School Choice, Teacher Access, and Student Outcomes

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2025 Dynamic Structural Estimation Conference at HKU

Motivation

- Teachers are among the most important factors determining students' academic and lifetime outcomes

  Rockoff, 2004, Rivkin et al., 2005, Kane et al., 2008, Chetty et al., 2014a, Chetty et al., 2014b

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- Introducing charter schools will further reshape the existing student-teacher matching
  - Simultaneously create enrollment options for students and job opportunities for teachers
- Most studies on charter schools focus on the student-side response

  Mehta, 2017, Walters, 2018, Ferreyra and Kosenok, 2018, Singleton, 2019, Gilraine et al., 2023

Overview

This paper investigates how the entry of charter schools affects teacher access at existing public schools

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- Incorporate joint sorting of students and teachers

More broadly, it provides a unified framework to understand inequality in teacher access

- Teacher hiring process, school choice process, and test score production

Research Questions

1. How does charter school expansion affect the sorting pattern of students and teachers?
2. What is the role of *joint sorting* in reshaping teacher access and student outcomes under charter school expansion?
3. Can policymakers achieve a better balance between teacher access and school choice?

Preview of Main Findings

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- Teachers and high-income students jointly sort into new charter schools, particularly from low-income public schools
- DID analysis: average teacher value-added $\downarrow$ by 0.023σ, share of low-income students $\uparrow$ by 3.15 p.p. at nearby low-income public schools post-entry

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2. What is the role of *joint sorting* in reshaping teacher access and student outcomes under charter school expansion?

- Charter school expansion exacerbates *joint sorting for high-income students*
- Counterfactual analysis: joint sorting for high-income students $\uparrow$ the income achievement gap by 0.006σ one-year post-entry $\sim$ \$2,400 lifetime earnings gap

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2. What is the role of *joint sorting for high-income students* in reshaping teacher access and student outcomes under charter school expansion?
3. Can policymakers achieve a better balance between teacher access and school choice?

- Improve accessibility of charter schools to low-income students
- Policy simulation: providing bus services to charter schools + relocating charter schools to low-income neighborhoods $\downarrow$ the gap by 0.003σ

Contribution to the Literature

- A general equilibrium framework to understand inequality in teacher access

  Lankford et al., 2002, Clotfelter et al., 2005, Boyd et al., 2005, Boyd et al., 2013, Mansfield, 2015, Biasi et al., 2025, Bobba et al., 2021, Bates et al., 2025, Delgado, 2023, Laverde et al., 2025, Ederer, 2023, Abdulkadiroğlu et al., 2020

- Modeling peer preference in the joint sorting framework

  Tincani, 2021, Sorensen and Holt, 2021

- A new perspective on impacts of charter schools: the teacher-side response

  Imberman, 2011, Mehta, 2017, Gilraine et al., 2021, Sorensen and Holt, 2021, Mumma, 2022, Gilraine et al., 2023

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Institutional Background: Charter Schools

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- Public: funded by the government and tuition-free
- Accountable: approved and monitored by the public authorizing agency
- Autonomous: more flexibility than traditional public schools in operations (location, curriculum, etc)
  $\rightarrow$ various student body characteristics (Bergman and McFarlin Jr, 2018, Unterman, 2017, Setren, 2021, Singleton, 2019)

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- In the 2022-2023 school year, 8150 charter schools in the US, with 3.7 million students and 251,000 teachers (National Alliance for Public Charter Schools)

Institutional Background: Charter Schools in North Carolina

Charter school expansion in North Carolina:

- NC first approved in 1997 and set a 100-school cap on the number of charter schools
- In 2011, NC removed the 100-school cap
- In the 2024-2025 school year, 208 charter schools enroll 10% of public school students in NC

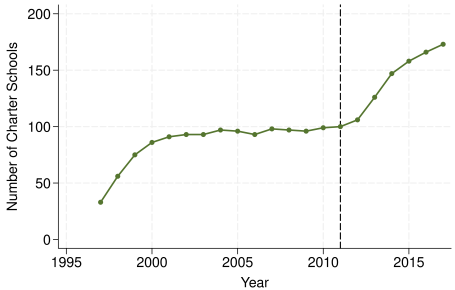

Figure: Number of Charter Schools in North Carolina 1997-2017

Data

- All public schools in North Carolina, 2009-2017
- Student-level: enrollment, test scores, demographics, residential location
- Teacher-level: employment, demographics, experience, educational level, subject/course taught, wage[1]
- Course-level: student-teacher match
- School-level: location, magnet/charter, student body composition

[1] I only observe wage for traditional public schools. I use NTPS data to infer the average wage schedule at charter schools.

