	(0.0147)
Economically Disadvantaged	0.052*
	(0.0266)
Male Repeat grade	-0.013
	(0.0271)
	-0.008*
	(0.00432)
Observations (School-vear)	15 236

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• Overall effect of performance pay seems small



- Overall effect of performance pay seems small
- I fail to find evidence for teachers closer to the threshold responding more to the incentive

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- Overall effect of performance pay seems small
- I fail to find evidence for teachers closer to the threshold responding more to the incentive
- Why?
 - Teachers may not have any idea what their predicted VA is or how/if their effort changes their VA

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- Why?
 - Teachers may not have any idea what their predicted VA is or how/if their effort changes their VA

- The large noise in single-year VA may weaken incentives
 - Makes it hard to learn from one's VA
 - Makes it hard to get teachers to buy in

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 - The large noise in single-year VA may weaken incentives
 - Makes it hard to learn from one's VA
 - Makes it hard to get teachers to buy in
 - Incentive targets high-performing teachers; do they have less margin for improvement?
Conclusion

- Overall effect of performance pay seems small
- I fail to find evidence for teachers closer to the threshold responding more to the incentive
- Why?
 - Teachers may not have any idea what their predicted VA is or how/if their effort changes their VA
 - The large noise in single-year VA may weaken incentives
 - Makes it hard to learn from one's VA
 - Makes it hard to get teachers to buy in
 - Incentive targets high-performing teachers; do they have less margin for improvement?

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 Are teachers already sufficiently focused on test scores? (NCLB) Use multiple years to evaluate teacher VA, incorporate into salary increases

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- Use multiple years to evaluate teacher VA, incorporate into salary increases
- Evaluate small groups of teachers to encourage teamwork and reduce noise

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- Use multiple years to evaluate teacher VA, incorporate into salary increases
- Evaluate small groups of teachers to encourage teamwork and reduce noise

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 Focus more incentives on bottom of the teacher VA distribution