

Road to the Future: Identifying Impacts of Roads on Education in Colombia

Jaime Polanco ¹

¹School of Economics and Management Sciences
Pontifical Xavierian University
https://github.com/JAPJ182/ROAD_TO_THE_FUTURE
<https://sites.google.com/view/jaime-polanco/inicio>

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Why I did this.

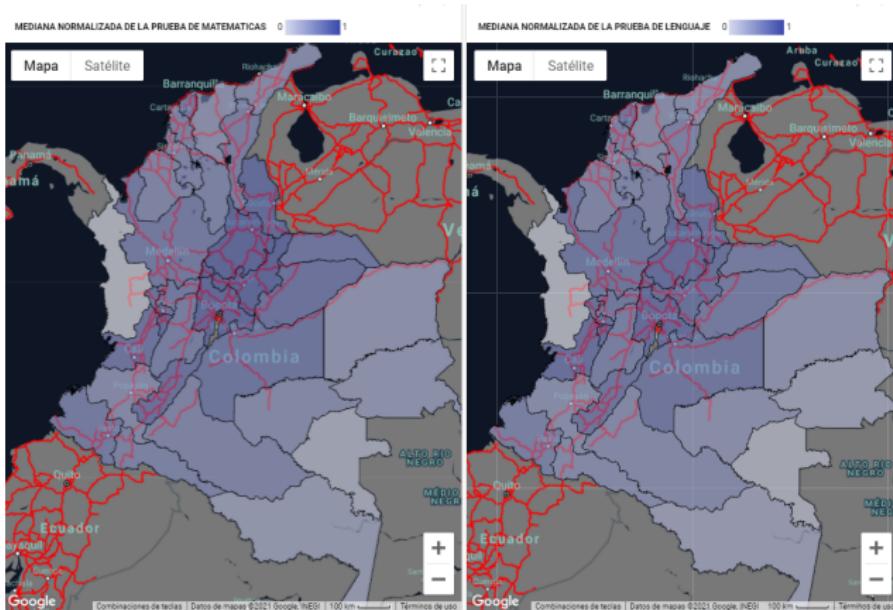


Figure: The spatial relationship between tests Saber11 road coverage at a departmental scale. The red line indicates the road network, and the polygons in the gray-to-blue scale show the scale of results in the saber 11 test.

Is this correlation hidding a causal effect of the roads infraestructure over the education performance?

Here's what I did.

Research question:

Does the intervention of roads under a concession contract have an impact on education in Colombia?

This study contribute to the literature showing **evidence that road concession agreements in Colombia impacts education** in the following outcomes:

- Heterogeneous effects on private and public schools.
- Effect on labor force participation of students in the last year of secondary.
- Effect on human capital accumulation.
- Estimation of causality when the treatment occurs in continuous time.

Here's what I found.

- I find an increase in average reading and math scores in schools located less than a kilometer from the road intervention.
- In the early stages of the road intervention, I find an increase in average reading and math scores mainly in schools located less than 1,500 meters from the road under construction.
- In the final stages of the road intervention, I find an increase in average reading and math scores mainly in schools located more than 2,500 meters from the road.
- The fraction of students who participate in the labor force decreases while the fraction of students completing some level of higher education increases, which leads to an accumulation of human capital.
- The fraction of students from treated schools who complete a university degree increases.
- I show evidence of positive heterogeneous effects that affect public schools more than private schools.

How?

Data

This study was carried through the following data:

- General results and survey of the standardized exam of the last year of high school called Saber 11. (2006-2020) Education
- General results of the state test for the last semesters post-secondary education students, called Saber pro (2006-2021).
- Vector of roads databases in Colombia. (2011-2019)
- Vector of schools databases in Colombia (DANE).
- Electronic survey of formal education – EDUC (C600).
- Road concession agreements and annual progress reports.

Mechanisms

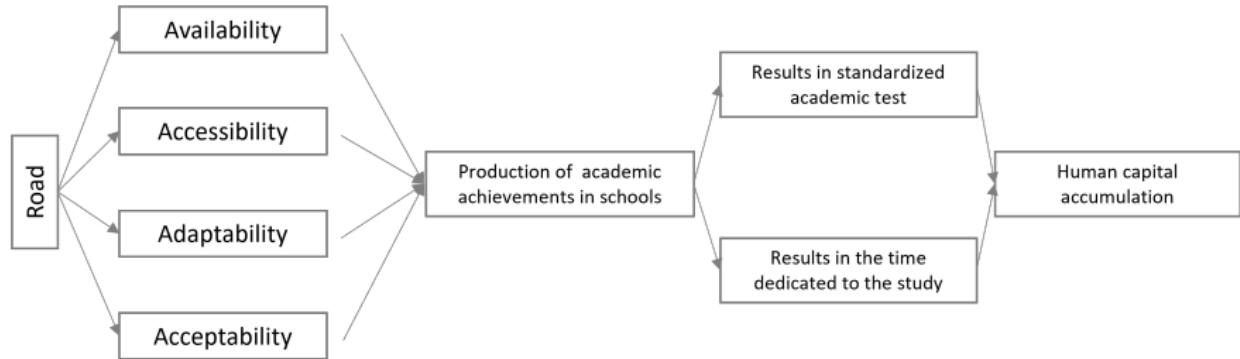
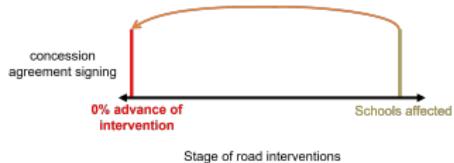
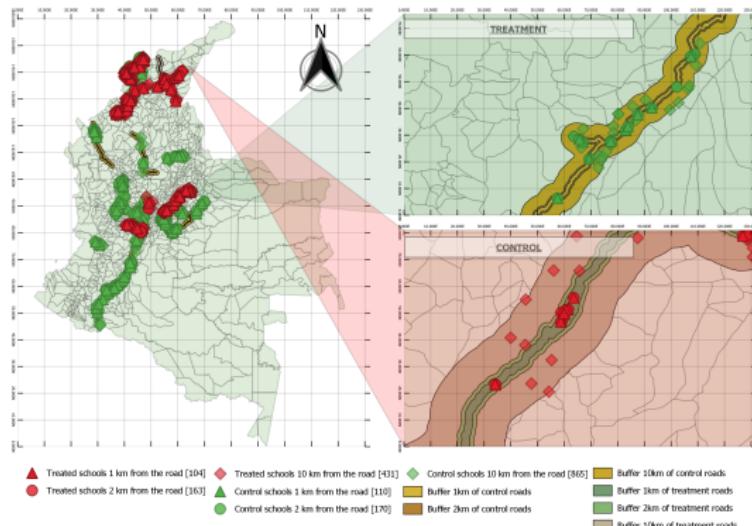


Figure: Summary of the mechanism through which road construction under a concession agreement affects educational performance.

Treated and Control



Location of schools treated (green vignettes) and control schools (red vignettes) due to the construction of roads in the time of reference t .



- **Dynamic difference-in-difference model** stimation is based on:
 - ▶ Two ways fixed effects estimators.
 - ▶ the estimator proposed by Callaway and Sant'Anna, 2021,
 - ▶ the estimator proposed by Sun and Abraham, 2021
- **Assumptions Sun and Abraham, 2021**
 - ▶ Parallel trends,
 - ▶ No anticipatory behavior,
 - ▶ Treatment effect heterogeneity.
- **The two sources of variation are:**
 - ▶ Contruction of the road. (The time of contruction or whether the cosntruction was or not)
 - ▶ Distance between schools and roads contructed.

Specification

$$\hat{\tau} = \bar{Score}_{before road} - \bar{Score}_{after road} \quad (1)$$

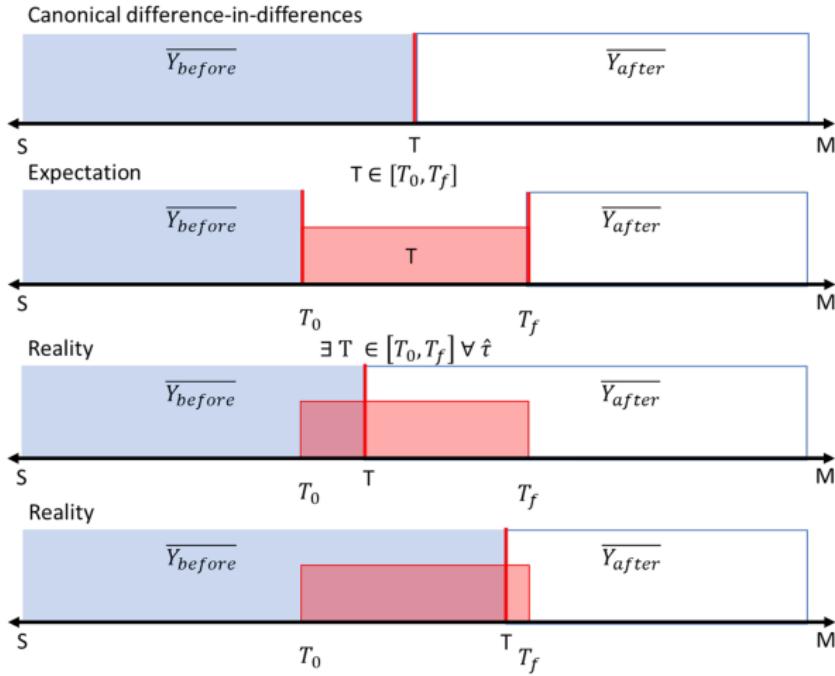
$$Score_{c,t,j}^{\varphi} = \sum_{\tau=-S}^{-2} \mu_{\tau} \cdot D_{c,\tau} + \sum_{\tau=0}^M \mu_{\tau} \cdot D_{c,\tau} + \sigma_t + \gamma_c + \varepsilon_{c,t} \quad (2)$$

Where:

- $t = -1$ Period relative to the treatment.
- γ_c School fixed effects.
- σ_t time fixed effects.
- $Score_{c,t,j}$ Is the outcome.
- μ_{φ} Is the effect of road construction on education.
- The effect of the construction of new roads is estimated with the bandwidth from $-S$ to M .
- $D_{c,\varphi}$ Represent a group of dummy variables that indicate the distance of each period from the treatment period.

Estimation problem.

$$\hat{\tau} = \overline{Y_{after}} - \overline{Y_{before}}$$

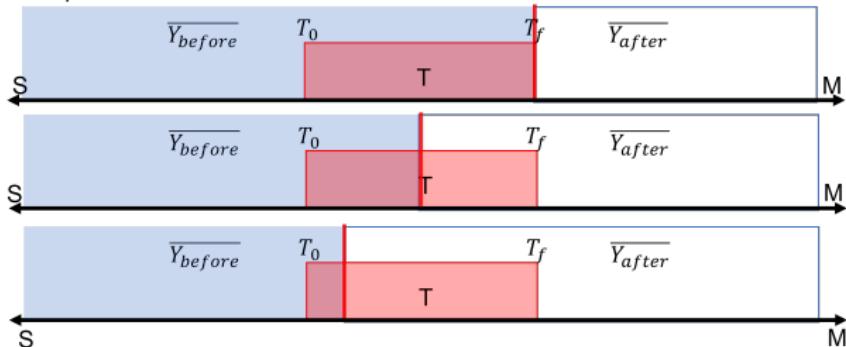


Estimation problem.