Details

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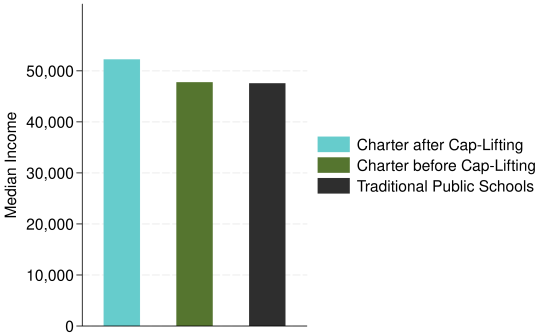
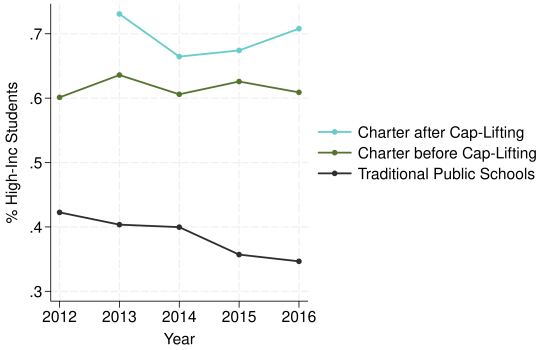
Motivating Evidence #1: Charter Schools in NC Predominantly Enroll High-Income Students



(a) Neighborhood Median Income (2016)



(b) % of High-Income Students (2012-2016)

Figure: Neighborhood & Student Characteristics at TPS vs Charter in North Carolina

Motivating Evidence #2: Joint-Sorting Under Charter School Expansion

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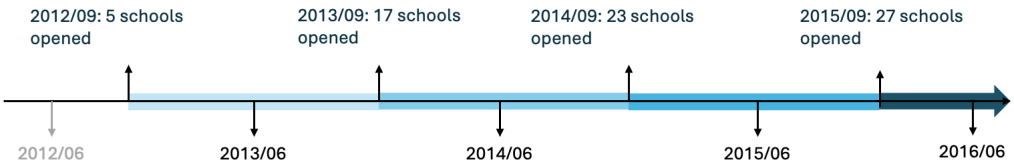

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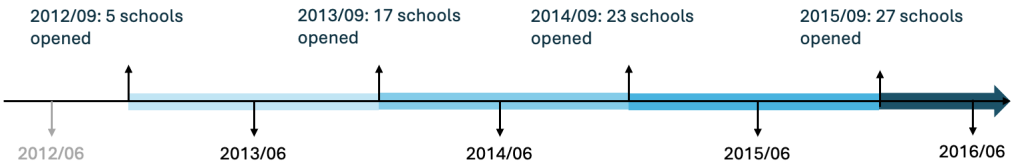

- Sample: traditional public schools in the largest three commuting zones of North Carolina
  - Treated schools: located within 5 miles of at least one new charter school
  - Control schools: located between 15 to 30 miles from any new charter school

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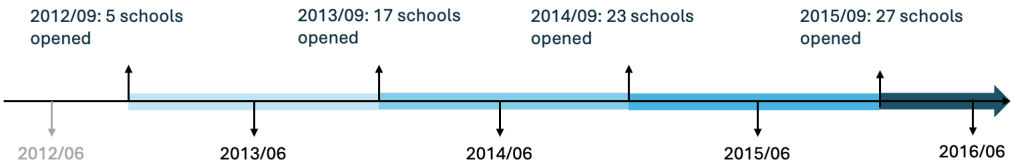

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  - Treated schools: located within 5 miles of at least one new charter school
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- Treatment intensity varies by the size of charter schools: per unit treatment is 500 seats

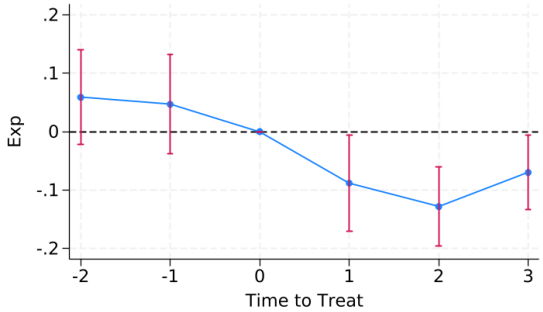
Motivating Evidence #2: Joint-Sorting Under Charter Expansion

