The Multidimensional Impact of Teachers on Students

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Overview of Teacher Quality

Teacher quality

- Teachers are a key component of educational process
- Teacher quality largely measured using value-added models
- Value-added models rely exclusively on standardized test scores

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Use of test-score value-added

- Large and valuable body of research using test-score value-added
- Many states and school districts use test-score value-added in teacher evaluations

Education Production Function

Multidimensional education production function

- Many have argued test scores do not fully capture teachers' impact on students
- Early theoretical value-added models had multiple dimensions of student output (Hanushek 1971)
  - "This model simply states that education output [is] a multidimensional factor."
- Focusing only on test scores may lead to a mismeasurement of overall teacher quality and resource misallocation

Our Paper Has Two Main Parts

1. **Create Test-Score and Non-Test-Score Value-Added**
   - How teachers affect students' suspensions, GPA, absences, and assessments of students' social and learning skills
   - Modify value-added framework by using students' next year teacher assessment
   - Find little correlation between a teacher's test-score and non-test-score quality

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2. **Estimate Long-Term Effects**
   - Estimate the effect of each dimension of teacher quality on high school outcomes
   - Having a high quality non-test-score teacher is just as important as having a high quality test-score teacher

Three Applications Within Education

1. **Teacher Removal Policy Simulation**
   - Quantify the benefit of using multiple dimensions of teacher quality
   - By using both dimensions of teacher quality, teacher dismissal policies can improve most high school outcomes by over 50 percent compared to just test-score value-added

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2. **Critical Period of Effects**
   - Estimate when in the educational life cycle having a high quality teacher matters most
   - Teacher effects in both dimensions are larger in middle school and high school than elementary school

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2. **Critical Period of Effects**
   - Estimate when in the educational life cycle having a high quality teacher matters most
   - Teacher effects in both dimensions are larger in middle school and high school than elementary school
3. **Value-Added in Untested Subjects**
   - Estimate the long-term effects of teacher quality in untested subjects
   - Teacher effects for students' math, reading, and writing are larger than other subjects

Literature Review

Test-score value-added measures

- Hanushek (1971) developed the concept of teacher value-added
- Tennessee started using test-score valued-added to measure teachers (Sanders and Horn 1994)
- Test-score value-added are now used in teacher evaluations (Florida, Ohio, Tennessee), selective dismissal (Goldhaber and Hansen 2010), and incentive pay (Goodman Turner 2013; Fryer 2013; Neal 2011)
- High test-score value-added teachers increase students' earnings and likelihood of attending college (Chetty, Friedman, Rockoff 2014)

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Non-test-score measures

- Non-test-score teacher value-added estimates on short-term outcomes (Jennings and DiPrete 2010; Ruzek et al. 2014; Gershenson 2016; Blazar and Kraft 2016; Kraft and Grace 2016)
- Jackson (2016) shows teacher effects for 9th graders' behavior on high school graduation

Data and Background

Los Angeles Unified School District

- Second largest school district in the nation
- Over 600,000 students per year
- 72 percent of students are Hispanic

Data

- Administrative panel data from 2002-03 to 2014-15
- Over 110,000 3rd through 5th graders per year
- Links teachers and students over time

Student Output Data

Available for grades 2 to 11

- End of year math and English test scores

Available for all grades

- Suspensions
- Absences
- Held back
- GPA

Available for grades 1 to 5

- Effort GPA
- Learning and social skills GPA
- Work and study habits GPA

Progress Report

PROGRESS REPORT

School Year:

Principal:
Teacher: **Room:**
Grade Level:

Birth Date:	Grade Reporting Period					
	1		2		3	
Academic Subjects	AC	EF	AC	EF	AC	EF
Reading						
ELD Reading						
Writing						
ELD Writing						
Listening						
ELD Listening						
Speaking						
ELD Speaking						
Mathematics						
History/Social Science						
Science						
Health Education						
Physical Education						
Arts						

ACHIEVEMENT SCORES
***Meets Standards**
4 = Advanced*
3 = Proficient*
2 = Partially Proficient
1 = Not Proficient

(ELD) ENGLISH LANGUAGE DEVELOPMENT SCORES
4 = Advanced Progress
3 = Average Progress
2 = Partial Progress
1 = Limited Progress

EFFORT SCORES
4 = Strong
3 = Consistent
2 = Inconsistent
1 = Poor

Work and Study Habits	Reporting Period		
	1	2	3
Makes good use of time			
Works independently			
Organizes materials			
Presents neat and careful work			
Completes homework on time			
Learning and Social Skills			
Follows directions and procedures			
Accepts and respects authority			
Cooperates well in a group situation			
Shows dependability			
Takes responsibility			
Exercises self-control			
Resolves conflicts appropriately			
Demonstrates appropriate social interaction with peers			
Demonstrates fairplay			

Student Assessment

Instructional Programs
Master Plan Program

ELD Level **Start Date** **End Date** **Grade Period**

Instructional Services
Interventions

Intervention **Date**

Office Copy

GPA Progress Report

Birth Date:	Grade Reporting Period					
	1		2		3	
Academic Subjects	AC	EF	AC	EF	AC	EF
Reading						
ELD Reading						
Writing						
ELD Writing						
Listening						
ELD Listening						
Speaking						
ELD Speaking						
Mathematics						
History/Social Science						
Science						
Health Education						
Physical Education						
Arts						

Learning Skills Progress Report

Work and Study Habits	Reporting Period		
	1	2	3
Makes good use of time			
Works independently			
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Learning and Social Skills			
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Outcome Data

Test scores

- Math and English high school exit exams
- Math, English, science, and history end of year state tests
- SAT (score and taking it or not)

GPA

- Achievement, effort, and cooperation

Additional Outcomes

- High school dropout
- Days suspended
- Log absences
- Held back

Value-Added Methodology

Intuition

- How much does a teacher increase a students' test scores compared to the previous year
- Simplest version is a first difference of the students' test scores for a teacher
- Requires that students are not sorted to teachers on unobservable components of student achievement

Value-Added Methodology

Residualize student output

$$S_{ijt} = \Gamma X_{ijt} + \varepsilon_{ijt}$$

$$\text{where } \varepsilon_{ijt} = \mu_{jt} + \alpha_c + \gamma_{it}$$

Residuals

$$\nu_{ijt} = S_{ijt} - \hat{\Gamma} X_{ijt}$$

- S_{ijt}: student test scores
- X_{ijt}: third degree polynomial of prior student, class, and grade achievement, behavior, learning skills, and demographics fully interacted with grade fixed effects

Value-Added

Estimated value-added

- Mean of the student residuals for each teacher and year:

$$\bar{\nu}_{jt} = \frac{1}{N} \sum_{i=1}^{N} \nu_{ijt}$$

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- Estimate $\hat{\psi}$ using:

$$\boldsymbol{\psi} = \underset{\{\psi_{t-x},\ldots,\psi_{t+x}\}}{\arg\min} \sum_{j}^{J} \left(\bar{\nu}_{jt} - \sum_{s=t-x}^{t+x} \psi \bar{\nu}_{js} 1[s \neq t] \right)^2$$

Non-Test-Score Value-Added

Challenges to measuring non-test-score value-added

- Since non-test-score student outputs are assessed by teachers, using the concurrent year may bias the value-added estimate
  - Lenient teachers may suspend students less, but negatively effect students' future behavior
  - Grade inflation
- Teachers could easily manipulate non-test-score value-added if concurrent year is used

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Use student outputs in the next year

$$S_{ij(t+1)} = \Gamma X_{ijt} + \varepsilon_{ijt}$$

Three Indices

Test-score index

- Math and English test scores

Behavior index

- Suspended, absences, held back, and achievement GPA

Learning skills index

- Effort GPA, work and study habits GPA, and learning and social skills GPA

Computing Indices

Steps to compute value-added indices

1. Standardize value-added variables
2. Sum value-added variables with equal weights to form index
3. Standardize index

Robustness checks

1. Factor analysis within each of the three indices
2. Factor analysis including all value-added variables
3. Include each value-added variable individually (i.e. no indices)

Correlations Between Value-Added Measures

Value-Added	Test Score	Behavior	Learning Skills
Test Score	1		
Behavior	0.145	1	
Learning Skills	0.174	0.459	1

Long-Term Effects Methodology

Long-term effects

$$y_{ijT} = \beta^s \hat{\theta}^s_{jt} + \beta^b \hat{\theta}^b_{jt} + \beta^l \hat{\theta}^l_{jt} + \Gamma X_{ijt} + \eta_{ijt}$$

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Key assumption for causal effect

- No sorting of students with unobservables that lead to better long run outcomes to teachers with better value-added scores