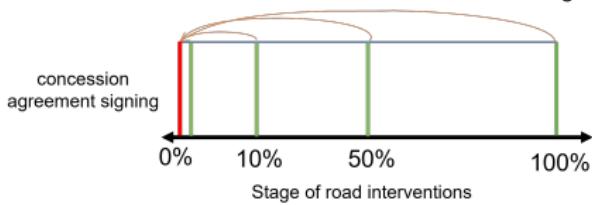
$$\hat{t} = \overline{Y_{after}} - \overline{Y_{before}}$$

$$\exists T \in [T_0, T_f] \forall \hat{t}$$

Proposed Solution



Where the time of treatment defines the treat and control group



Effect size of Results

	Effect size						
	Overall		Math		Reading		Enrollment
Effect size	sd^1	sd^2	sd^1	sd^2	sd^1	sd^2	sd^1
Small	0.08	0.04	0.05	0.08	0.03	0.08	0.03
Moderate	0.1	0.1	0.07	0.07	0.14	0.12	0.06
Large	0.45	0.47	0.31	0.37	0.5	0.5	0.38
Number of studies	96	747	199	314	269	495	33

Note: sd^1 refers to the studies carried out by Evans, 2022 and sd^2 refers to the studies carried out by Kraft, 2020. The distribution of sample size is based on all RCT studies

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Mathematics score for all the different stages of construction

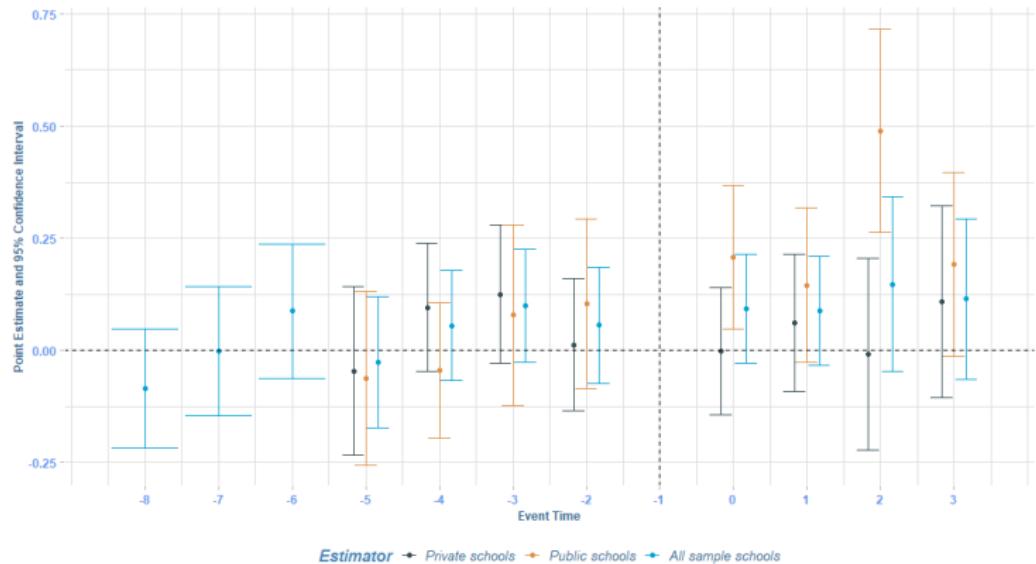


Figure: 100 % advance of construction

Mathematics score for all the different stages of construction

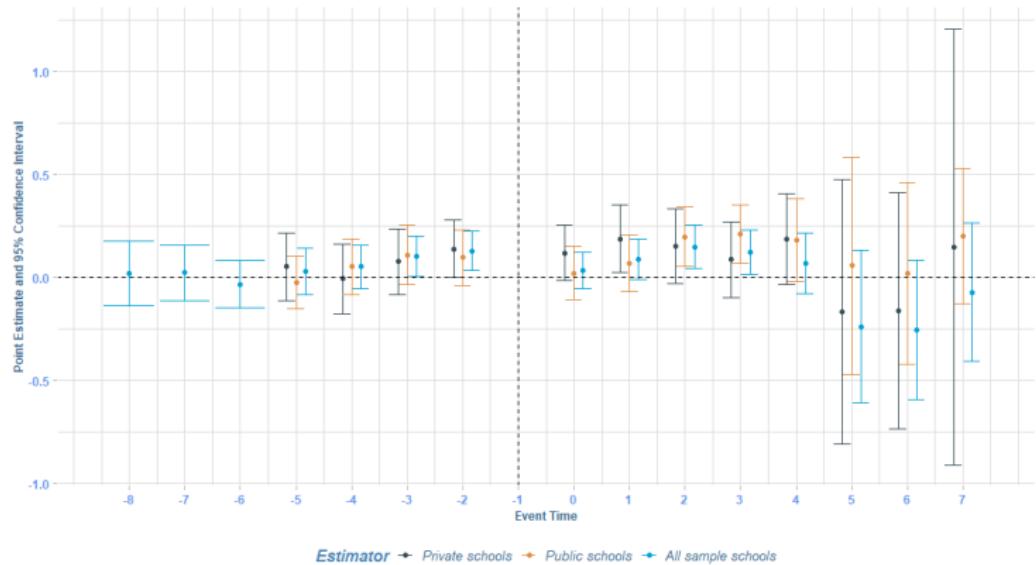


Figure: 50 % advance of construction

Mathematics score for all the different stages of construction

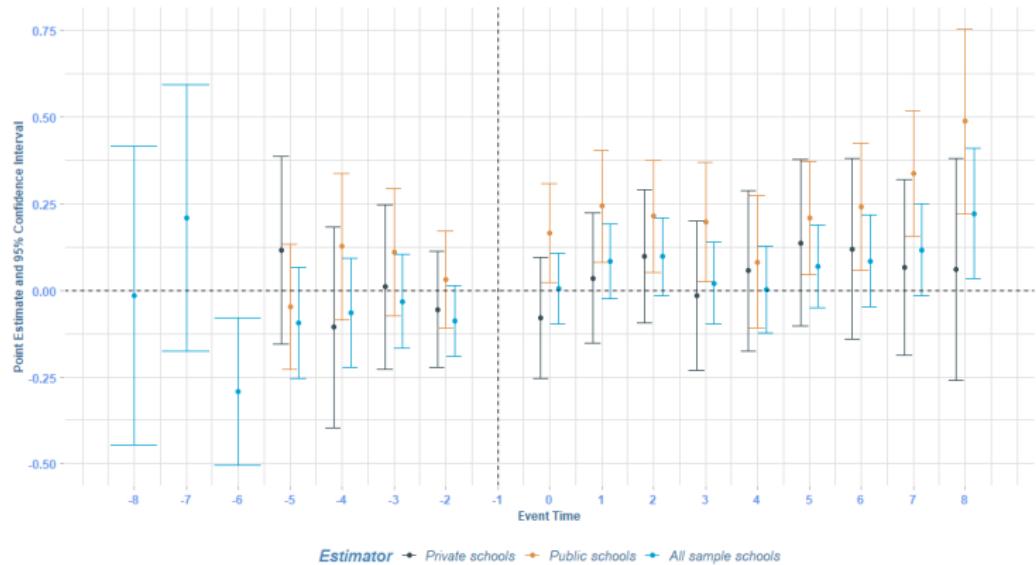


Figure: 10 % advance of construction all results!

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Reading Literacy score for all the different stages of construction

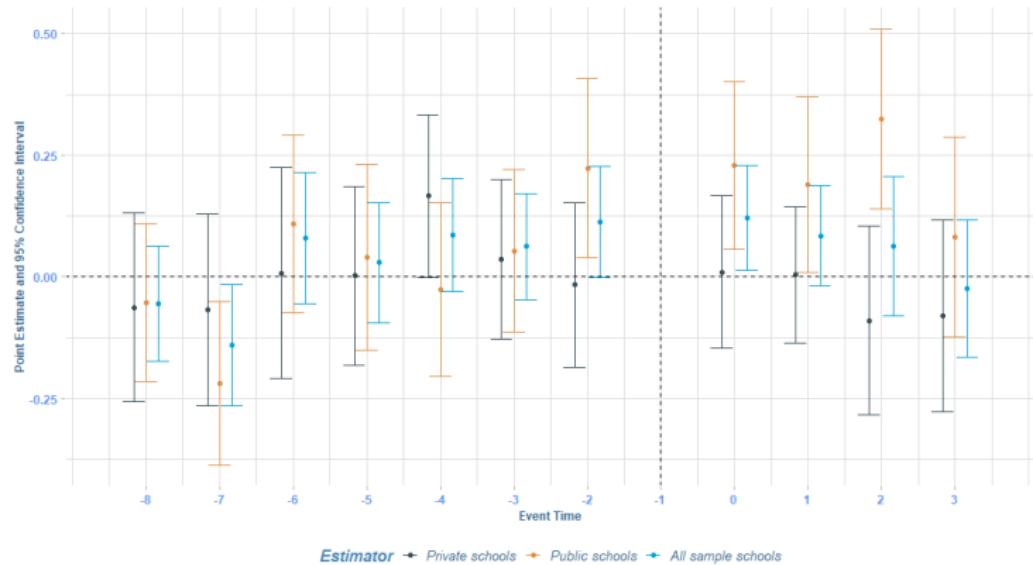


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Reading Literacy score for all the different stages of construction

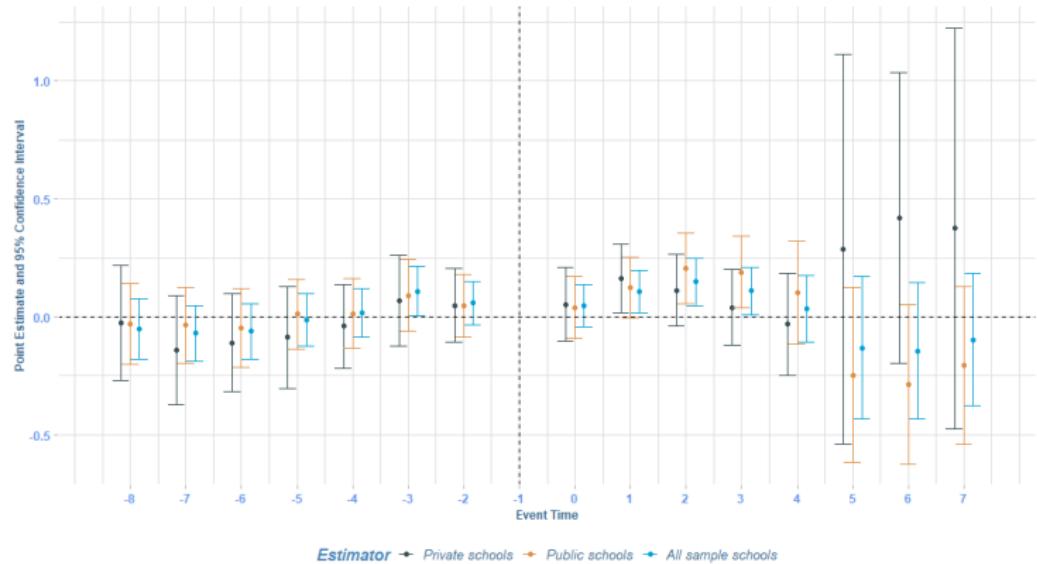


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Reading Literacy score for all the different stages of construction