I estimate the following equation via staggered DID (De Chaisemartin and d'Haultfoeuille, 2022)

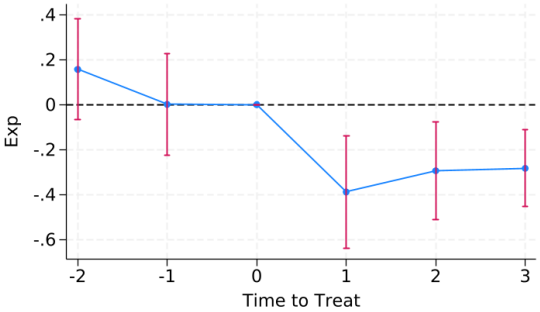
$$y_{kt} = \sum_{s=2009}^{2011} \beta_s(\mathbb{1}(t = s) \times treated_k) + \sum_{s=2013}^{2016} \beta_s(\mathbb{1}(t = s) \times treated_k) + X_{kt}\delta + \phi_k + \psi_t + \epsilon_{kt}$$

- School k, year t
- y_{kt}: average teacher experience, average teacher value-added, share of low-income students
- X_{kt}: enrollment size, the share of low-income students, the share of white students, the unemployment rate, and median income at the county level

Motivating Evidence #2: Impacts on Teacher Experience



(a) All TPS

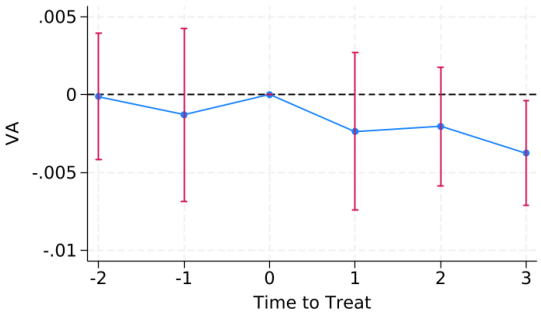


(b) Low-Income TPS

Figure: Per Unit Treatment Effect on Avg Teacher Experience

Robustness

Motivating Evidence #2: Impacts on Teacher Value-Added



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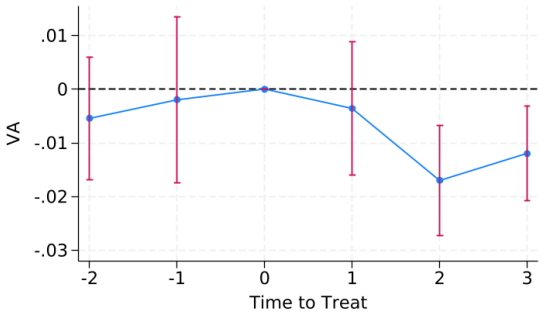

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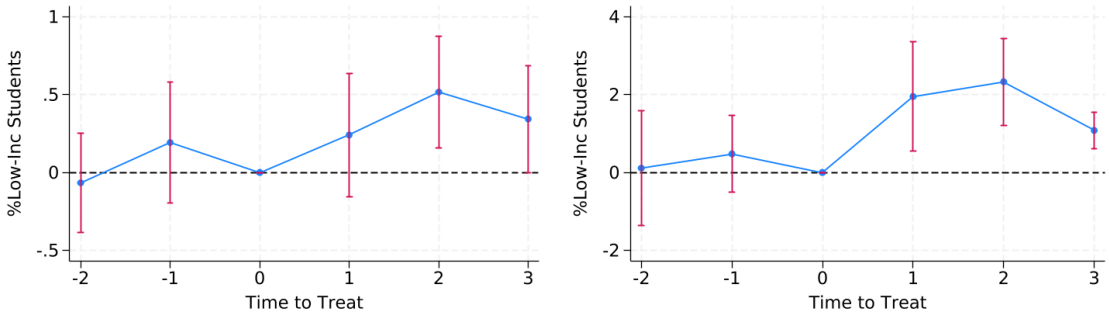
Figure: Per Unit Treatment Effect on Avg Teacher Value-Added