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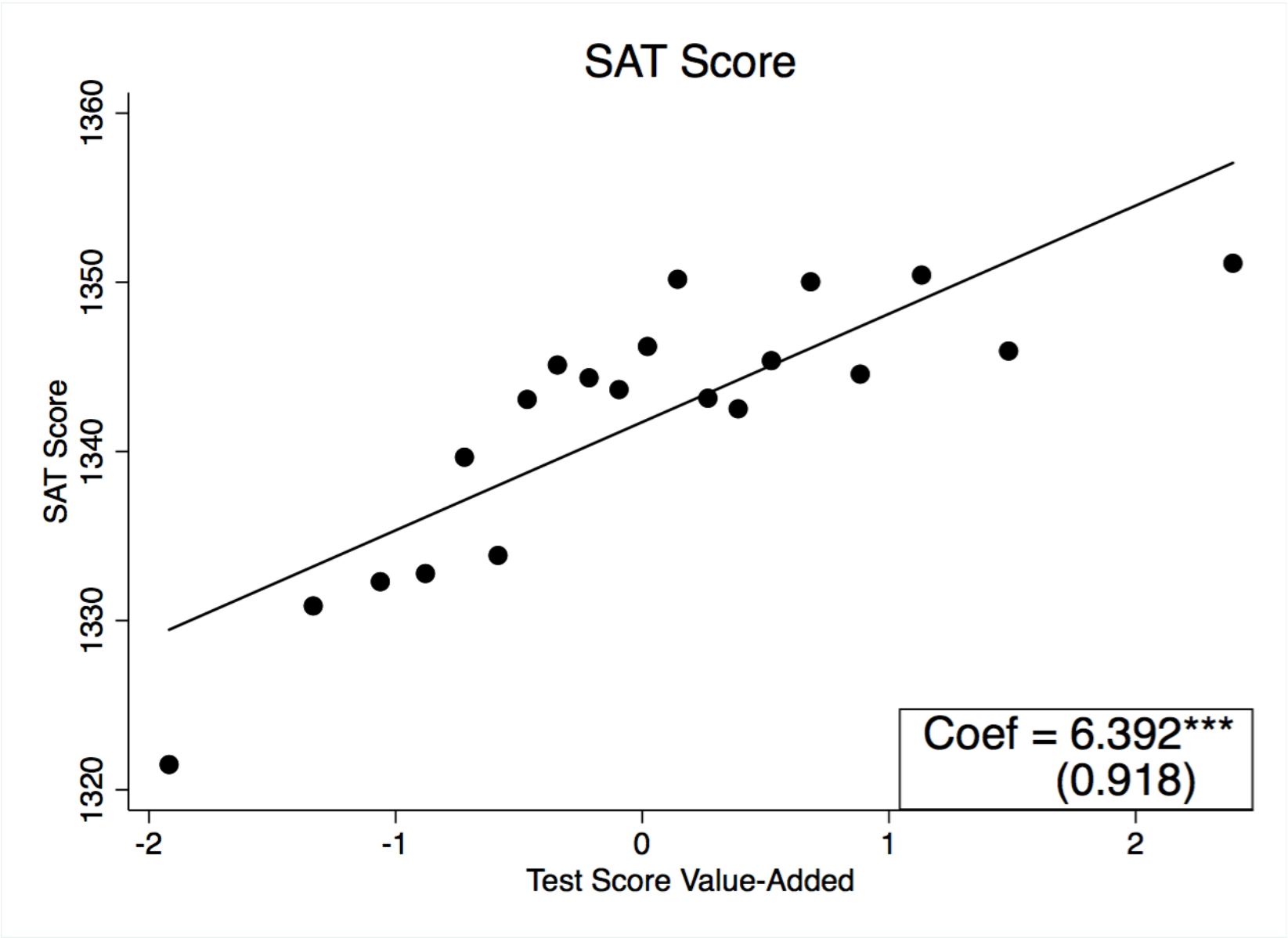
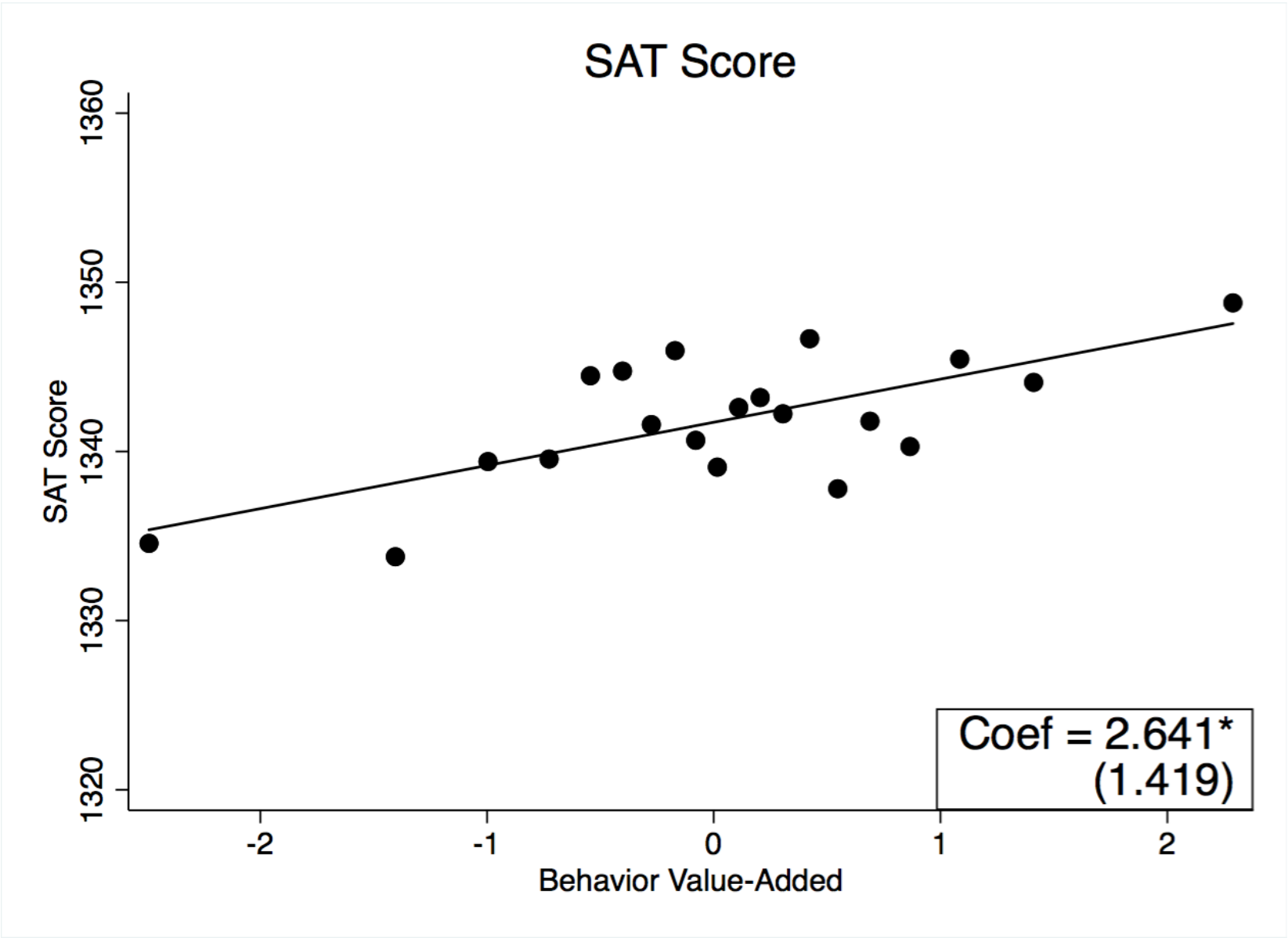
Little evidence of bias

- Value-added measures are forecast unbiased
- Find no effect on predicted outcomes as a placebo test
- Similar results from a quasi-experiment using teachers switching between grades and schools
- Kane and Staiger's (2008) LAUSD random-assignment experiment

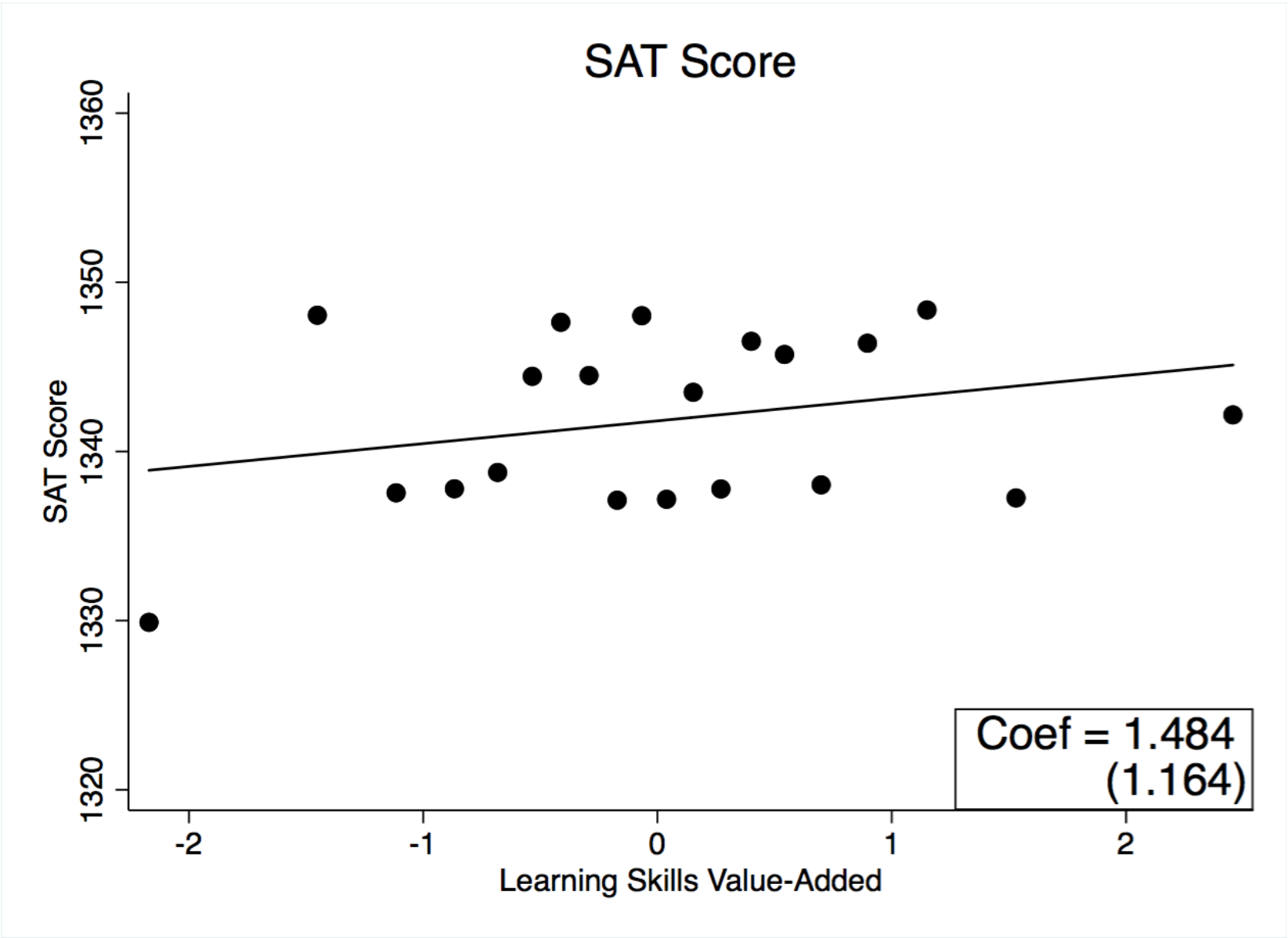
Effect of Test-Score Value-Added: SAT Score



Effect of Behavior Value-Added: SAT Score



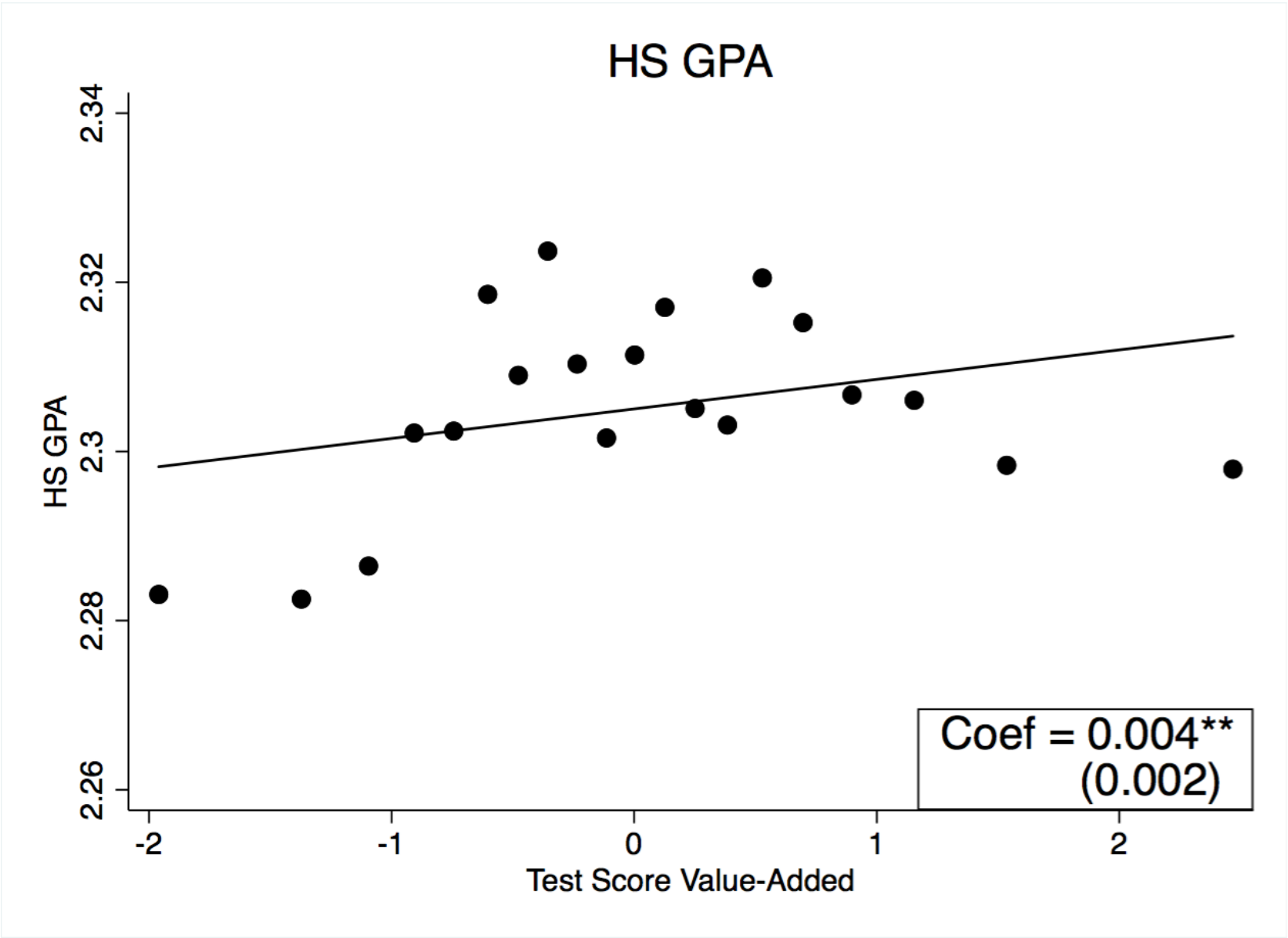
Effect of Learning Skills Value-Added: SAT Score