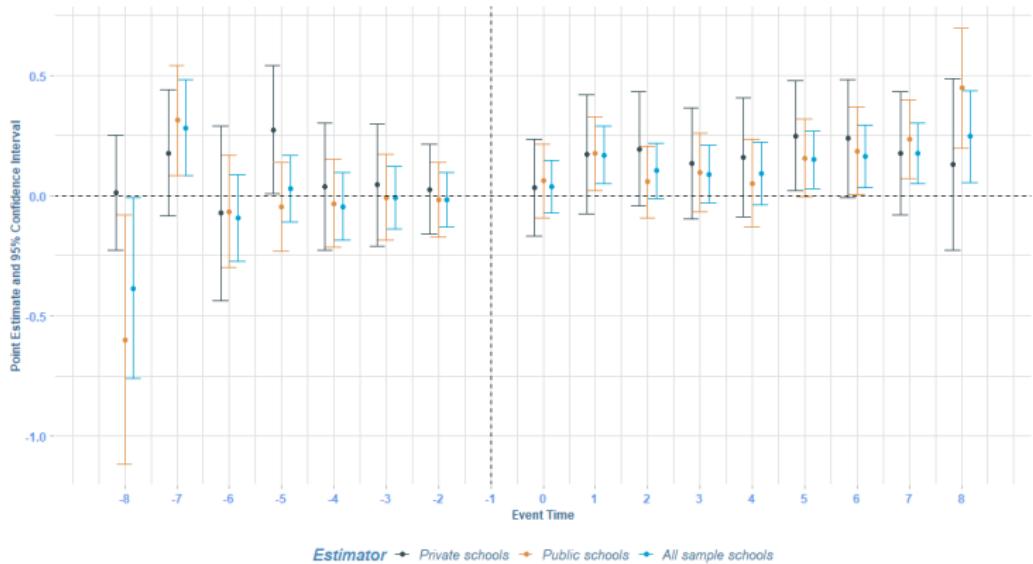


Figure: 10 % advance of construction all results!

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Human capital accumulation

Impact of Roads on average results of exam Saber 11 in reading literacy score.

Heterogenities by schools nature!

Heterogenities by distance

$$\dot{h}(t) = \phi(s(t), h(t)) - \delta_h h(t) \quad (3)$$

Acemoglu 2010 Acemoglu, 2010- The Ben-Porath model

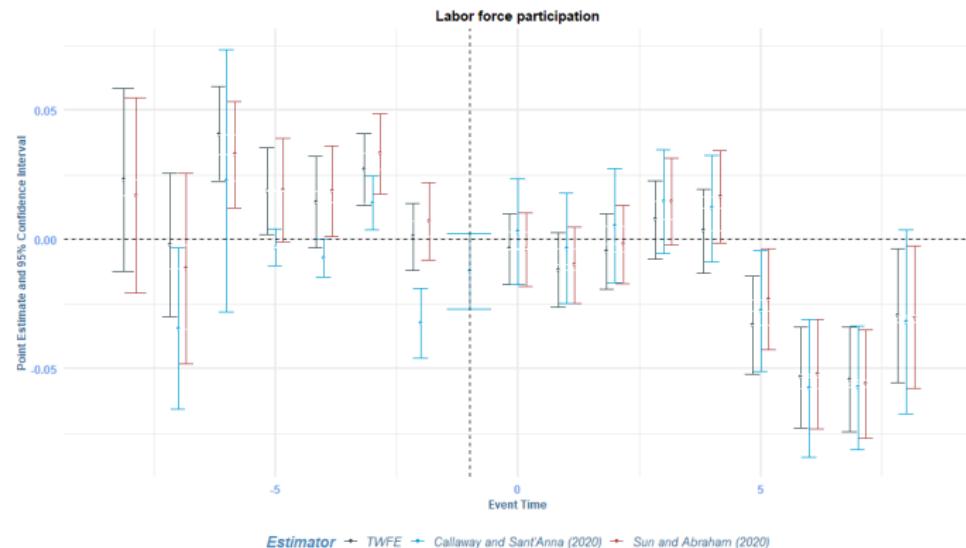


Figure: Impact on the fraction of students who participate in labor force

Fraction of students who participate in labor force

Dependent Variable:	Fraction of students who participate in labor force					
Model by level of construction :	10 %	graph!	50 %	graph!	100 %	graph!
<i>Variables</i>						
year = -8	0.3341 (0.1894)		0.0429 (0.0866)		0.1899 (0.0966)	
year = -7	0.1566 (0.3387)		0.3807 (0.0985)		-0.0574 (0.0787)	
year = -6	0.0765 (0.1561)		0.0685 (0.0815)		0.0028 (0.0843)	
year = -5	-0.0458 (0.1150)		0.0578 (0.0788)		0.1307 (0.0986)	
year = -4	0.0415 (0.0910)		0.0709 (0.0756)		0.0286 (0.0820)	
year = -3	0.2354 (0.0819)		0.0228 (0.0653)		0.0773 (0.0846)	
year = -2	0.0879 (0.0945)		-0.0199 (0.0528)		0.0933 (0.0941)	
year = 0	-0.0100 (0.0670)		0.0872 (0.0661)		-0.0015 (0.0812)	
year = 1	-0.0506 (0.0687)		0.0482(0.0779)		-0.1120(0.0829)	
year = 2	-0.0279(0.0790)		-0.1970(0.0759)		-0.0700(0.1469)	
year = 3	-0.0699(0.0825)		-0.2323(0.0784)		0.0070(0.1439)	
year = 4	0.0377 (0.0947)		0.0151 (0.1105)			
year = 5	-0.0143 (0.0922)		0.1681 (0.2386)			
year = 6	-0.3295(0.0876)		-0.3180(0.2464)			
year = 7	-0.2900(0.0868)		0.1621(0.2181)			
year = 8	-0.2143(0.1088)					
<i>Fixed-effects</i>						
id_name	Yes		Yes		Yes	
year	Yes		Yes		Yes	
<i>Fit statistics</i>						
Observations	5,882		5,882		5,843	
R ²	0.47454		0.47006		0.46806	
<i>Results by buffer</i>						
Buffer 1000 m - 3500 m	Graph	!	Graph	!	Graph	!
Nature of school	Graph	!	Graph	!	Graph	!
<i>Clustered (id_name) standard-errors in parentheses</i>						

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Results in university participation

Fraction of students that finished some university level for all the different stages of construction

Dependent Variable: Model by level of construction :	Fraction of students that finished some university level	
	10 % advance	50 % advance
<i>Variables</i>		
year = -3	0.0016 (0.0499)	-0.1275 (0.1112)
year = -2	0.0525 (0.0521)	0.0038 (0.1437)
year = 0	0.0946 (0.0523)	-0.2892 (0.1876)
year = 1	0.1415 (0.0534)	0.1260 (0.1359)
year = 2	0.1342 (0.0633)	
<i>Fixed-effects</i>		
id_name	Yes	Yes
year	Yes	Yes
<i>Fit statistics</i>		
Observations	3,101	3,101
R ²	0.67737	0.66500
Within R ²	0.00350	0.00206
<i>Clustered (id_name) standard-errors in parentheses</i>		

Conclusions

- I evidenced an increase in the score of the results of mathematics and language on the standardized test for schools near roads under a concession agreement.
- I evidenced that the effect of the construction of a road under a concession agreement on education mainly benefits schools less than one kilometer away. The effect on education disappears in schools that are more than 1.5 km away from the highway.
- The effect of building a road under a concession agreement is greater in private schools than in public schools.
- The labor force participation of students in colleges less than a kilometer away from the road under a concession agreement decreases.
- The fraction of students from treated schools who complete a university degree increases.
- The educational cycle from high school to university is benefited by the construction of roads, which in this article I approach as the accumulation of human capital.

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Jaime Polanco-Jimenez
School of Economics and Management Sciences
Pontifical Xavierian University

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<https://sites.google.com/view/jaime-polanco/inicio>



Pontificia Universidad
JAVERIANA
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Characteristic of roads under a concession.

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- The time periods required for a road construction under a concession is in average **13 years**.
- In average the time require for reaching the **10%** advance is 7.25 years and 2 years more for reaching the **50%** of advance of the road.
- The concession length had an average of **191 km**
 - ▶ The shortest concession length was **31km**.
 - ▶ The largest concession length was **491 km**.
- 987 schools (Public 737, Private 250) were implicated within a radius of 1000 meters from the road which represent the focus of this research.

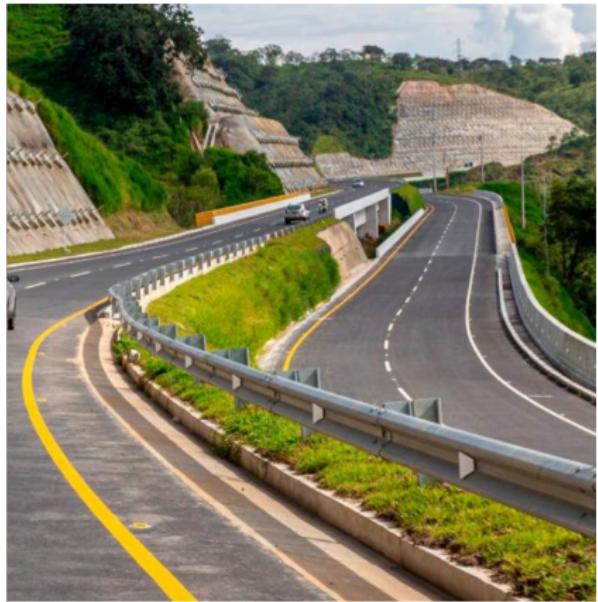


Figure: The spatial dispersion of the effect of road construction on education.

Road concession system

Road concession system

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What do we already know?

- Adukia et al., 2020 Children **stay in school longer and perform better on standardized tests** as an effect of 115,000 new roads.
- Donaldson, 2018 Railroads infrastructure **decreased trade costs and interregional price gaps, increased interregional and international trade and increased real income levels.**
- Fernández et al., 2020 shows how transportation infrastructure **promoted long-term employment opportunities and broke the labor bond between parents and children.**
- Fernald, 1999 Changes in roads has an **effect over the productivity** are mainly reflected in the intensive automotive production.
- Quintero and Sinisterra, WP2022 (**Colombia 1993-2012**) Measures road improvement and construction as a function of production and inequality.