VA Estimation Robustness

Motivating Evidence #2: Impacts on Student Income Composition



(a) All TPS

(b) Low-Income TPS

Figure: Per Unit Treatment Effect on % Low-Income Students

Robustness

Motivating Evidence #2: Impacts on Other Dimensions

	All TPS	Low-Income TPS
Panel A		
Teacher Turnover Rate	1.26^{***}	4.07^{***}
	(0.38)	(1.21)
% Teacher New-to-School	2.05^{***}	2.23
	(0.46)	(1.44)
% Teacher New-to-Teach	0.28	1.06^{*}
	(0.20)	(0.56)
Class Size	0.96	0.91
	(0.60)	(0.80)
Enrollment	-3.3	-17.2
	(3.76)	(10.18)
Obs	2494	456
Panel B		
Standardized Math Score	0.009	-0.061
	(0.010)	(0.082)
Obs	288811	44534

Table: Average Total Treatment Effects on Other Dimensions

Takeaway

Research Question #1:

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Under the expansion of high-income charter schools,

- Teachers and high-income students sort into new charter schools, particularly from low-income TPS

$\rightarrow$ A key potential mechanism: preferences for high-income students

Boyd et al., 2013, Bobba et al., 2021, Bates et al., 2025, Allende, 2019

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Under the expansion of high-income charter schools,

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→ A key potential mechanism: preferences for high-income students

Boyd et al., 2013, Bobba et al., 2021, Bates et al., 2025, Allende, 2019

However, student income composition at each school is an equilibrium outcome of students' choices

→ Generalizing impacts of charter schools is context-dependent

Connecting to the Model

Empirical Pattern		Model
Teachers sort between TPS and charter	$\rightarrow$	A two-sided matching process between teachers and schools
Students sort between TPS and charter	$\rightarrow$	A one-sided school choice process for students
Students' choices interact with each other due to peer preference	$\rightarrow$	Student income composition at each school is a realized equilibrium under rational expectation

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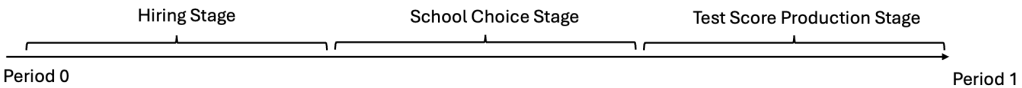
Model: Timing

A three-stage static model involving students, teachers, and schools:



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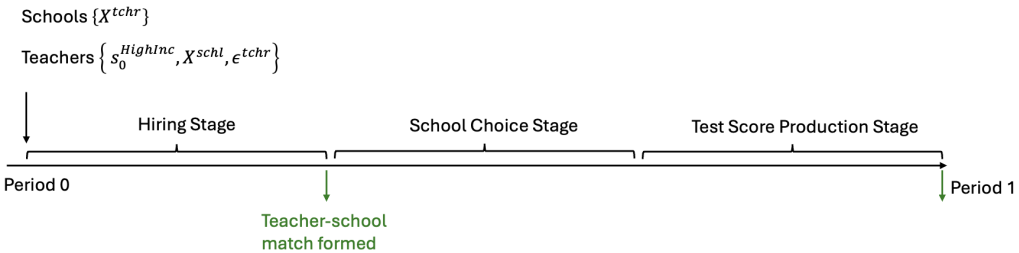

- Schools first make job offers to teachers simultaneously
- Given her offer set, each teacher chooses the most preferred offer

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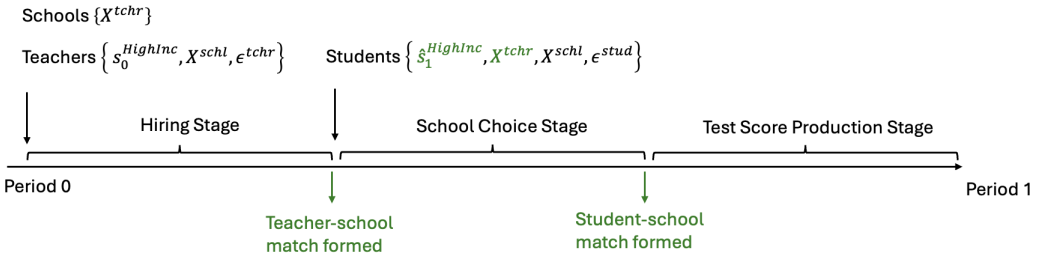