Effects on Tests

Value-Added	SAT Score	Took SAT	Math CAHSEE	English CAHSEE
Test Score	6.237***	-0.002	0.022***	0.016***
	(1.023)	(0.002)	(0.002)	(0.002)
Behavior	1.955	0.010***	0.013***	0.004
	(1.494)	(0.003)	(0.004)	(0.003)
Learning Skills	-0.547	-0.001	-0.005*	0.001
	(1.173)	(0.002)	(0.003)	(0.003)
Observations	60,694	102,517	152,345	151,820
R-squared	0.617	0.145	0.500	0.512

Effect of Test-Score Value-Added: HS GPA



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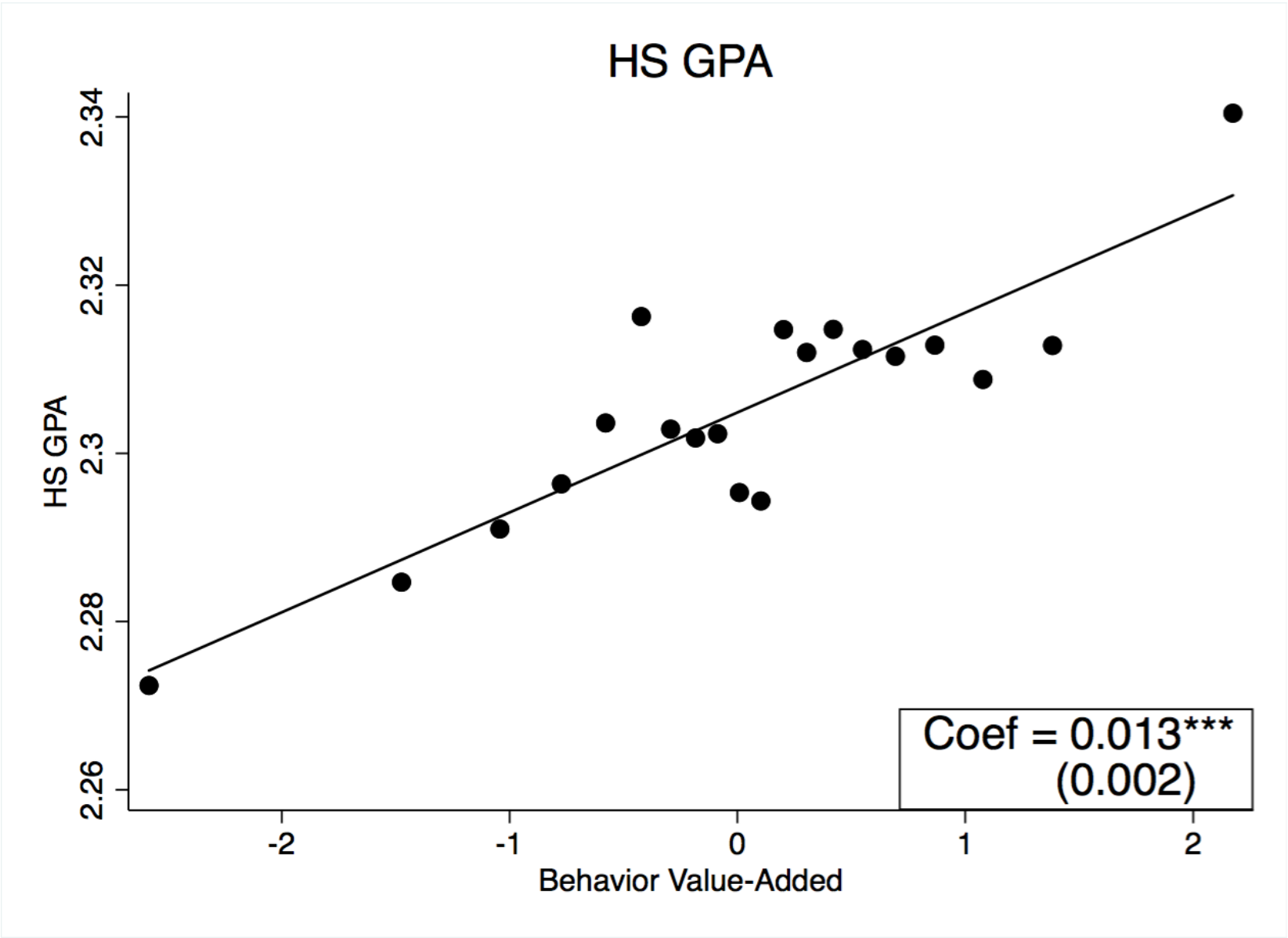

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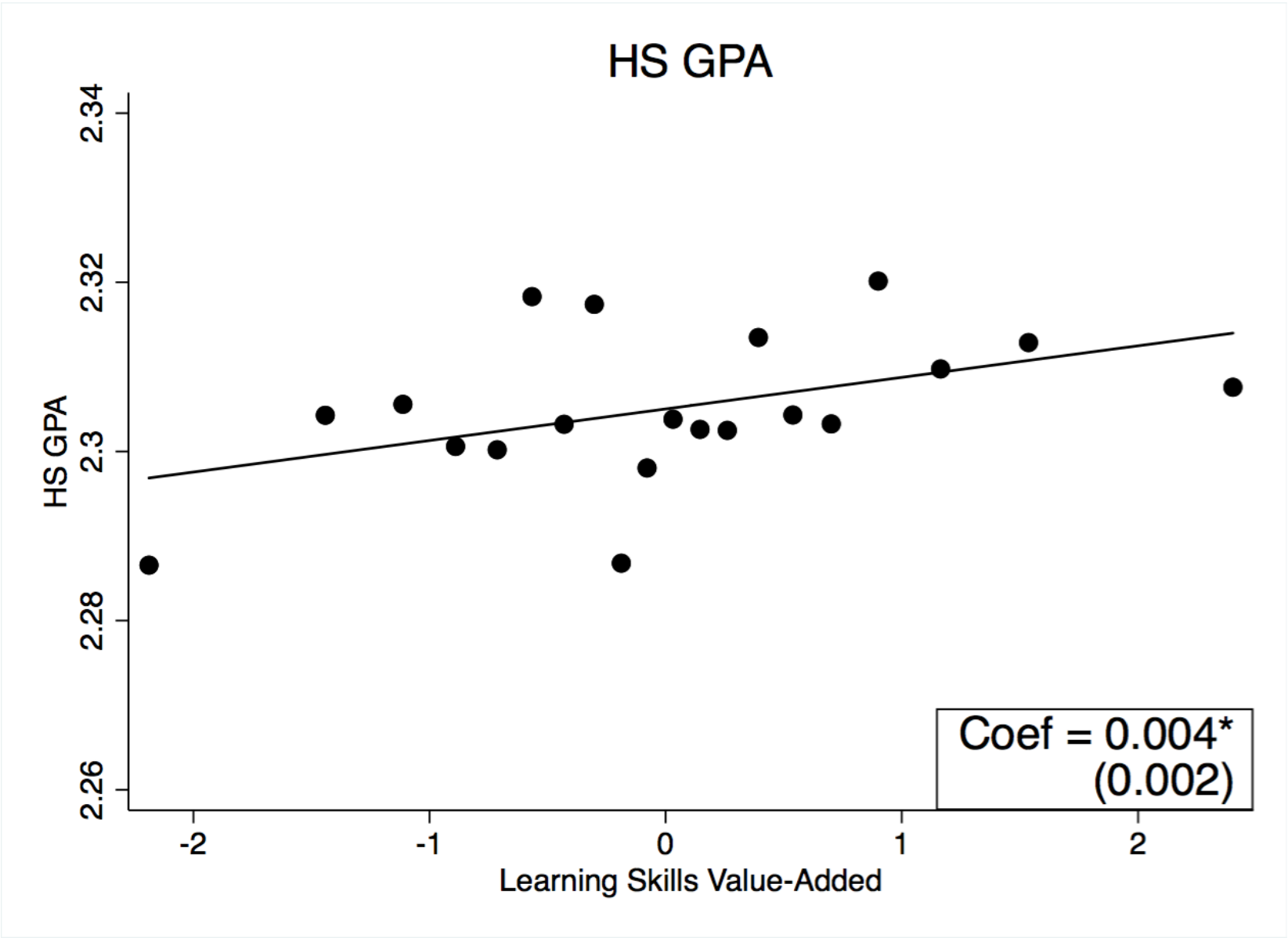
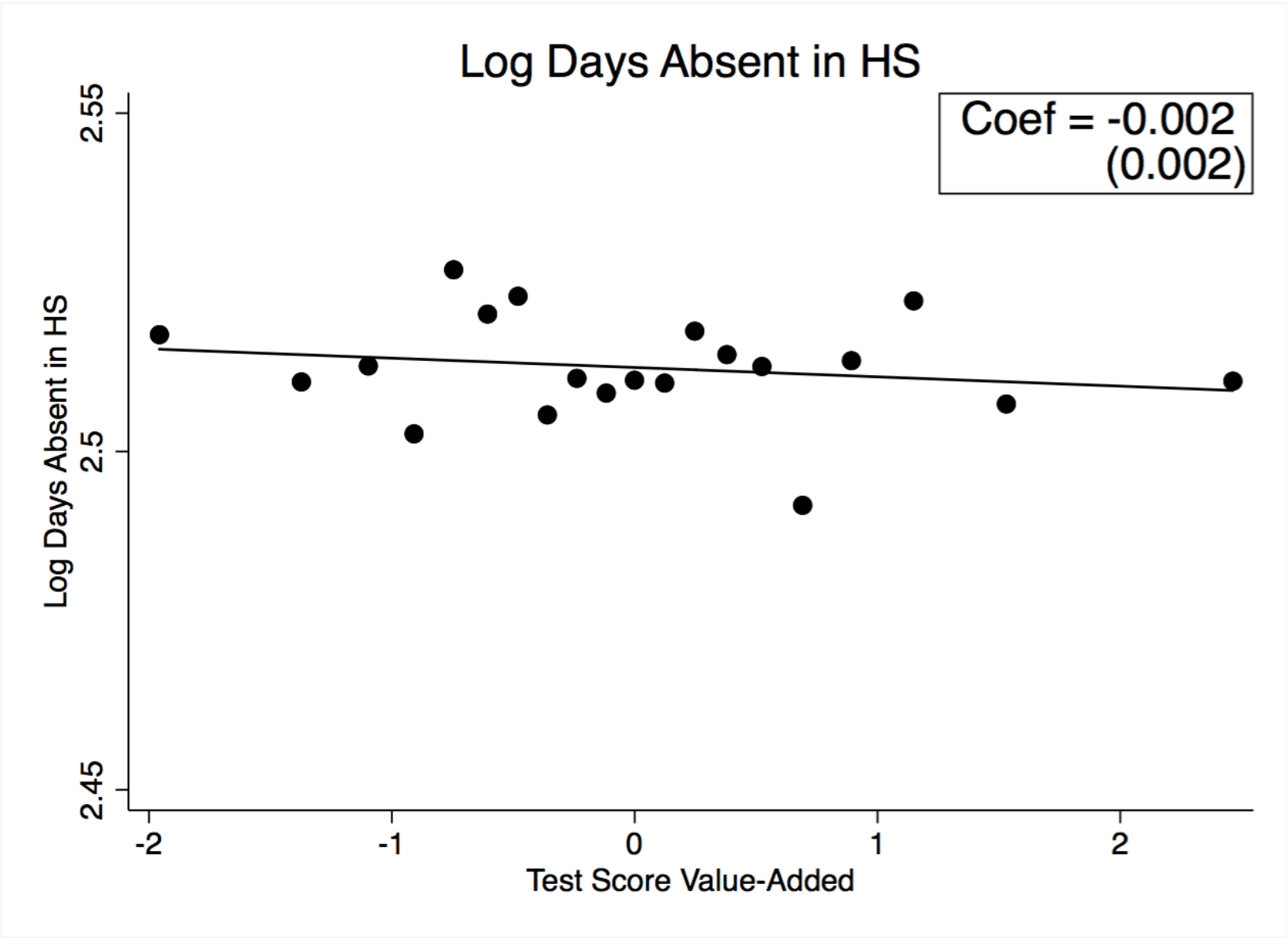