- 1780 secondary schools were located with API and made up the sample.
- **987 schools** were implicated within a radius of 1000 meters from the road.
 - ▶ 250 Private schools and 737 Public.
- **12.9%** and **10.4%** were **the percentage of students who participated in labor force** in private and public schools, respectively.
- **Public Schools** can not select their teachers due to the fact that teachers obtain their positions through merit contests.
- **Private Schools** can select their teachers and teachers can select the school where they want to work.
 - ▶ By seeing improvements in the infrastructure a teacher with better qualities could select a school and this could impact in the school achievements.

A frame of reference for the impacts on education.

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Table: Descriptive statistics of schools within a radius of 1000 meters from the road

	Schools within a radius of 1000 meters from the road			
	Treated schools		Control Schools	
	mean	sd	mean	sd
Students with university studies *	0.148	0.192	0.127	0.165
Students in labor force +	0.101	0.162	0.142	0.197
Reading literacy Score	0.491	0.057	0.484	0.051
Mathematics score	0.433	0.082	0.425	0.074
Number of schools			510	485
Number of observations			6565	5981

*Fraction of students who finished a university study,

+Fraction of students who participate in labor force

Impact of Roads on average results of exam Saber 11 in mathematics

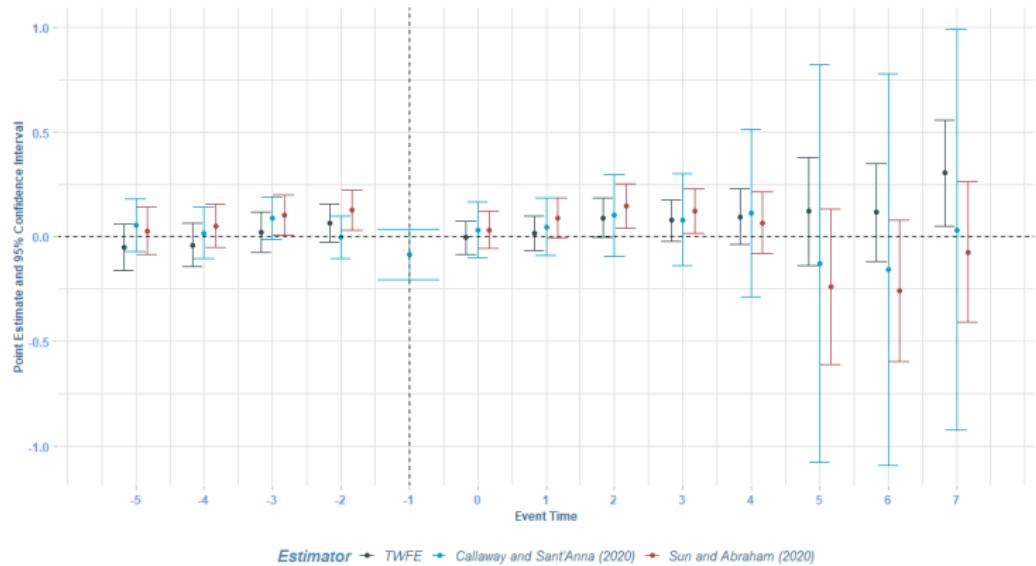


Figure: 50 % advance of construction

Impact of Roads on average results of exam Saber 11 in mathematics

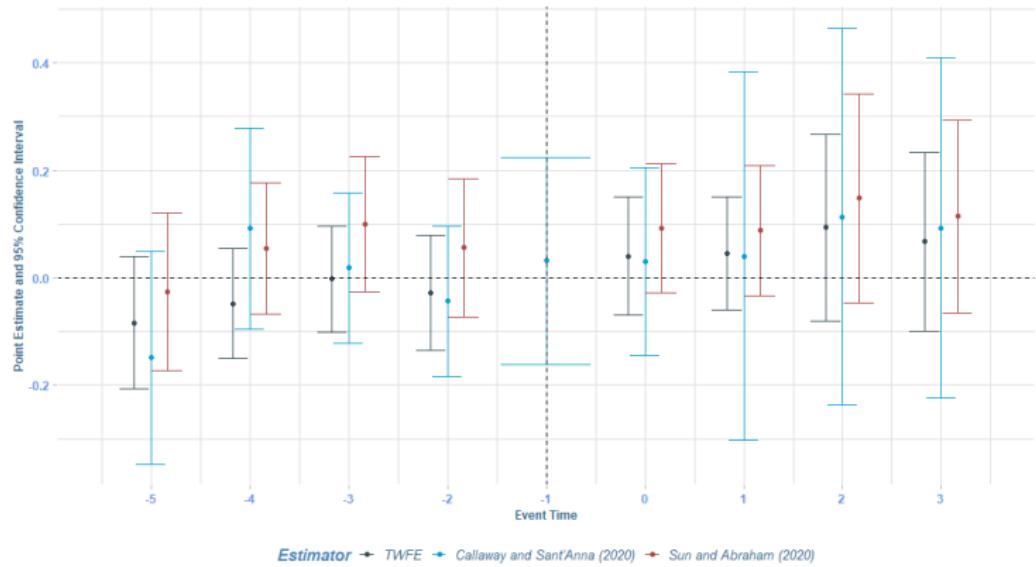


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Results in math test.

Impact of road construction on math score by distance of school from road in Math Result

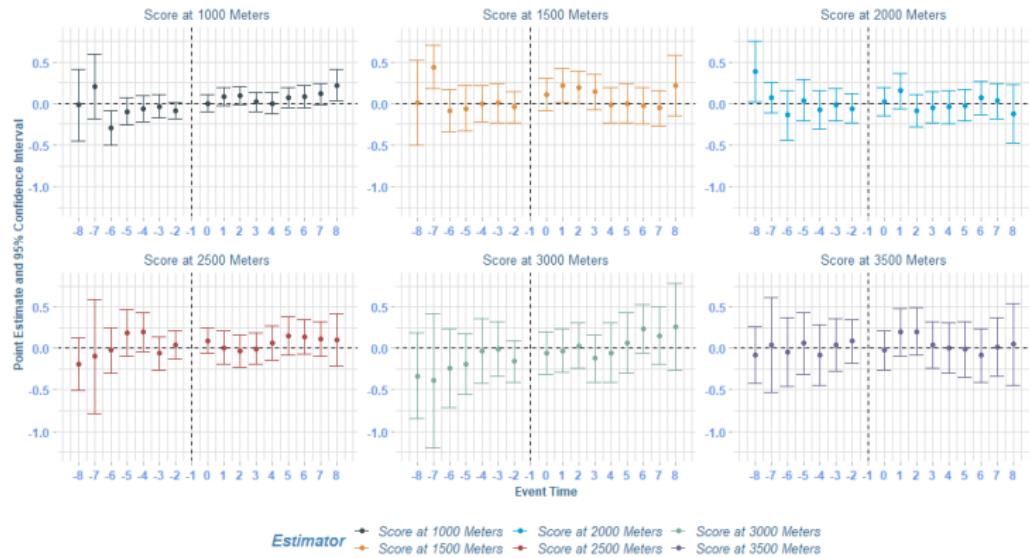


Figure: 10 % advance of construction

Results in math test.

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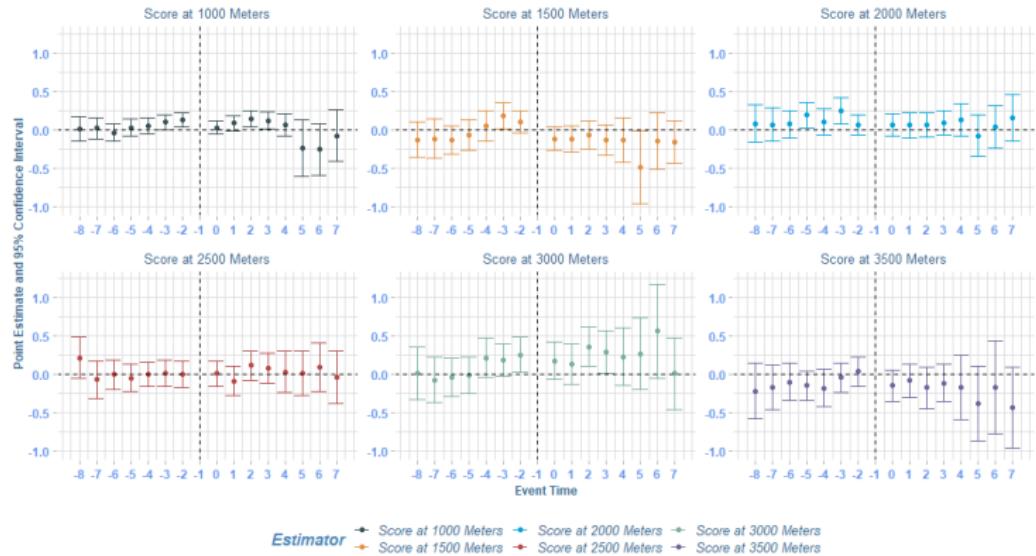


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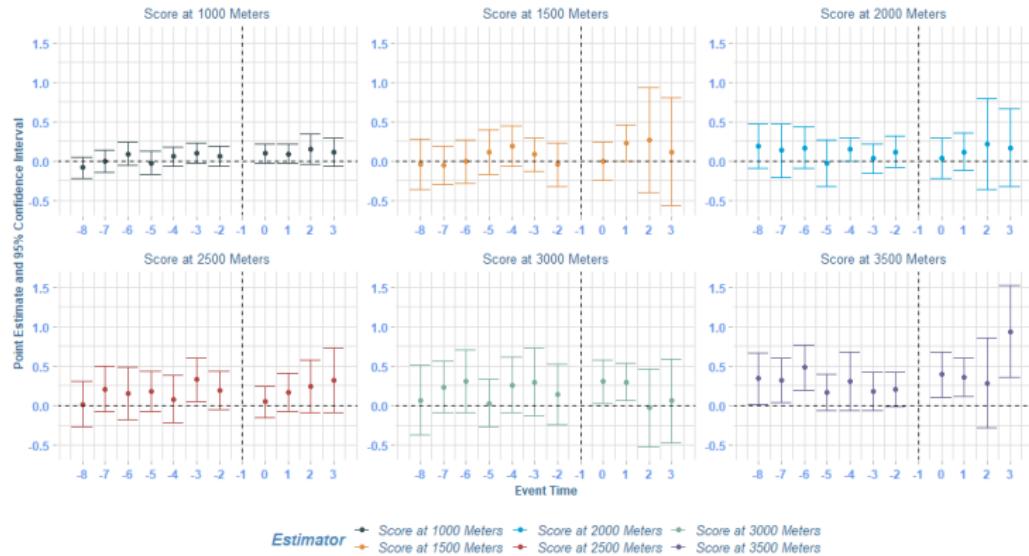


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Results in math test.