- Given the teacher-school match and the belief on student income composition, each student chooses her most preferred school

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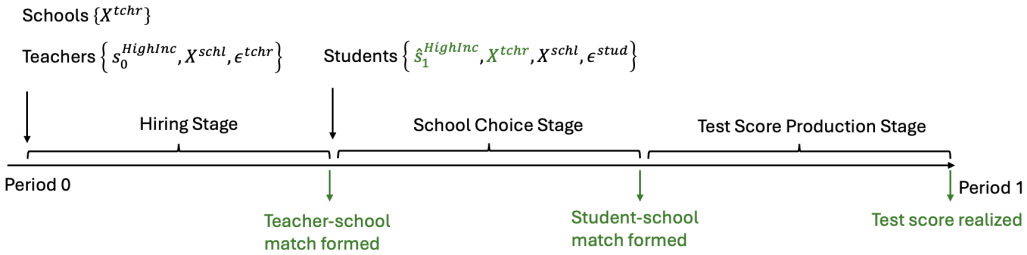

- Students are randomly assigned to teachers $\rightarrow$ test scores realize

Stage 1: Teacher Hiring[2]

School's Problem:

Teacher j's value to school k at time t is

$$U_{kjt}^{schl} = \beta_1 x_{jt} + \beta_2 v_{jt} + \beta_3 e_{jt} + \beta_4 v_{jt} \cdot a_{kt}$$

- x_{jt}: years of teaching experience
- v_{jt}: value-added
- e_{jt}: education level
- a_{kt}: share of high-achieving students at school k

[2]The teacher-hiring model closely follows Biasi et al., 2025.

Stage 1: Teacher Hiring

School k forms a belief about each teacher's probability of accepting the offer, s_{jkt}, and solves the following problem by making offer decisions o_{kt}:

$$\max_{o_{kt}} \sum_j o_{kjt} \cdot s_{jkt} \cdot U_{kjt}^{schl}$$

$$s.t. \sum_j o_{kjt} \cdot s_{jkt} \leq \kappa_{kt} \quad \text{(capacity constraint)}$$

$$o_{kjt} = 1 \text{ if } x_{jt} \geq 4 \text{ and } k_{jt-1} = k \quad \text{(tenure constraint)}$$

- κ_{kt}: capacity limit
- k_{jt-1}: teacher's last year employer

Solution

Teacher's Problem:

Teacher j's utility from working at school k is

$$U_{jkt}^{tchr} = \underbrace{\Gamma(k, k_{jt-1}|\Theta_1)}_{\text{moving cost}} + Z_{kt-1}\Theta_2 + w_{jkt}\theta_3 + \epsilon_{jkt}$$

$$\text{with } \Gamma(k, k_{jt-1}|\Theta_1) = \mathbb{1}(k \neq k_{jt-1})(\theta_0 + \theta_1 ln(distance_{k,k_{jt-1}}))$$

- $distance_{k,k_{jt-1}}$: distance between last year employer k_{jt-1} and potential employer school k
- Z_{kt-1}: student body characteristics at time $t-1$
- w_{jkt}: wage
- ϵ_{jkt}: type 1 extreme value (σ_ϵ normalized to 1)

Stage 1: Teacher Hiring

Teacher's optimal choice:

$$k_{jt}^{*} = \arg\max_{k \in O_{jt}} \; U_{jkt}^{tchr}$$

- $O_{jt} = \{k : o_{kjt} = 1\}$: teacher j's offer set

Student's Problem:

Student i's utility from attending school k is

$$U_{ikt}^{stud} = \beta_z^v \bar{v}_{kt} + \beta_z^s h_{kt} + \alpha_z d_{ik} + \alpha_z^A d_{ik} \times Assign_{ik} + \alpha_z^M d_{ik} \times Magnet_k + \beta_z^A Assign_{ik} + \beta_i^C Charter_k + \beta_z^M Magnet_k + \xi_k + \epsilon_{ikt}$$

- z: student income-by-race type
- $\bar{v}_{kt}$: *realized* average teacher value-added at time t
- h_{kt}: *expected* share of low-income students time t
- d_{ik}: traveling distance between school k and student i's residential location