Effects on GPA

Value-Added	GPA	Effort GPA	Cooperation GPA
Test Score	0.002	0.003**	0.005***
	(0.002)	(0.001)	(0.001)
Behavior	0.013***	0.007***	0.005***
	(0.003)	(0.002)	(0.001)
Learning Skills	-0.002	-0.003*	-0.003**
	(0.003)	(0.002)	(0.001)
Observations	293,028	233,078	233,078
R-squared	0.244	0.234	0.239

Effect of Test-Score Value-Added: Log Absences



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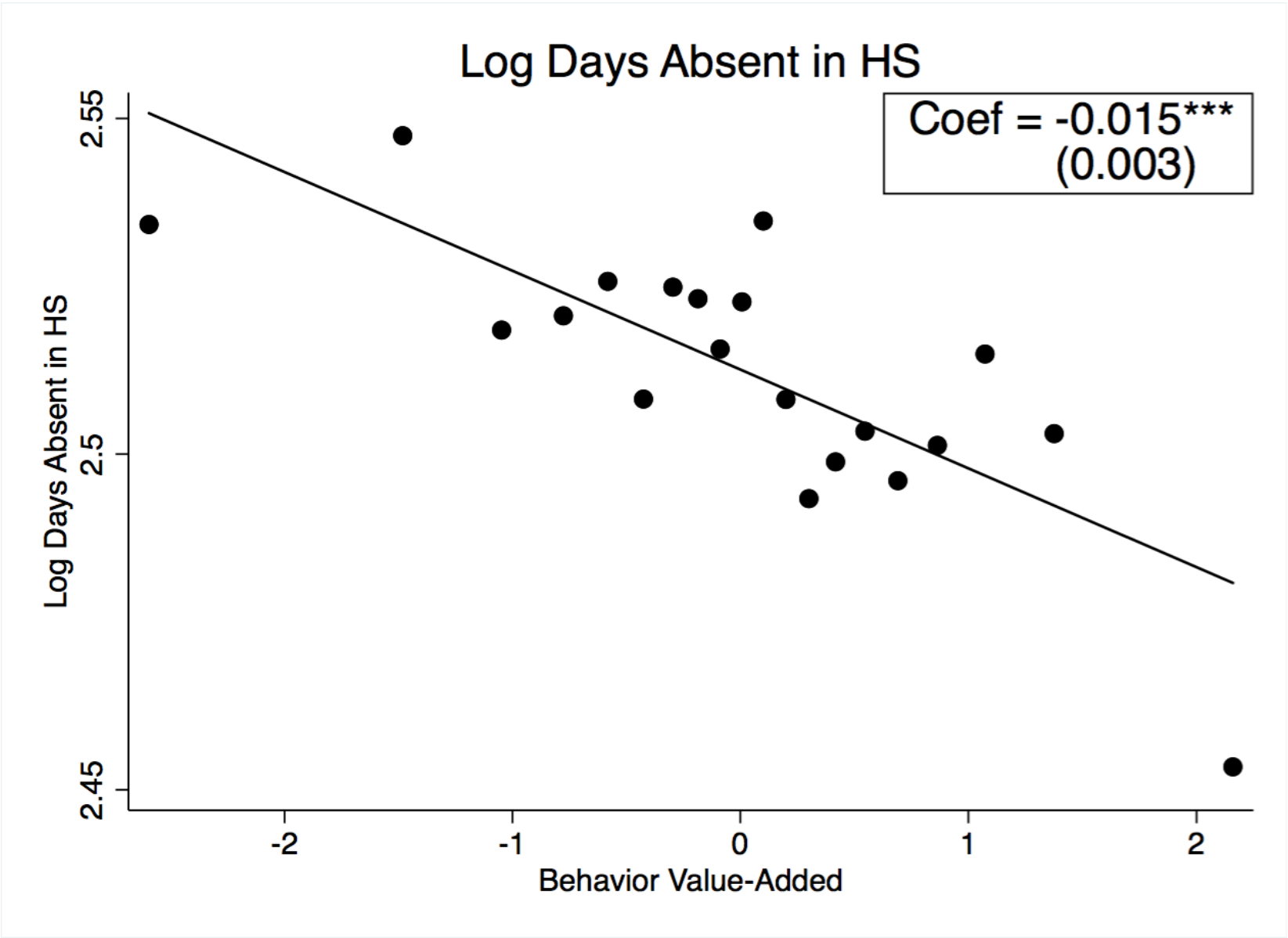

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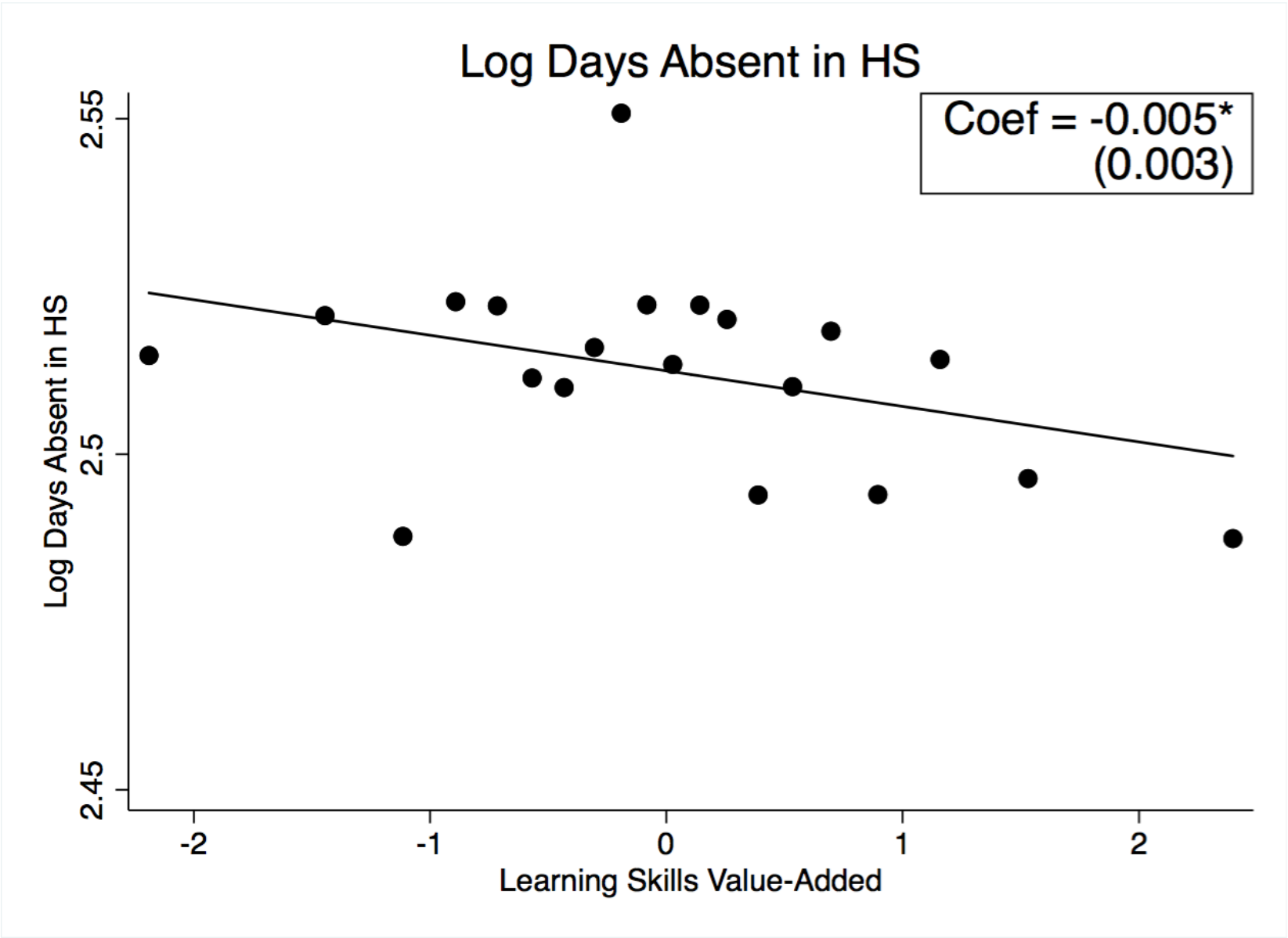


Effects on Behavior

Value-Added	Log Absences	LAUSD Dropout	Days Suspended	Held Back
Test Score	0.001	-0.002	0.001	0.001
	(0.003)	(0.002)	(0.001)	(0.001)
Behavior	-0.016***	-0.003	-0.003*	-0.006***
	(0.003)	(0.003)	(0.001)	(0.002)
Learning Skills	0.002	-0.000	-0.002	0.001
	(0.003)	(0.003)	(0.001)	(0.002)
Observations	277,333	135,786	316,123	221,757
R-squared	0.267	0.293	0.040	0.108

Effects Using Student Index Distribution

Value-Added	SAT Score	Took SAT	Math CAHSEE	English CAHSEE
Test Score	126.9***	0.015	0.402***	0.357***
	(15.7)	(0.030)	(0.039)	(0.035)
Behavior	49.8*	0.190***	0.266***	0.159***
	(26.7)	(0.049)	(0.067)	(0.060)
Learning Skills	30.1**	0.043**	0.067**	0.058**
	(12.7)	(0.019)	(0.027)	(0.023)
Observations	60,694	102,517	152,345	151,820

Effects Using Student Index Distribution

Value-Added	GPA	Effort GPA	Cooperation GPA
Test Score	0.117***	0.082***	0.110***
	(0.031)	(0.020)	(0.018)
Behavior	0.264***	0.138***	0.102***
	(0.048)	(0.030)	(0.026)
Learning Skills	0.065***	0.026*	0.013
	(0.021)	(0.013)	(0.012)
Observations	293,028	233,078	233,078