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Estimation of heterogeneities (Sun and Abraham, 2021 estimator) in mathematics results according to the nature of the school

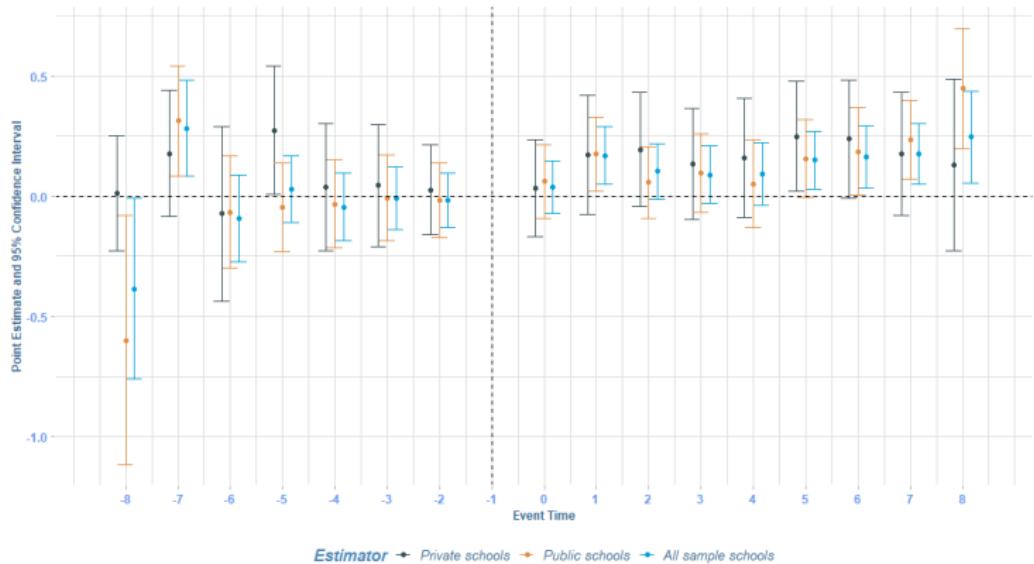


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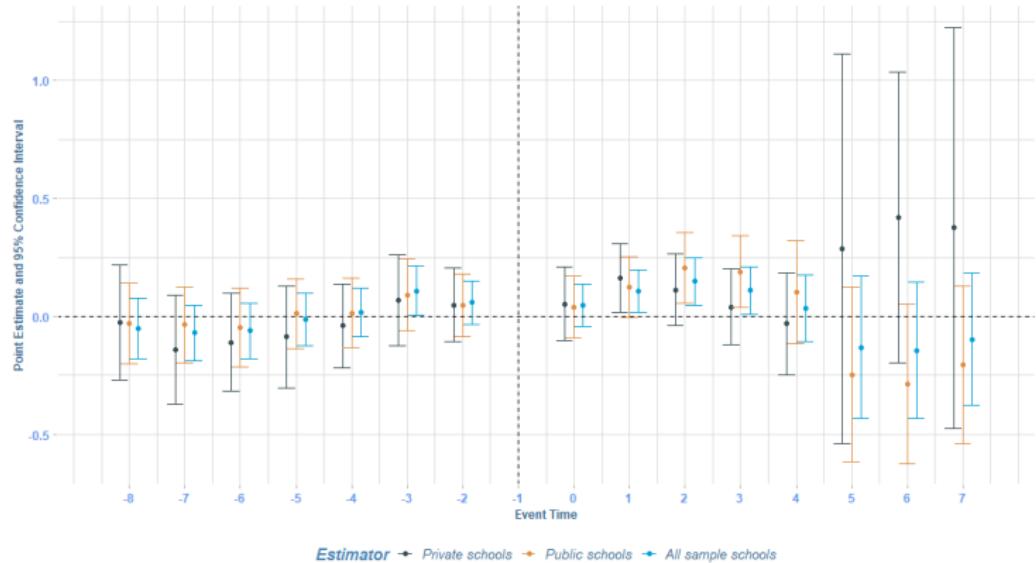


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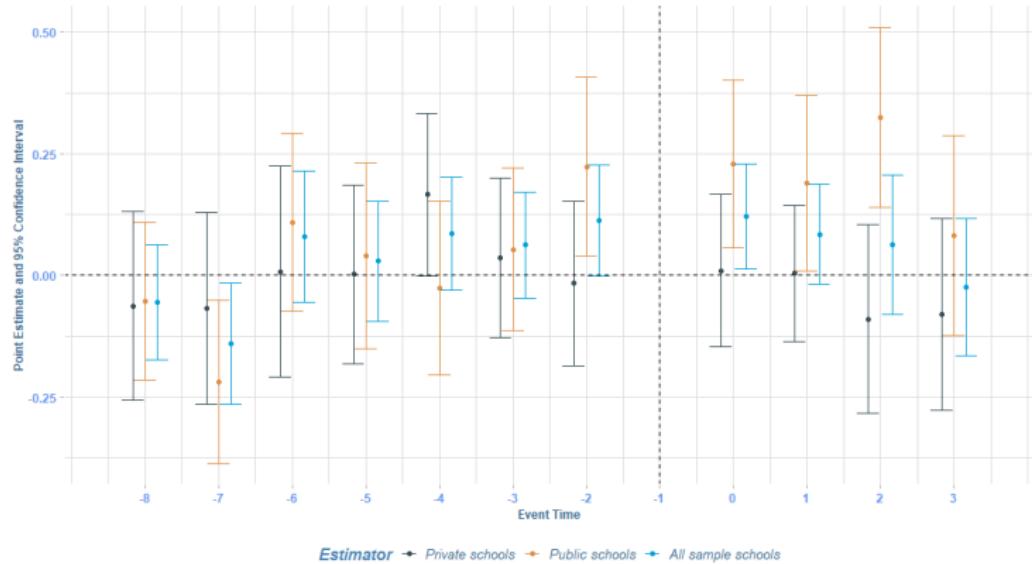


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Results in reading literacy test.

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Impact of Roads on average results of exam Saber 11 in reading literacy score.

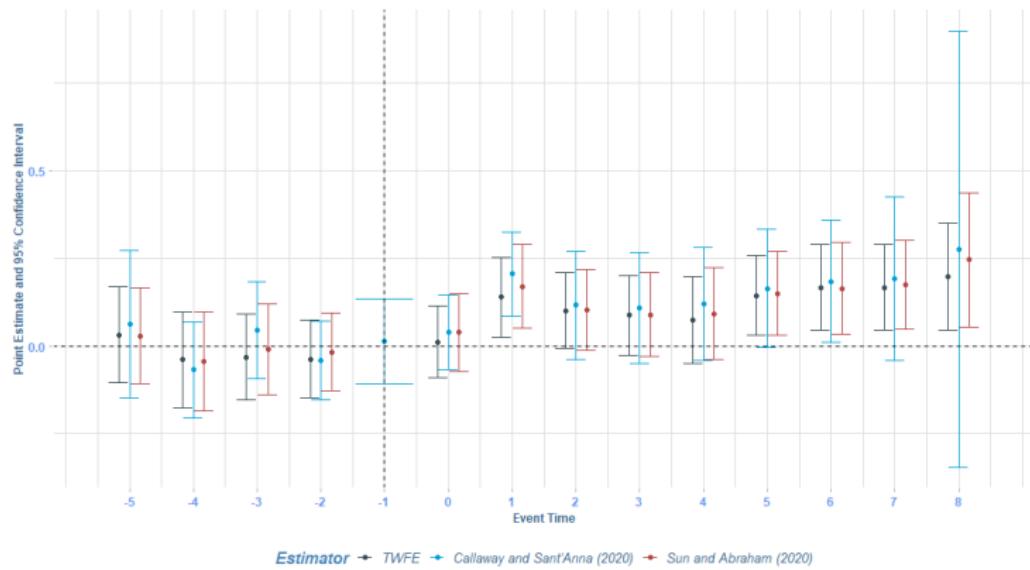


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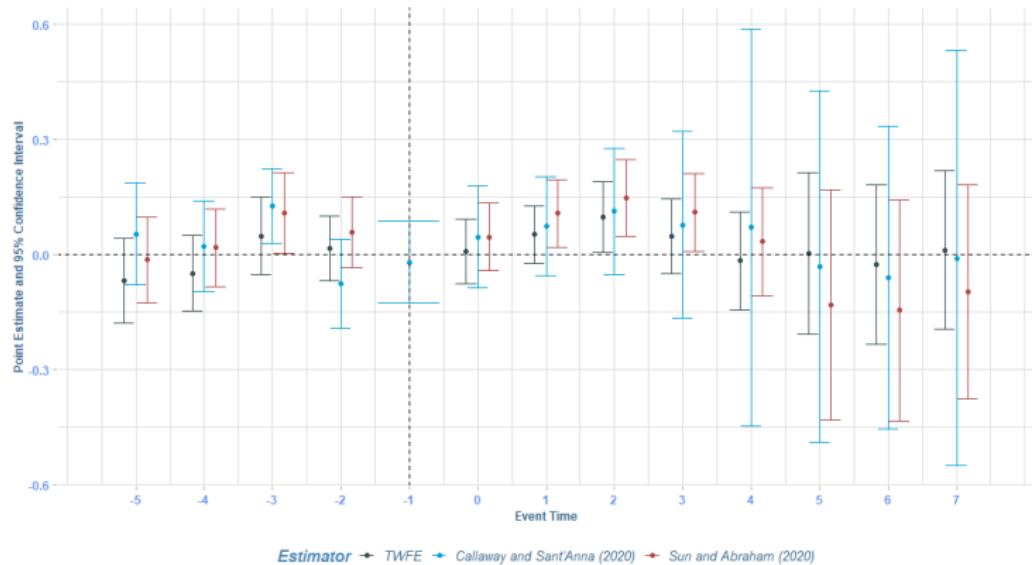


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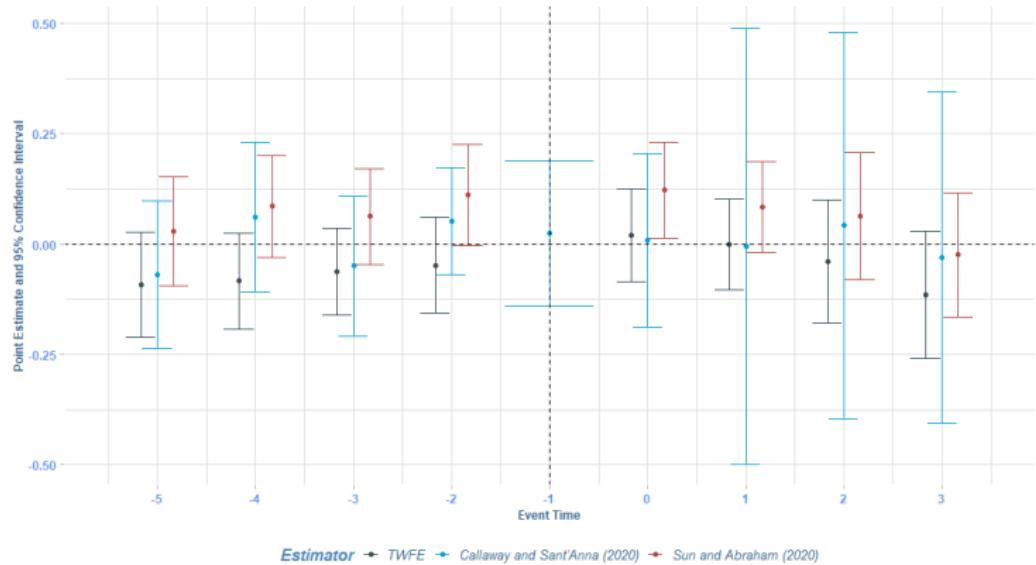


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Results in reading literacy test.