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Student i forms a belief about $\{h_{kt}\}_k$ and makes school choice:

$$k_i^* = \arg\max_{k \in C_i} U_{ikt}^{stud}$$

Stage 3: Test Score Production

Test score of student i enrolling at school k is

$$A_{ikt} = X_i\beta + Z_{kt}\gamma + \bar{v}_{kt}$$

- X_i: student individual characteristics
- Z_{kt}: peer and school characteristics in equilibrium
- $\bar{v}_{kt}$: average teacher value-added in equilibrium

Model: Equilibrium

Definition. An equilibrium is a tuple of decisions $\{\{k_i^*\}_i, \{k_j^*\}_j, \{o_k^*\}_k\}$ and beliefs $\{\{h_k^*\}_k, \{s_k^*\}_k\}$ such that

1. Given $\{\{k_j^*\}_j, \{o_k^*\}_k\}$ and belief $\{h_k^*\}_k$, $\{k_i^*\}_i$ solves the student's problem;
2. Given $\{o_k^*\}_k$, $\{k_j^*\}_j$ solves the teacher's problem;
3. Given belief $\{s_k^*\}_k$, $\{o_k^*\}_k$ solves the school's problem;
4. Belief $\{s_k^*\}_k$ is consistent with teachers' and schools' decisions $\{\{k_j^*\}_j, \{o_k^*\}_k\}$; belief $\{h_k^*\}_k$ is consistent with students' decisions $\{k_i^*\}_i$.

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Identification Challenges

Identification challenge #1:

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Identification challenge #2:

- The share of low-income students can be correlated with school unobserved characteristics ξ
- Solution: instrumental variables (Allende, 2019, Crema, 2023)
  - Share of low-income households nearby (excluding catchment areas)
  - Share of charter schools nearby

1st Stage Results

Estimation Results

Highlight #1: Both students and teachers prefer high-income students

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For a 10% $\uparrow$ in share of high-income students:

- A high-income white student will travel 1.32 miles further
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Highlight #3: High-income students prefer charter schools more

- But with a large degree of heterogeneity

Results

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Counterfactual #1: Understanding the Role of Joint-Sorting

Research Question #2:

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1. A baseline scenario with estimated preferences

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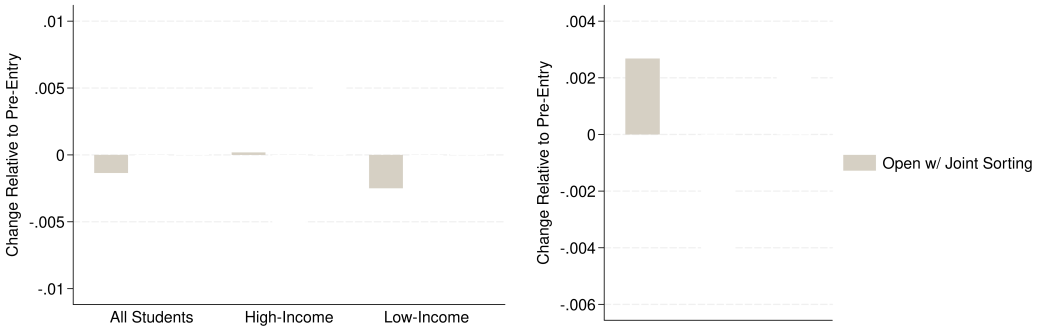
2. Turning off both teachers' and *high-income white* students' preferences for % of high-income students
3. Turning off teachers' preferences for % of high-income students only