Effects Using Student Index Distribution

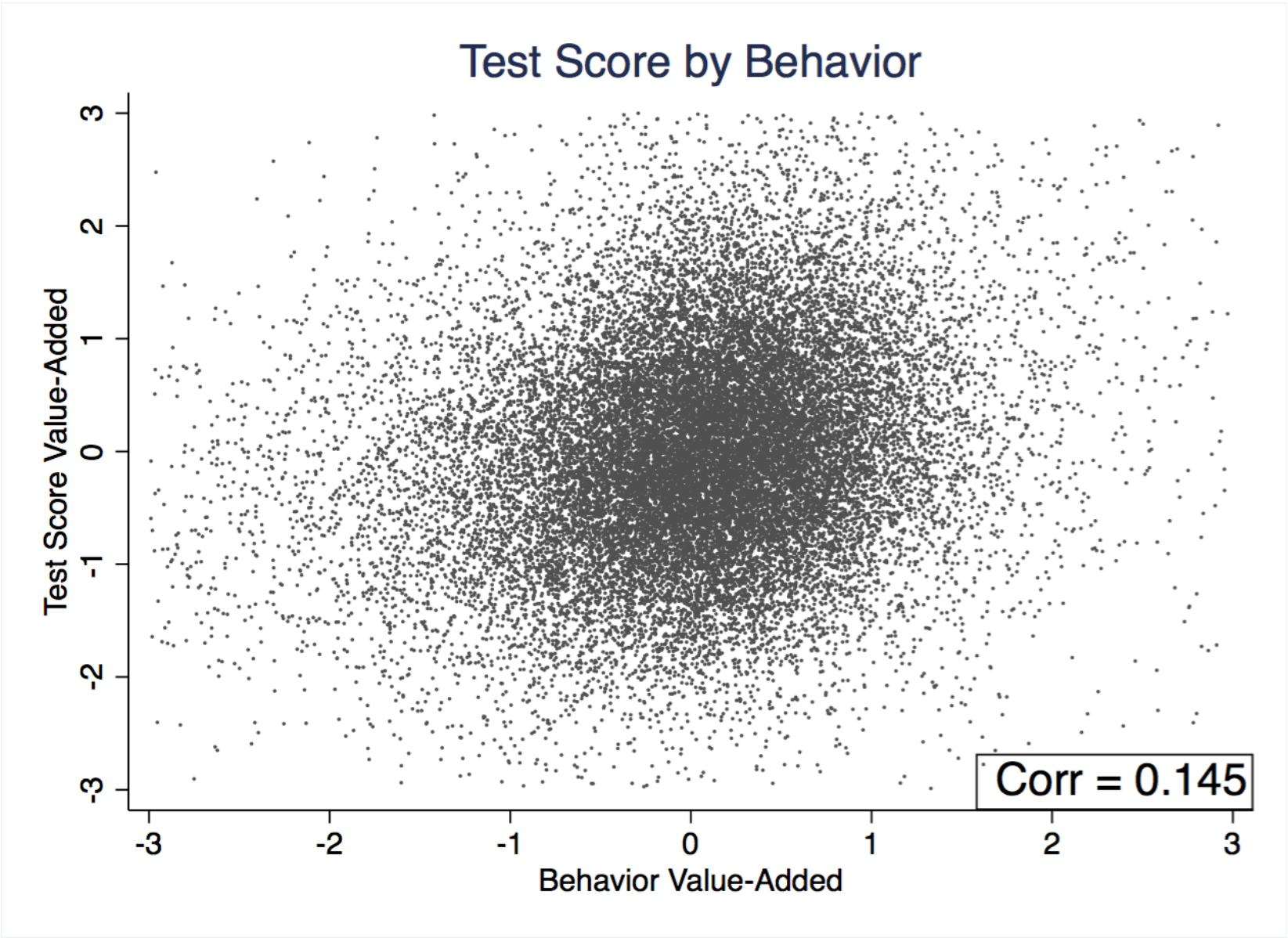
Value-Added	Log Absences	LAUSD Dropout	Days Suspended	Held Back
Test Score	-0.094**	-0.031	0.005	-0.010
	(0.045)	(0.032)	(0.018)	(0.020)
Behavior	-0.303***	-0.031	-0.060**	-0.094***
	(0.059)	(0.053)	(0.025)	(0.033)
Learning Skills	-0.075***	-0.013	-0.029***	-0.015
	(0.026)	(0.025)	(0.026)	(0.013)
Observations	277,333	135,786	316,123	221,757

Hypothetical Policy Simulation

Setup

1. Identify bottom 5 percent of teachers using:
   - Only test-score value-added
   - Only behavior value-added
   - Half test score and half behavior
   - Optimal combination of all three value-added
2. Replace bottom 5 percent with district average teacher
3. Estimate benefit to students who receive a new teacher

Hypothetical Policy Simulation



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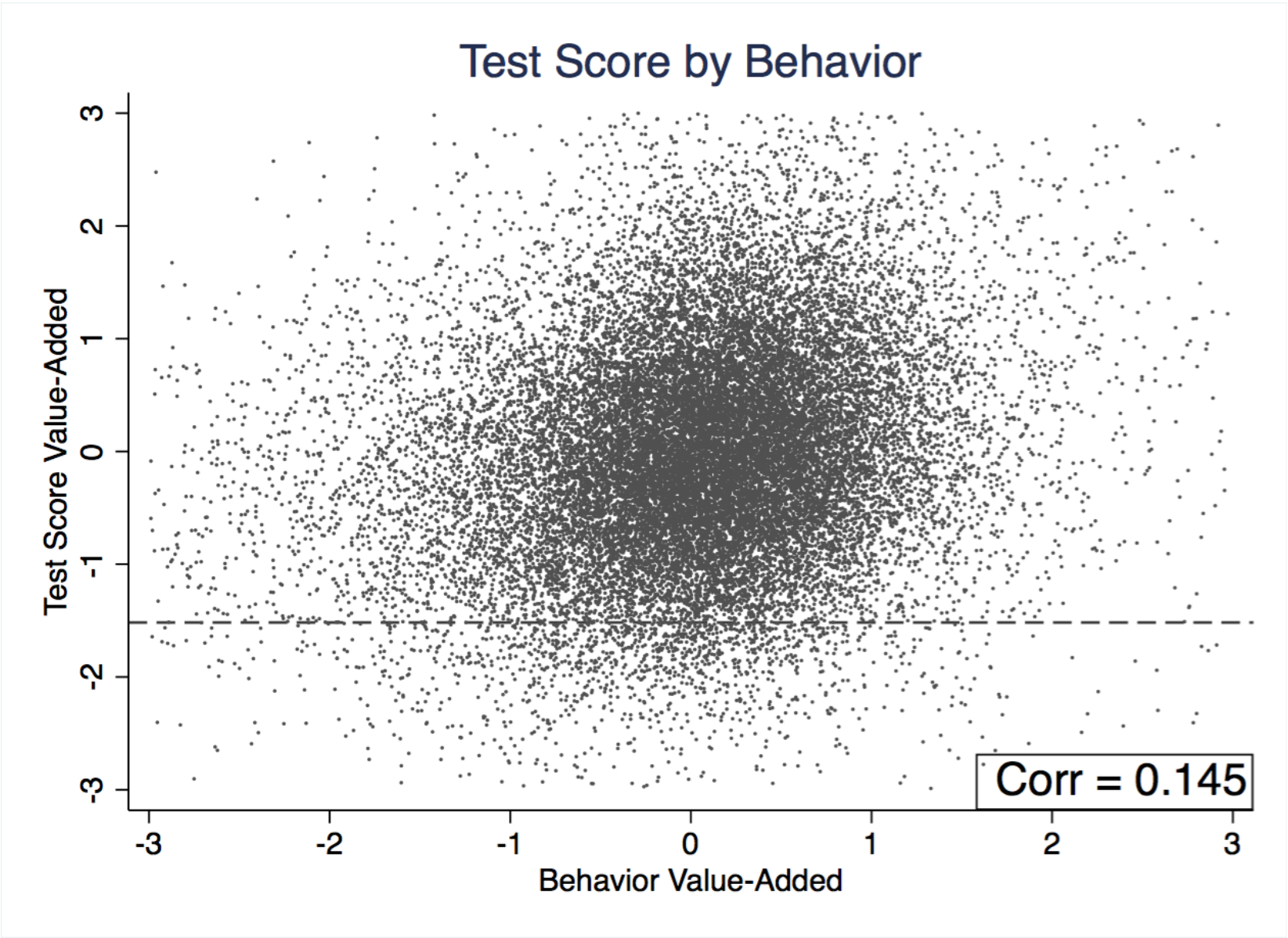

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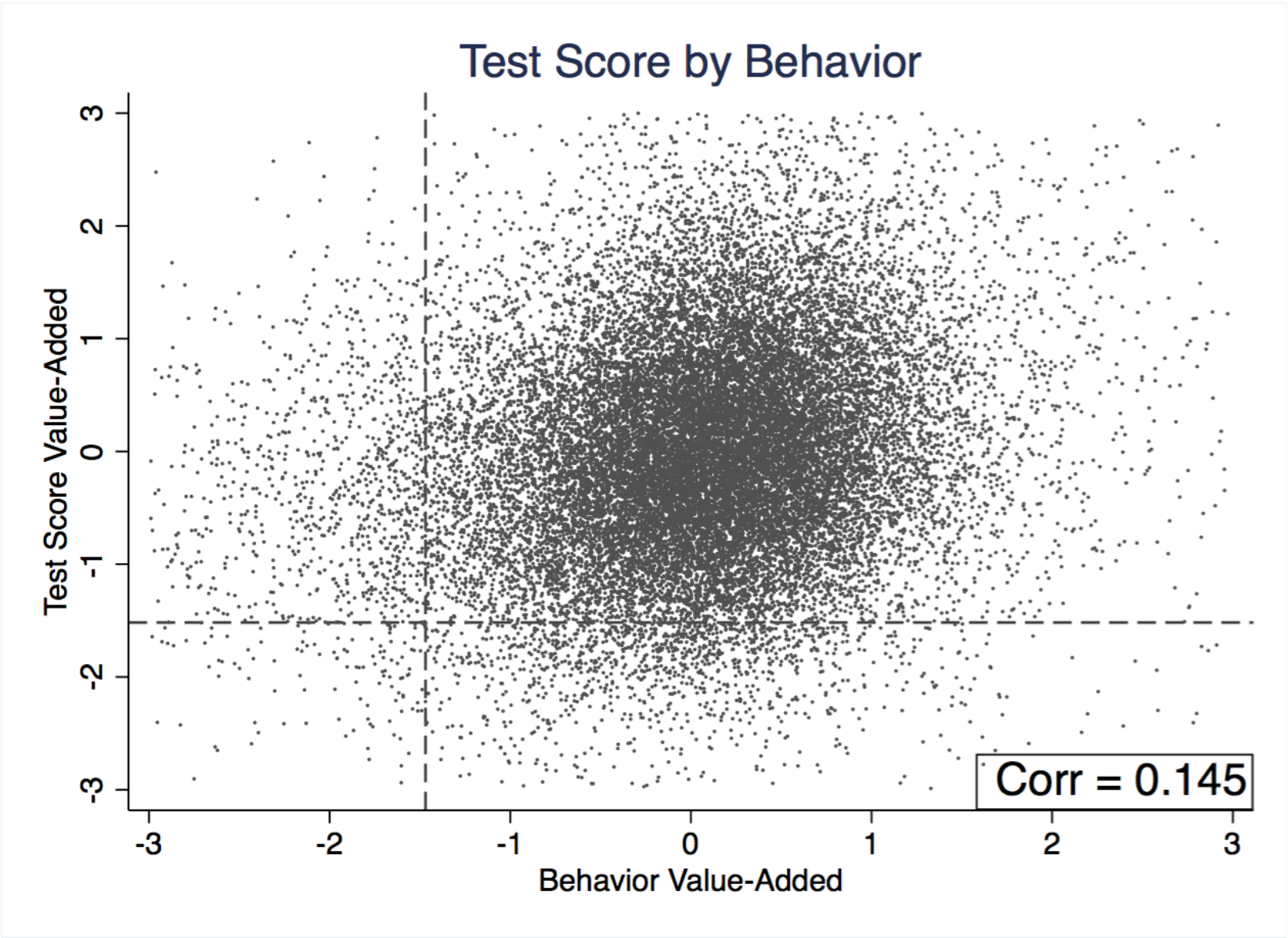