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Impact of road construction on reading literacy score by distance of school from road

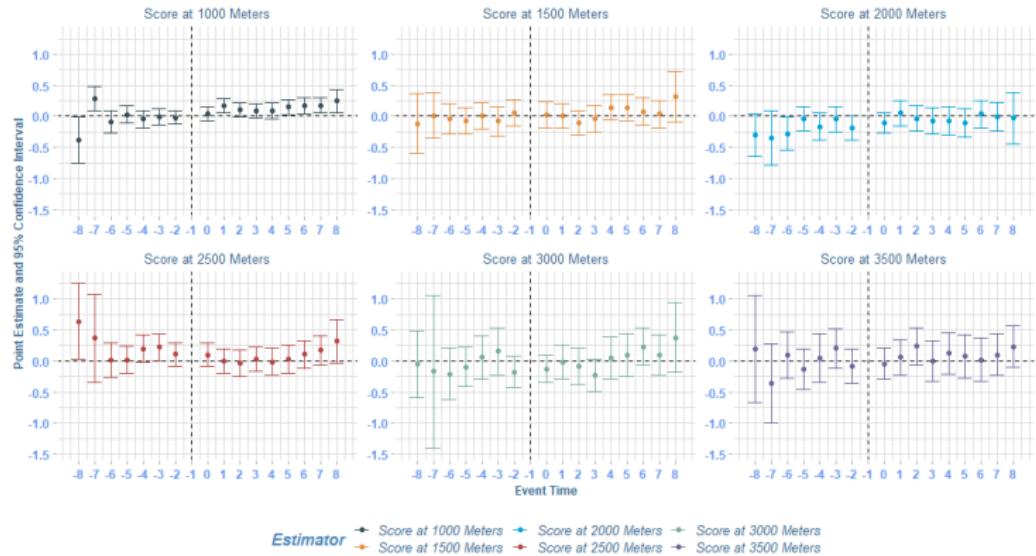


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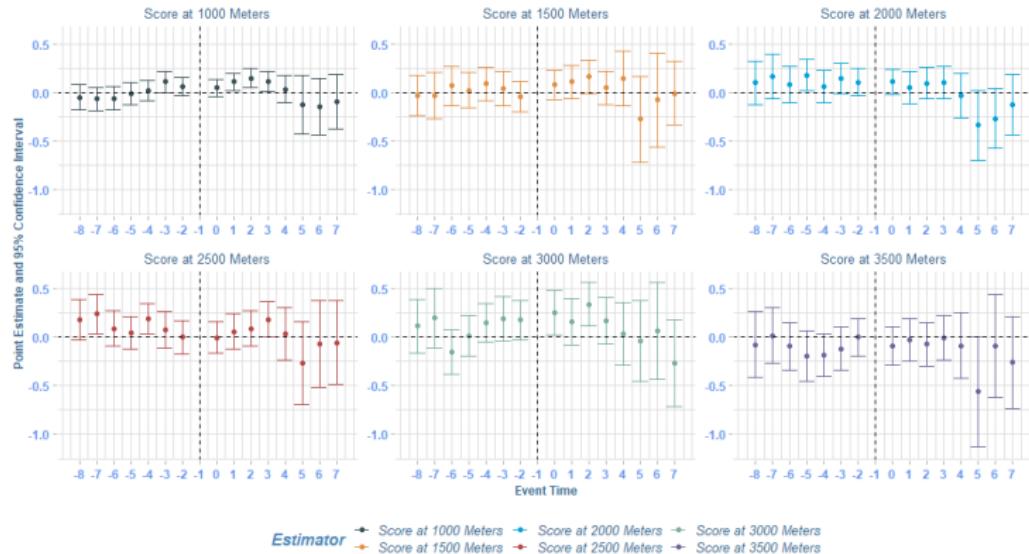


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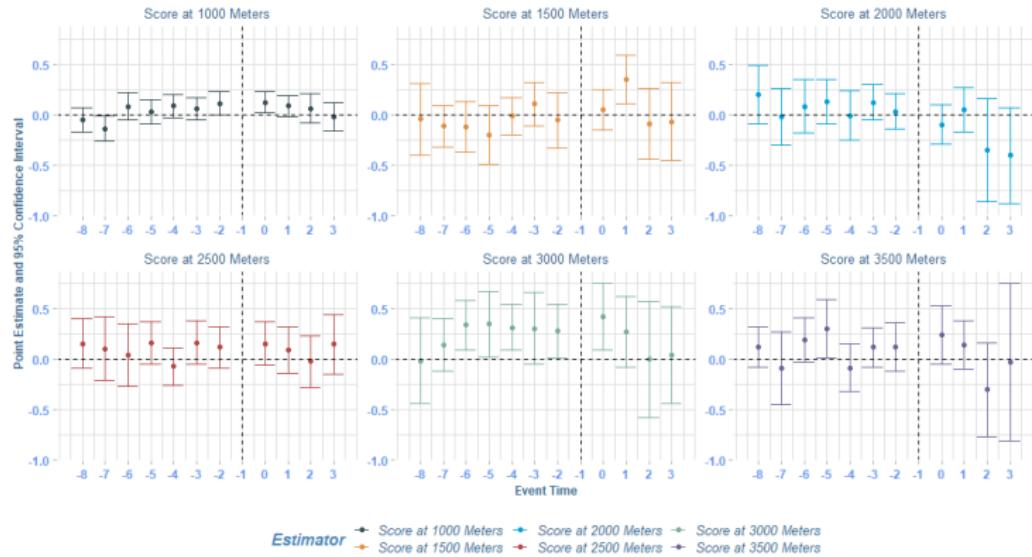


Figure: 100 % advance of construction

Results in reading literacy test.

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Heterogeneities in reading literacy score of students by nature of the school

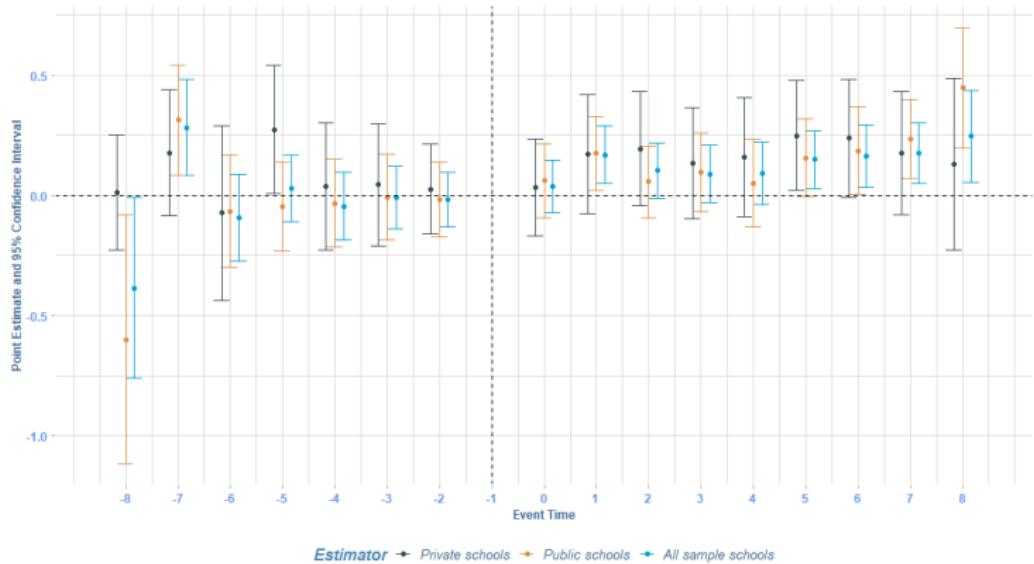


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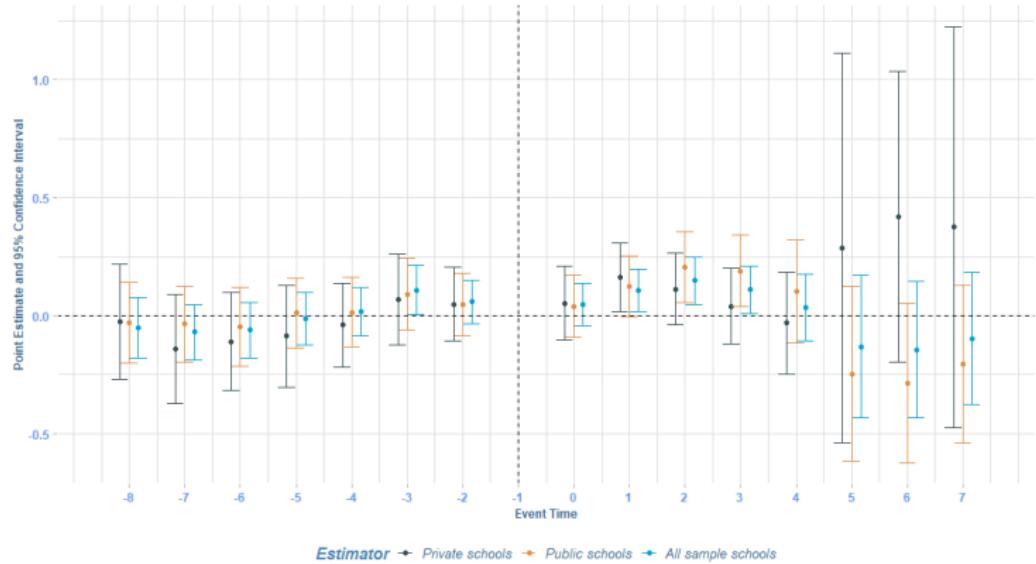