Counterfactual #1: Baseline Scenario



(a) Changes in Test Score

(b) Changes in Test Score Gap

Figure: Impacts on Students at Existing Public Schools

Counterfactual #1: Shut Down Joint-Sorting

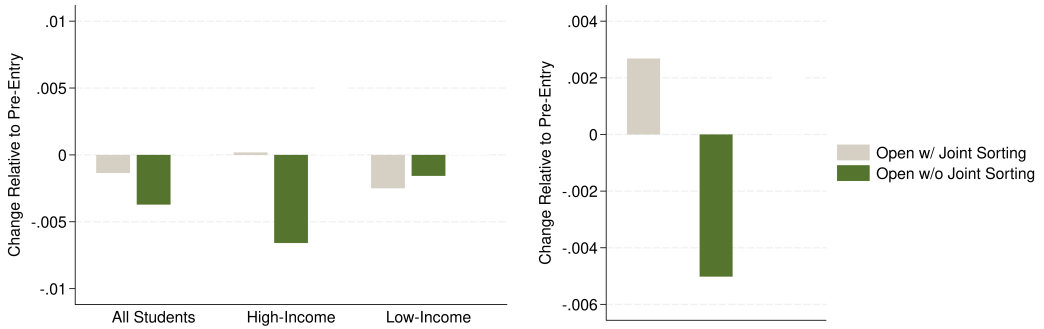


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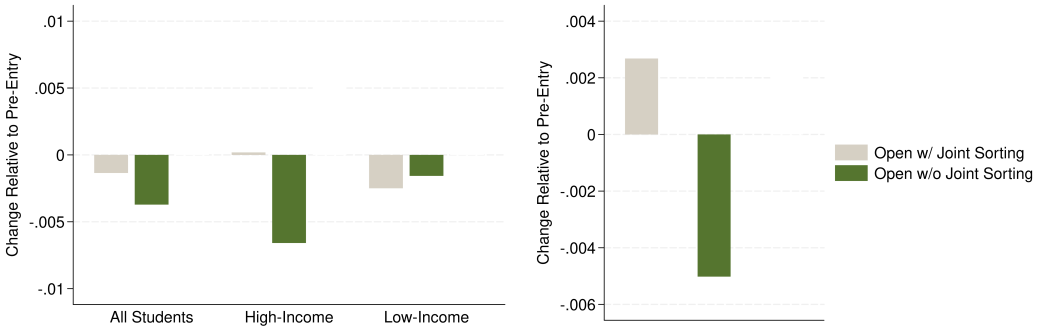
Figure: Impacts on Students at Existing Public Schools

Counterfactual #1: Shut Down Joint-Sorting



(a) Changes in Test Score

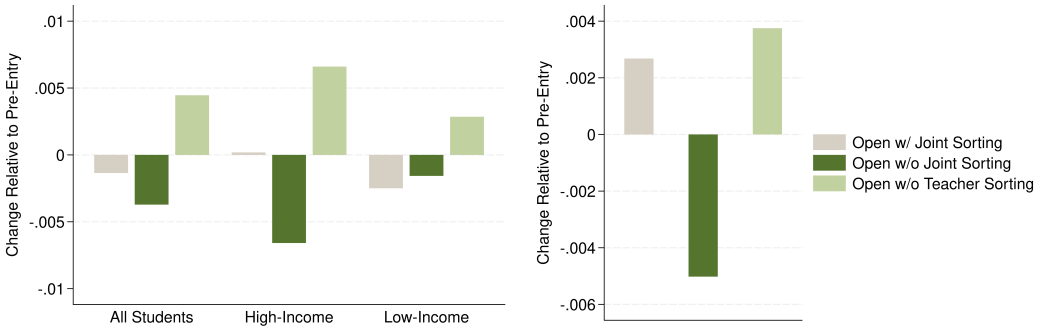
(b) Changes in Test Score Gap

Figure: Impacts on Students at Existing Public Schools

Economic impact: a $0.006\sigma \downarrow$ in the income achievement gap $\sim$ a $\$2,400 \downarrow$ in lifetime earnings gap

Chetty et al., 2014b: replacing teachers with value-added in the bottom 5% with average ones $\uparrow$ lifetime earnings by $8,865

Counterfactual #1: Shut Down Teacher-Side Sorting



(a) Changes in Test Score

(b) Changes in Test Score Gap

Figure: Impacts on Students at Existing Public Schools

Counterfactual #2: Policy Interventions

Research Question #3:

- Can policymakers achieve a better balance between teacher access and school choice?

Counterfactual #2: Policy Interventions

Research Question #3:

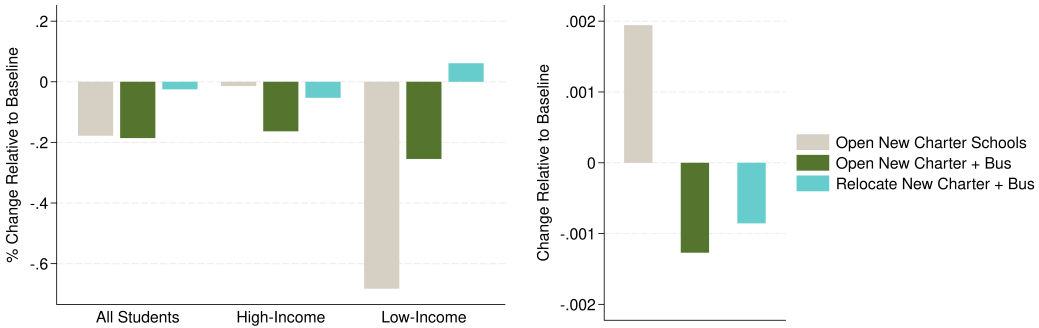
- Can policymakers achieve a better balance between teacher access and school choice?