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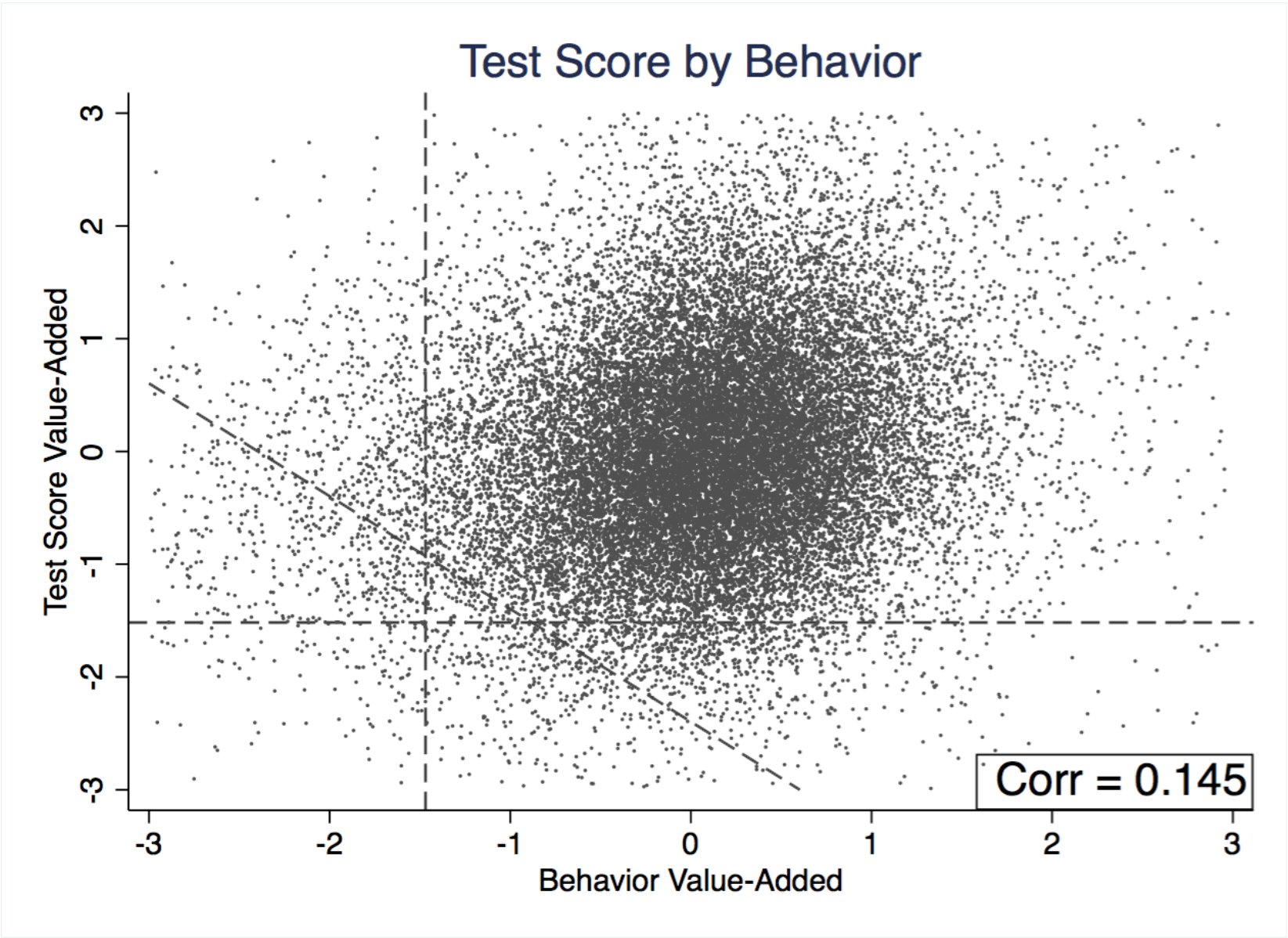

Policy Simulation Results

Value-Added	Took SAT	LAUSD Dropout	Days Suspended	Log Absences	Held Back
Test Score	-0.002	-0.004	-0.000	-0.003	0.001
	(0.003)	(0.004)	(0.002)	(0.005)	(0.002)
Behavior	0.019***	-0.007	-0.007***	-0.031***	-0.011***
	(0.004)	(0.006)	(0.003)	(0.007)	(0.003)
Half and Half	0.012***	-0.008	-0.005*	-0.023***	-0.007**
	(0.004)	(0.006)	(0.003)	(0.007)	(0.003)
Optimal	0.019***	-0.008	-0.008**	-0.031***	-0.011***
	(0.005)	(0.008)	(0.003)	(0.008)	(0.004)
% Gain	200%+	128%	200%+	200%+	200%+

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	(0.005)	(0.008)	(0.003)	(0.008)	(0.004)
% Gain	200%+	128%	200%+	200%+	200%+

Policy Simulation Results

Value-Added	SAT Score	Math CAHSEE	English CAHSEE	GPA	Effort GPA	Coop GPA
Test Score	13.198***	0.048***	0.035***	0.008**	0.005**	0.009***
	(1.895)	(0.004)	(0.004)	(0.003)	(0.002)	(0.002)
Behavior	5.446*	0.028***	0.014**	0.026***	0.013***	0.008***
	(2.926)	(0.007)	(0.005)	(0.005)	(0.003)	(0.003)
Half and Half	12.723***	0.052***	0.034***	0.023***	0.013***	0.012***
	(2.812)	(0.007)	(0.005)	(0.005)	(0.003)	(0.003)
Optimal	13.981***	0.054***	0.037***	0.027***	0.014***	0.013***
	(2.565)	(0.006)	(0.005)	(0.006)	(0.003)	(0.002)
% Gain	-4%	7%	-3%	200%+	137%	39%

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Effects Over Educational Life Cycle

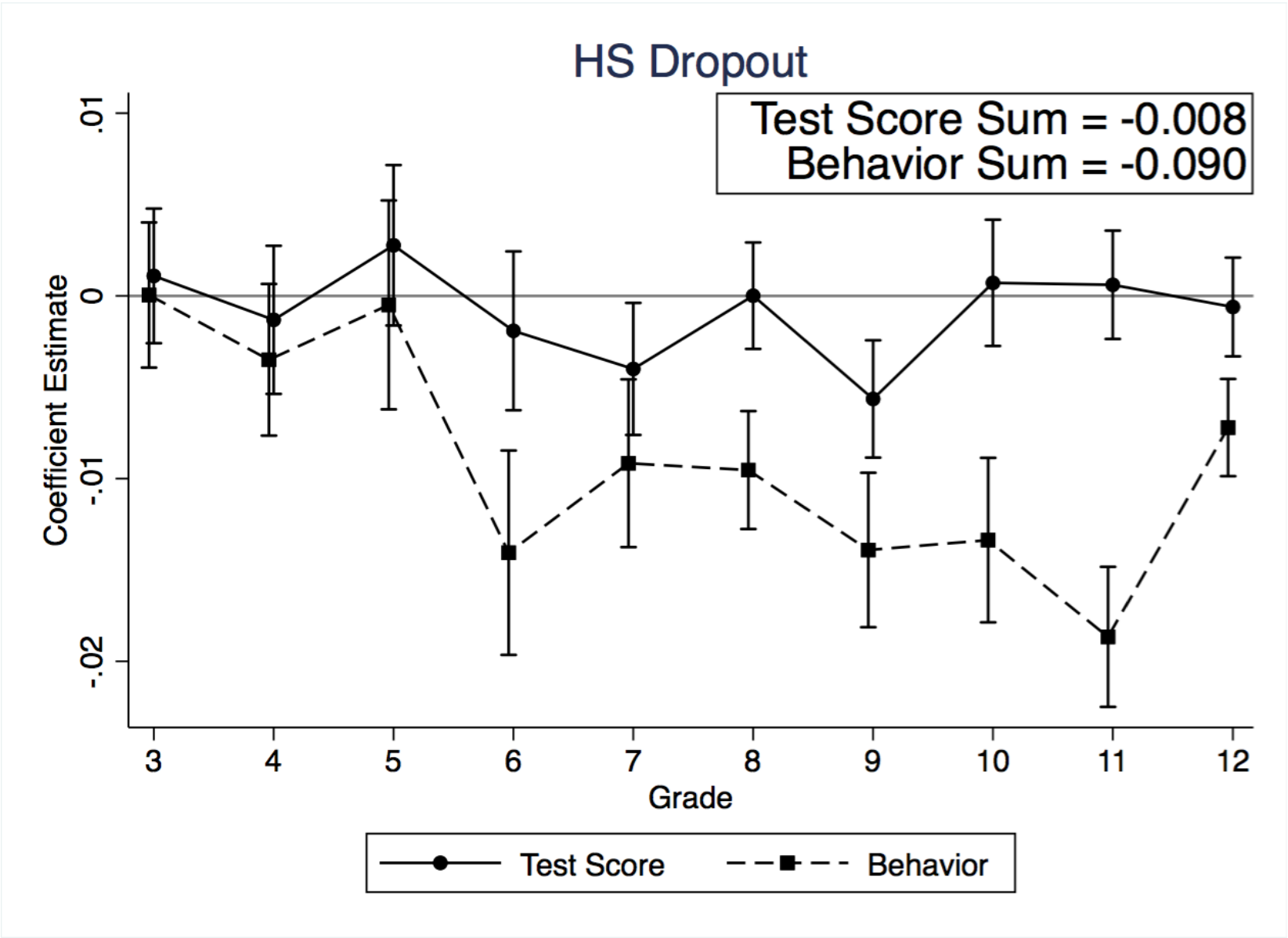
Estimating effects over the educational life cycle

$$y_{ijT} = \beta^s \hat{\theta}^s_{j(T-\tau)} + \beta^b \hat{\theta}^b_{j(T-\tau)} + \Gamma X_{ij(T-\tau)} + \varepsilon_{ijt}$$

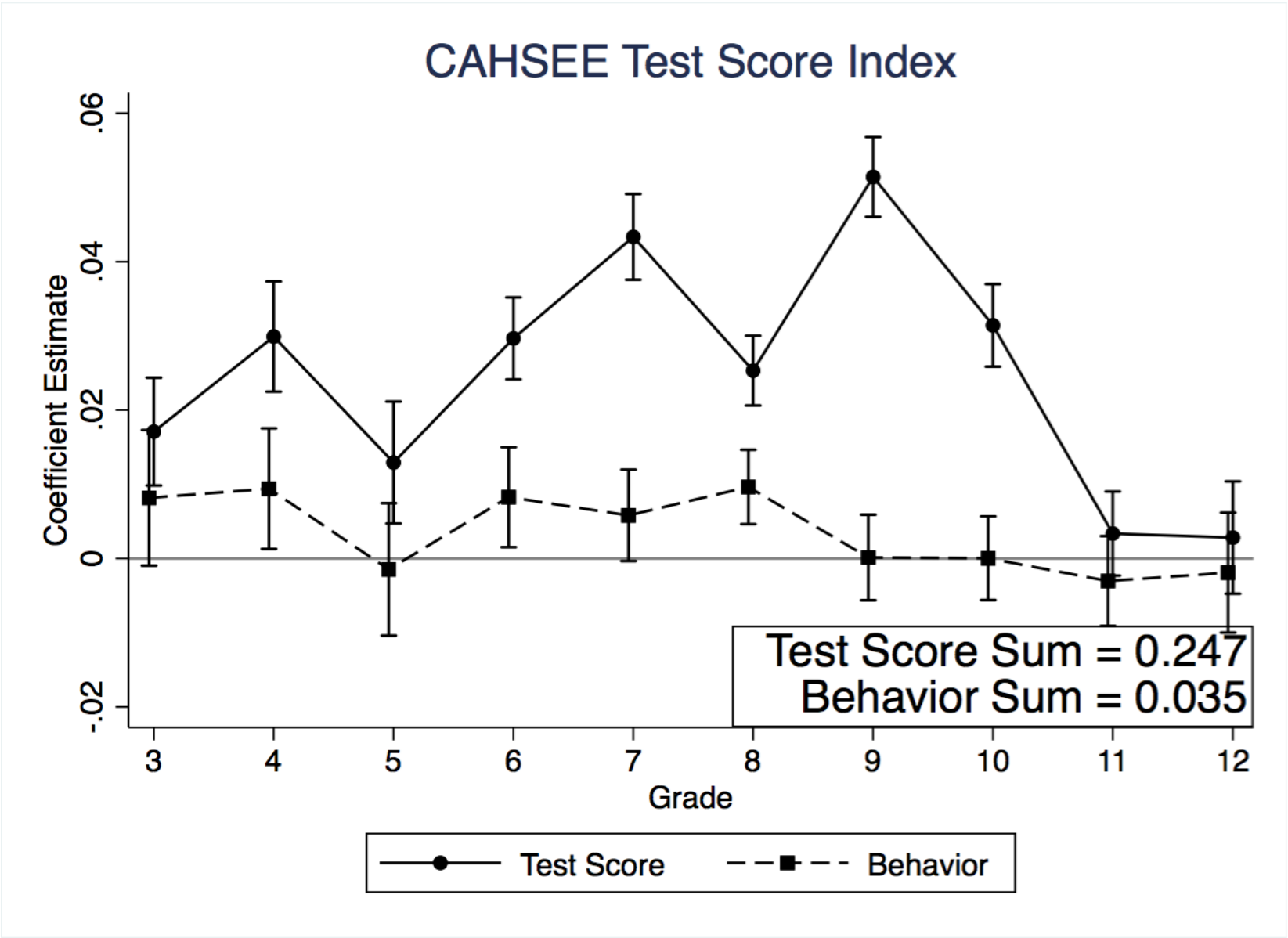
Cumulative effect

- Is an upper bound
- Does not take tracking into account
- Could be decreasing returns to high quality teachers