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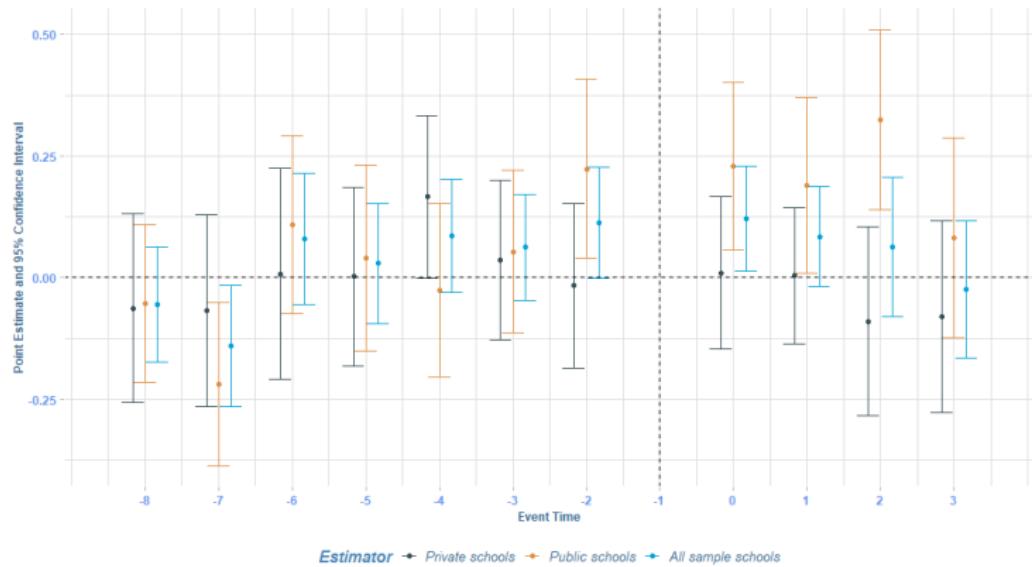


Figure: 100 % advance of construction

Results in labor force.

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Impact of Roads on average results on the fraction of students who participate in labor force in the last year of secondary education.

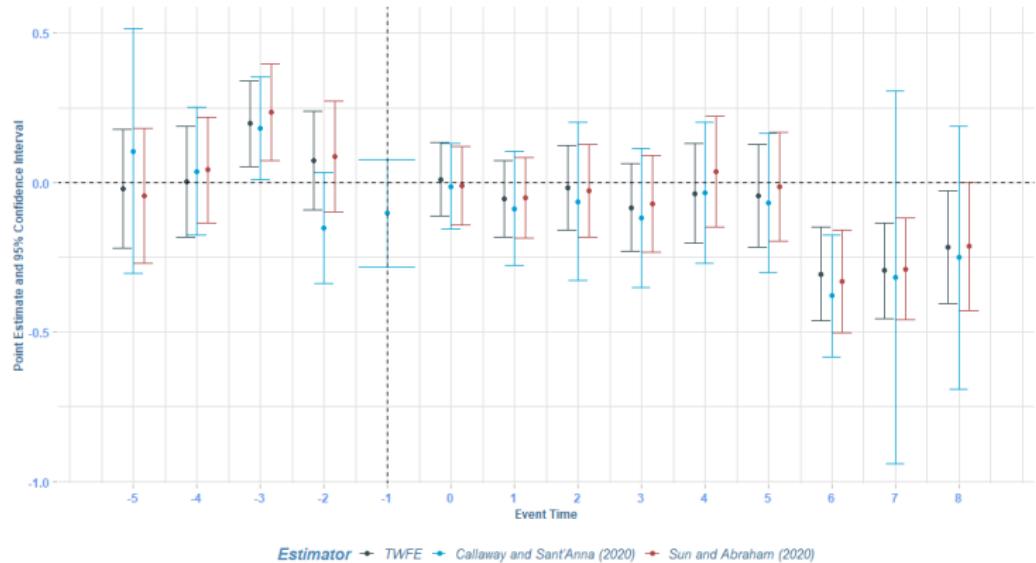


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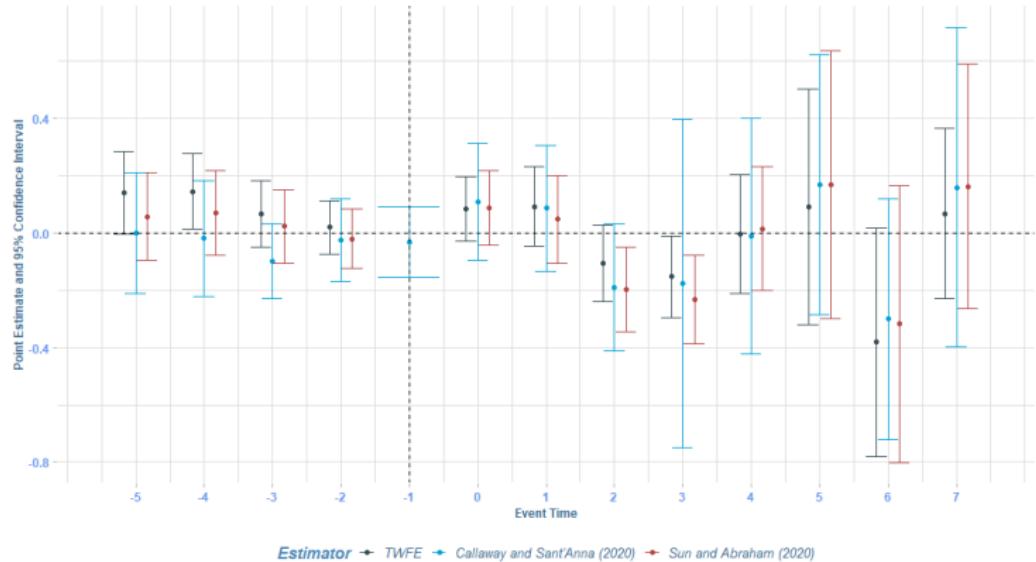


Figure: 50 % advance of construction

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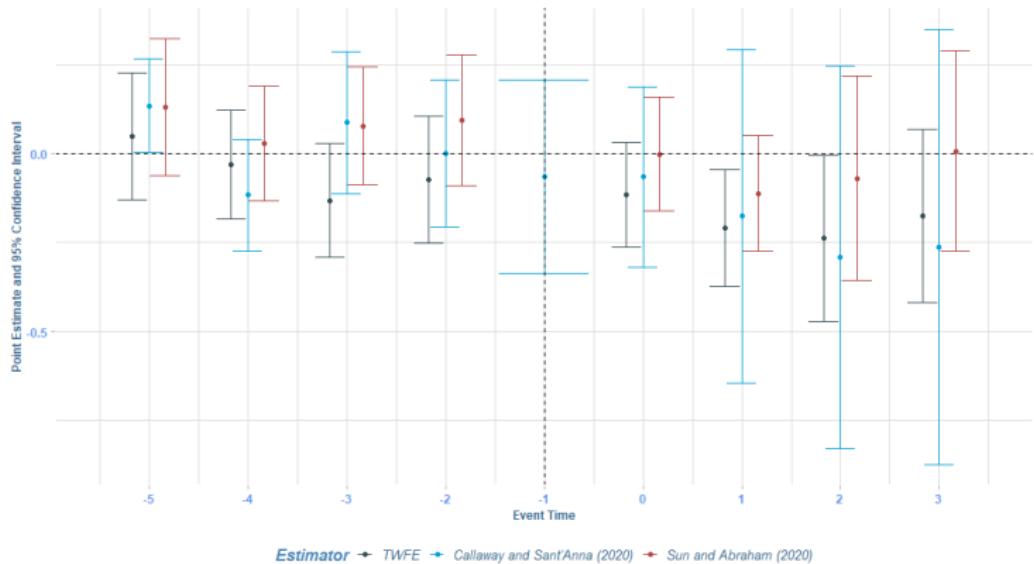


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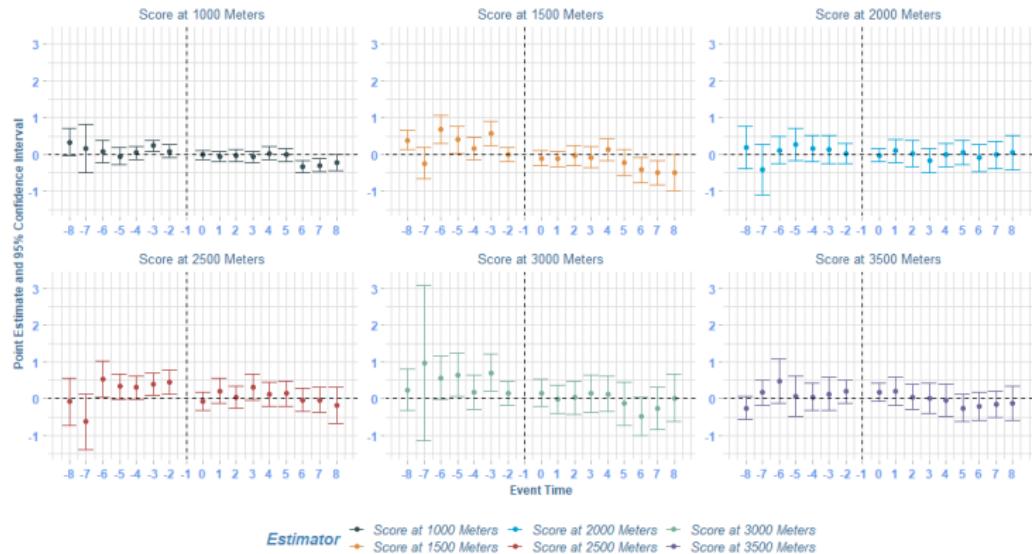


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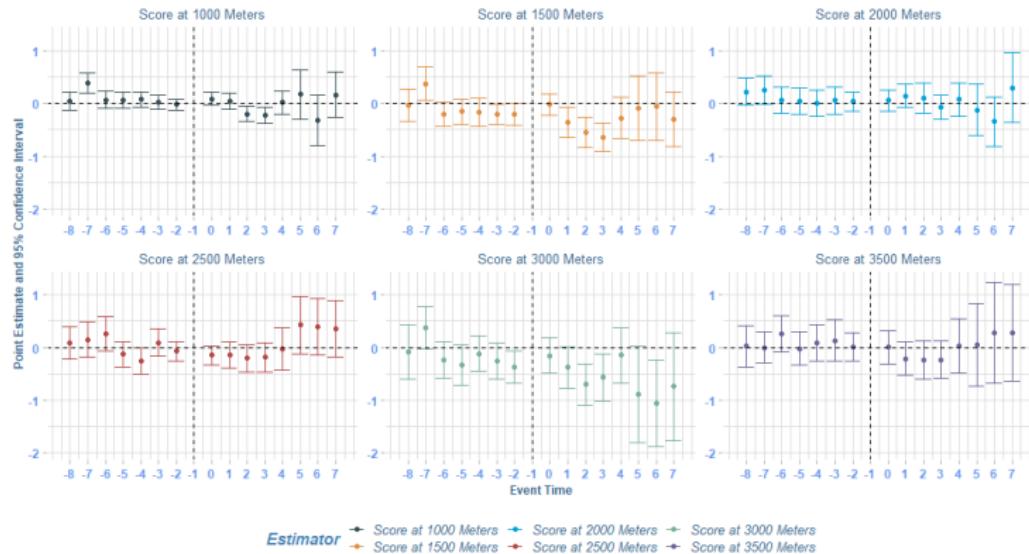


Figure: 50 % advance of construction

Results in labor force.

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Impact of Roads on average results on the fraction of students who participate in labor force in the last year of secondary education.

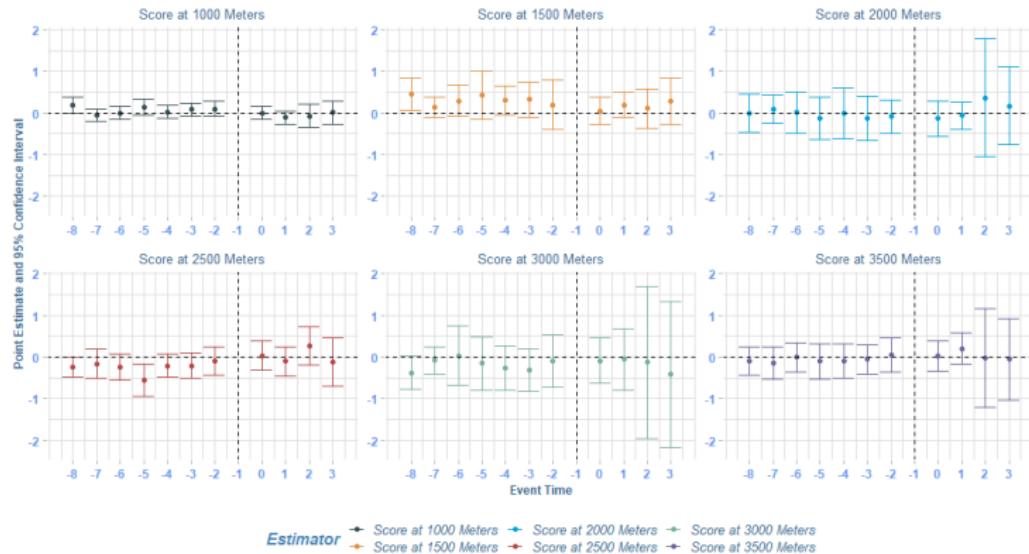


Figure: 100 % advance of construction

Results in labor force.

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Estimation of heterogeneities (Sun and Abraham, 2021 estimator) in labor force results according to the nature of the school.

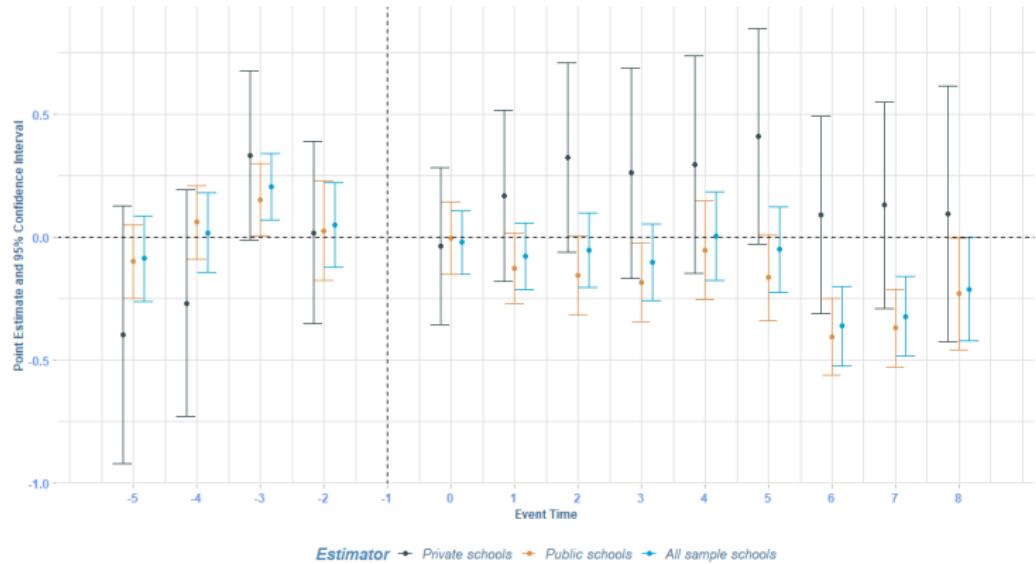


Figure: 10 % advance of construction

Results in labor force.

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Estimation of heterogeneities (Sun and Abraham, 2021 estimator) in labor force results according to the nature of the school.

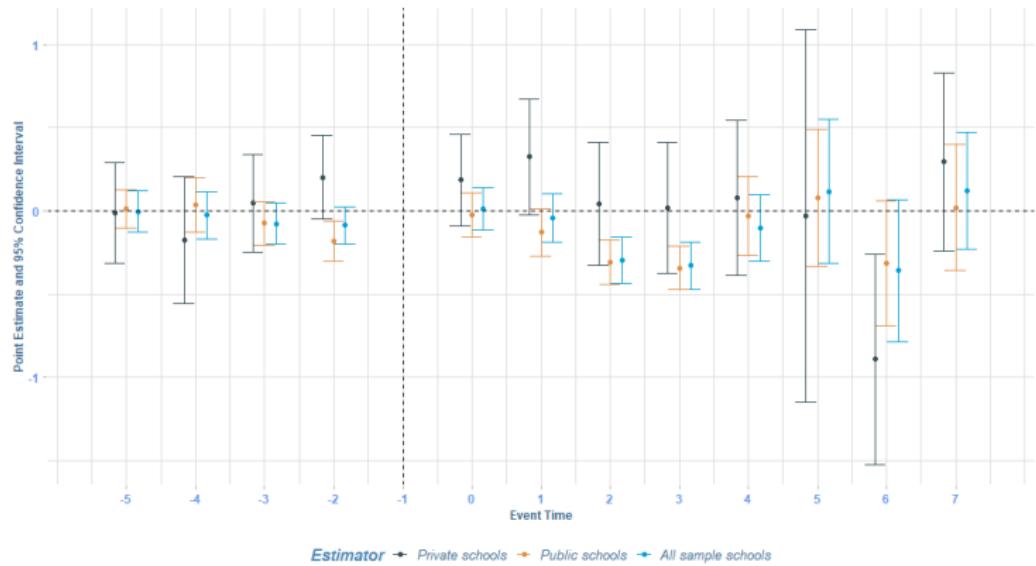


Figure: 50 % advance of construction

Mathematics score for all the different stages of construction

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Dependent Variable:	score in mathematics					
Model by level of construction :	10 %	graph!	50 %	graph!	100 %	graph!
<i>Variables</i>						
year = -8	-0.0149 (0.2195)		0.0173 (0.0804)		-0.0844 (0.0676)	
year = -7	0.2077 (0.1964)		0.0208 (0.0699)		-0.0026 (0.0734)	
year = -6	-0.2923 (0.1077)		-0.0347 (0.0587)		0.0872 (0.0760)	
year = -5	-0.0940 (0.0818)		0.0280 (0.0583)		-0.0266 (0.0747)	
year = -4	-0.0654 (0.0796)		0.0510 (0.0532)		0.0550 (0.0624)	
year = -3	-0.0328 (0.0691)		0.1018 (0.0494)		0.0997 (0.0640)	
year = -2	-0.0873 (0.0520)		0.1275 (0.0484)		0.0562 (0.0658)	
year = 0	0.0039 (0.0518)		0.0319 (0.0455)		0.0926 (0.0616)	
year = 1	0.0830 (0.0549)		0.0869 (0.0494)		0.0878 (0.0619)	
year = 2	0.0967 (0.0568)		0.1465 (0.0537)		0.1478 (0.0993)	
year = 3	0.0200 (0.0605)		0.1227 (0.0548)		0.1142 (0.0915)	
year = 4	0.0018 (0.0642)		0.0667 (0.0744)			
year = 5	0.0695 (0.0607)		-0.2395 (0.1893)			
year = 6	0.0843 (0.0674)		-0.2568 (0.1723)			
year = 7	0.1164 (0.0671)		-0.0735 (0.1711)			
year = 8	0.2204 (0.0958)					
<i>Fixed-effects</i>						
id_name	Yes		Yes		Yes	
year	Yes		Yes		Yes	
<i>Fit statistics</i>						
Observations	5,882		5,882		5,843	
R ²	0.73786		0.73699		0.73070	
<i>Results by buffer</i>						
Buffer 1000 m - 3500 m	Graph	!	Graph	!	Graph	!
Nature of school	Graph	!	Graph	!	Graph	!

Clustered (*id_name*) standard-errors in parentheses

Signif. Codes: : 0.01, : 0.05, : 0.1

Reading literacy score for all stages of construction.

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Dependent Variable:	Reading literacy					
Model by level of construction :	10 %	graph!	50 %	graph!	100 %	graph!
<i>Variables</i>						
year = -8	-0.3852(0.1915)		-0.0521 (0.0651)		-0.0552(0.0608)	
year = -7	0.2824(0.1017)		-0.0701 (0.0594)		-0.1408 (0.0635)	
year = -6	-0.0934 (0.0919)		-0.0622 (0.0596)		0.0795 (0.0693)	
year = -5	0.0283 (0.0702)		-0.0131 (0.0571)		0.0293 (0.0630)	
year = -4	-0.0446 (0.0714)		0.0176 (0.0523)		0.0857 (0.0590)	
year = -3	-0.0094 (0.0666)		0.1078 (0.0540)		0.0621 (0.0558)	
year = -2	-0.0173 (0.0568)		0.0580 (0.0465)		0.1121 (0.0584)	
year = 0	0.0381 (0.0562)		0.0459 (0.0453)		0.1219 (0.0551)	
year = 1	0.1691 (0.0611)		0.1074 (0.0452)		0.0841 (0.0526)	
year = 2	0.1027 (0.0587)		0.1474 (0.0506)		0.0630 (0.0735)	
year = 3	0.0888 (0.0610)		0.1097 (0.0519)		-0.0247 (0.0718)	
year = 4	0.0917 (0.0666)		0.0335 (0.0718)			
year = 5	0.1497 (0.0615)		-0.1309 (0.1534)			
year = 6	0.1640 (0.0666)		-0.1449 (0.1471)			
year = 7	0.1752 (0.0643)		-0.0966 (0.1423)			
year = 8	0.2455 (0.0982)					
<i>Fixed-effects</i>						
id_name	Yes		Yes		Yes	
year	Yes		Yes		Yes	
<i>Fit statistics</i>						
Observations	5,882		5,882		5,843	
R ²	0.74701		0.74888		0.74911	
<i>Results by buffer</i>						
Buffer 1000 m - 3500 m	.	▶	.	▶	.	▶
Nature of school	.	▶	.	▶	.	▶
<i>Clustered (id_name) standard-errors in parentheses</i>						