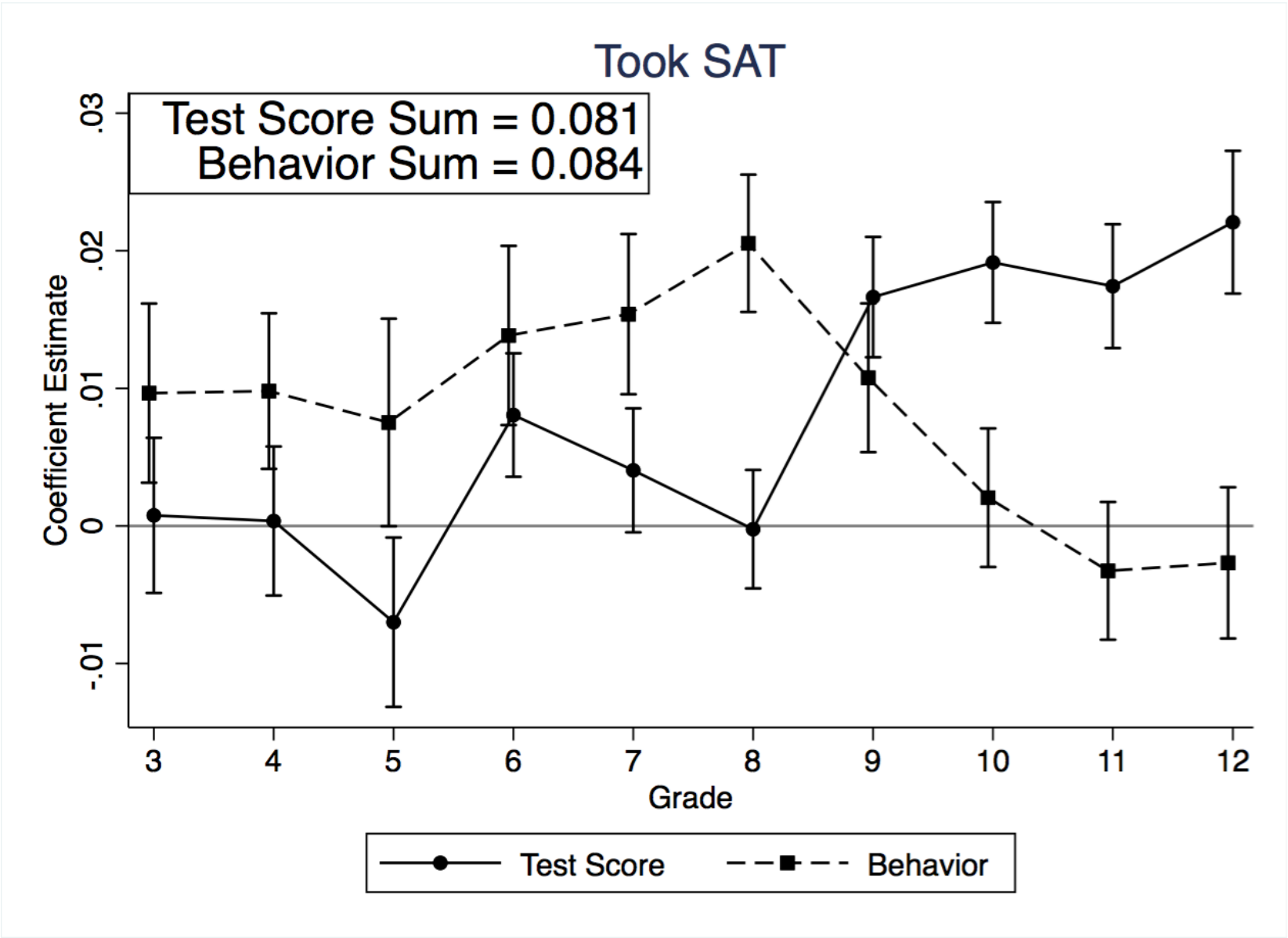
Effects by Grade: HS Dropout



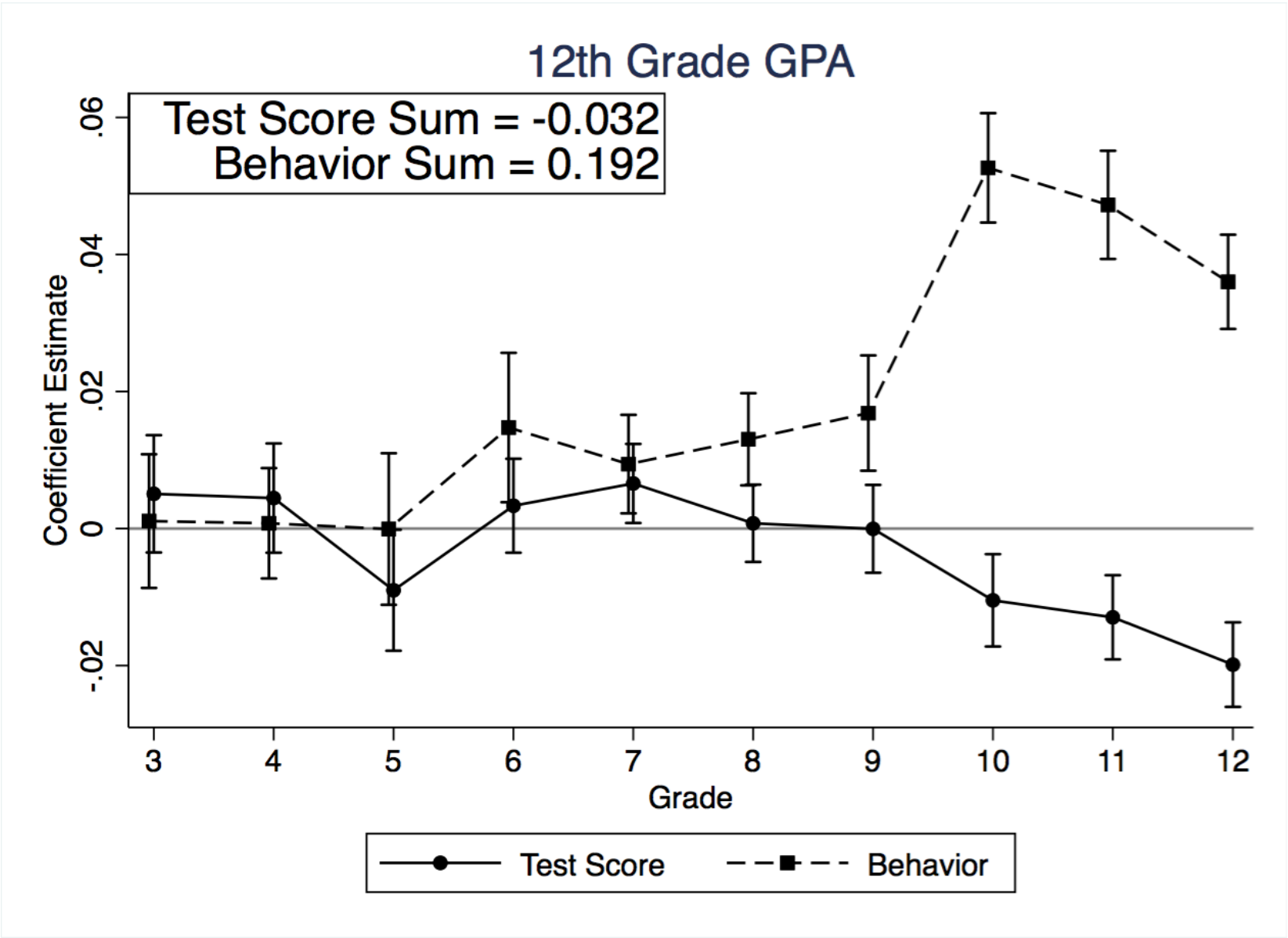
Effects by Grade: HS Exit Exam



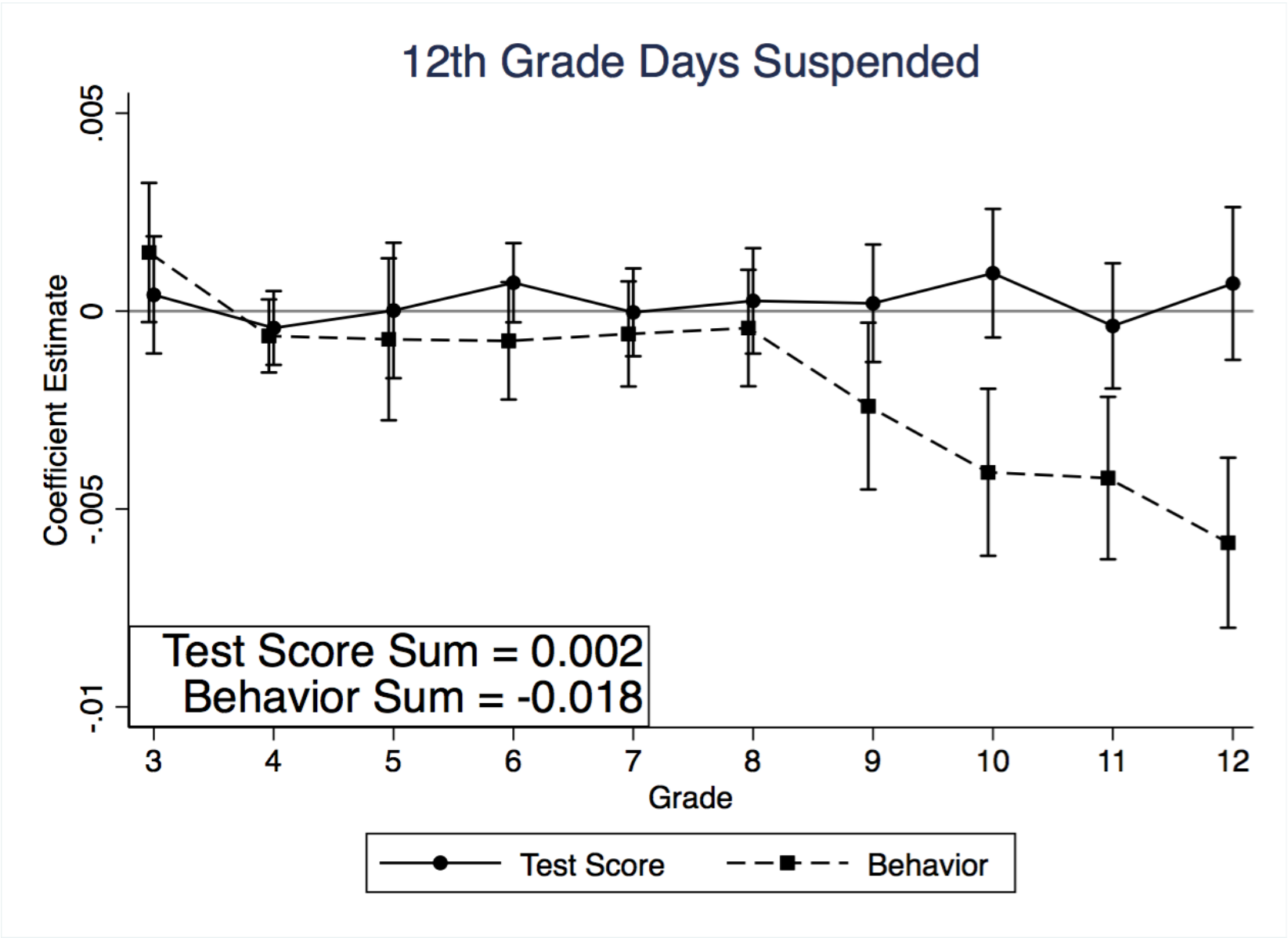
Effects by Grade: Took SAT



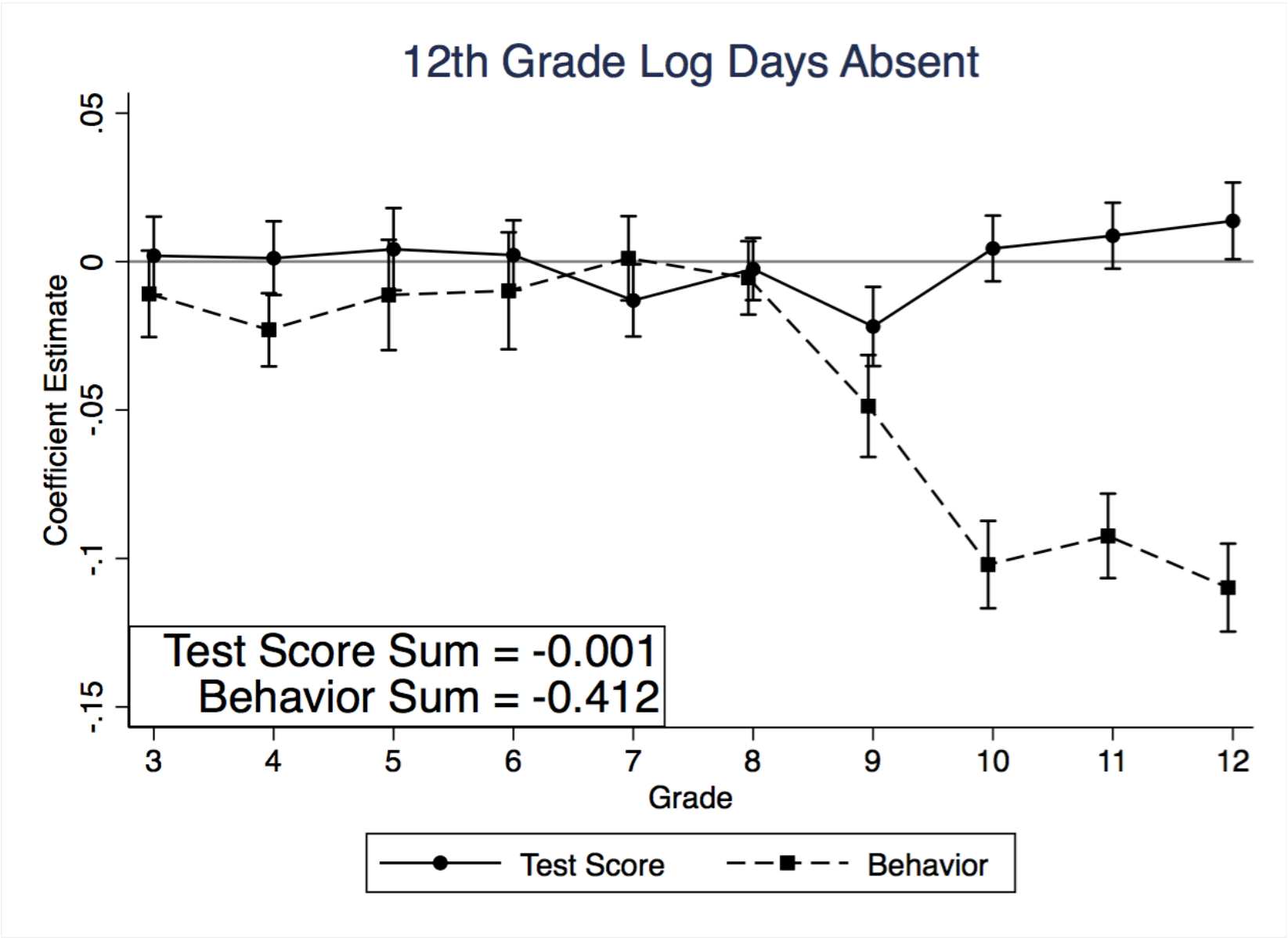
Effects by Grade: GPA



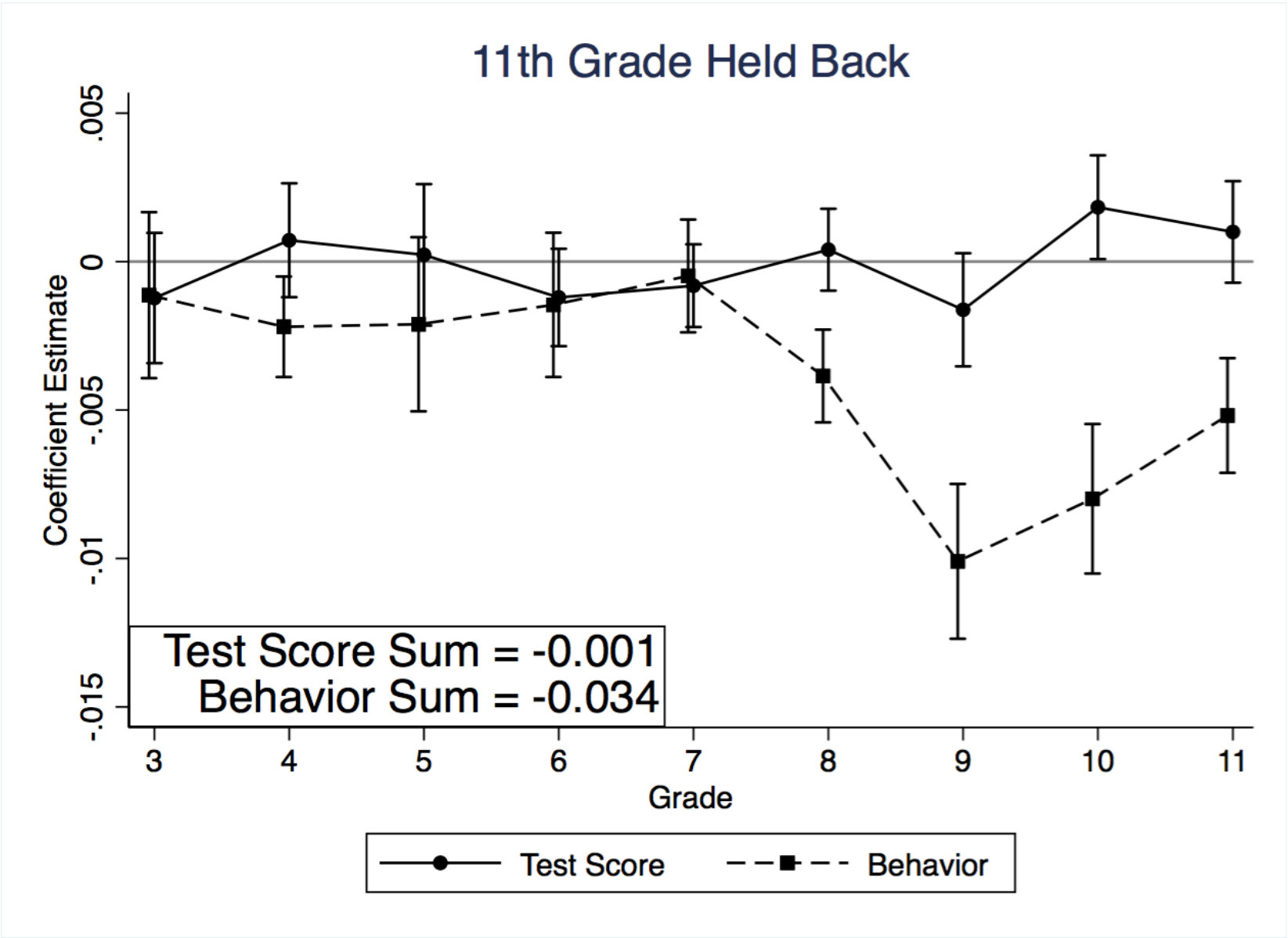
Effects by Grade: Days Suspended



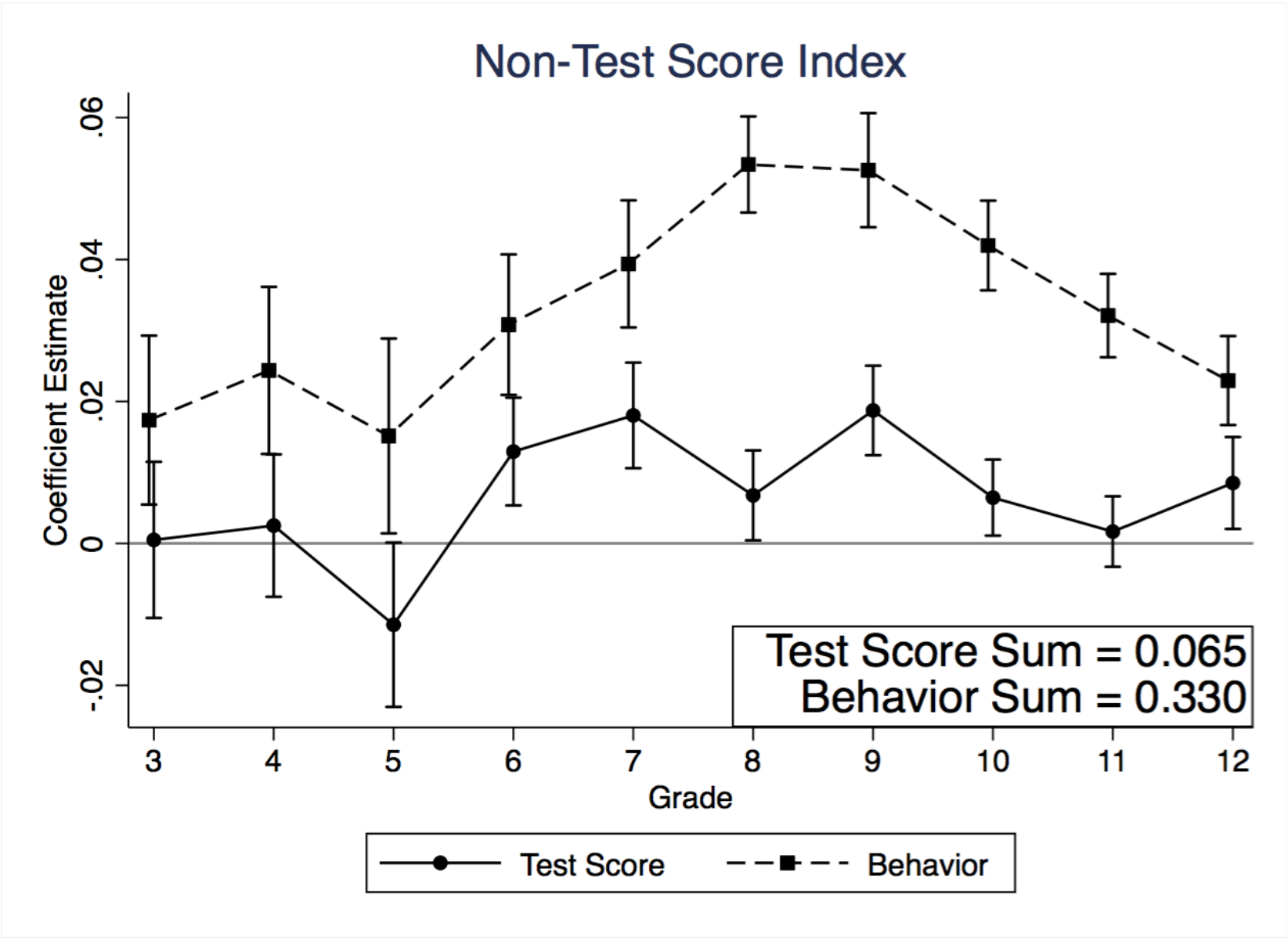
Effects by Grade: Log Days Absent



Effects by Grade: Held Back



Effects by Grade: High School Non-Test-Score Index



Policy Implications

Potential Benefits

- Behavior measures use data readily available to school districts
- Help measure the quality of all teachers (not just math and English)
- Improve the overall measure of teacher quality used in many education policies
  - Teacher evaluations
  - Teacher hiring, dismissal, and tenure decisions
  - Pay-for-performance
- Alleviate potential distortions from focusing solely on test scores

Conclusion

Summary

- Multiple dimensions of teacher quality affect students' long-term outcomes
- Two dimensions of teacher quality are weakly correlated which allows potential gains from using both
- Effects are larger in later grades and certain subjects

Future work

- Explore how policies that emphasize test-score value-added may distort the efficient allocation of teachers' time and resources
- Expand value-added framework to include additional student outcome measures
- Use adult income and college attendance as final outcomes