I simulate a set of policies to improve accessibility of charter schools to *low-income* students:

- Providing bus services to charter schools
- Providing bus services to charter schools + Relocating new charter schools to low-income neighborhoods

⏩ Algorithm

Counterfactual #2: Policy Interventions



(a) Changes in Test Score

(b) Changes in Test Score Gap

Figure: Impacts on Students at Existing Public Schools

Conclusion

- By exploiting the cap-lifting in North Carolina, I document the joint sorting pattern among students and teachers
- By modeling a unified framework of teacher hiring and school choice, I show
  - how joint sorting exacerbates outcome inequality under charter school expansion
  - how policymakers can achieve a better balance between school choice and teacher access
- More generally, this framework can be applied to other educational policies
  - School admission policies, school vouchers, school closure/consolidation, etc

Comments are welcome!

yaotu@bc.edu ◇ https://www.yuzhi-yao.com/

Scan for the paper

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Appendix: Infer Wage Schedule at Charter Schools

I infer the wage schedule at charter schools using the National Principal and Teacher Survey:

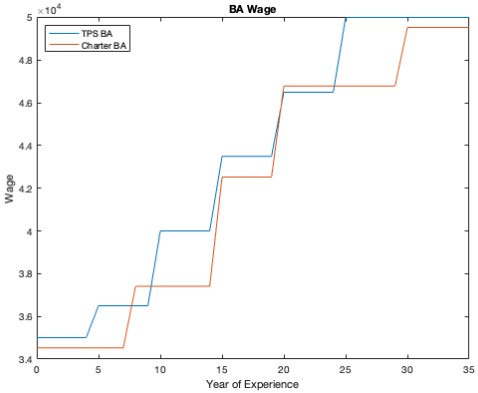
- Public version reports summary statistics for different sub-samples (e.g., by year of experience and educational level)
- It contains information on teachers' full-time status, years of teaching experience, educational degree, base salary, and total school-related earnings
- I restrict the sample to full-time charter school teachers in North Carolina

An example:

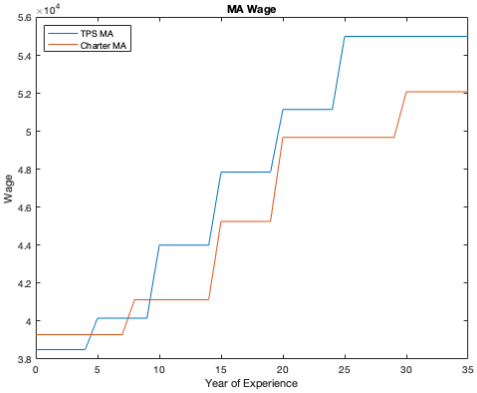
1. Restrict sample to teachers with seven years of experience or below
   $\rightarrow$ average salary is $\$35,836$ for 3494 teachers
2. Restrict sample to teachers with seven years of experience or below AND a Bachelor's degree
   $\rightarrow$ average salary is $\$34,525.5$ for 2533 teachers
3. The inferred average salary for teachers with seven years of experience or below AND a Master's degree is

$$\$35,836 = \frac{\$34,525.5 \times 2533 + \bar{W}_M \times (3494 - 2533)}{3494} \Rightarrow \bar{W}_M = \$39290$$

Appendix: Wage Schedule at Charter vs TPS



(a) Bachelor



(b) Master or above

Figure: Inferred Wage Schedule at Charter Schools vs Certified Wage Schedule at TPS

Appendix: Value-Added Estimation

I estimate teacher value-added following Chetty et al., 2014a. The test score of student i in year t, A_{it}^* is

$$A_{it}^* = X_{it}\beta + \nu_{it}$$
$$\text{where } \nu_{it} = \mu_{jt} + \theta_c + \epsilon_{it}$$

The observed part X_{it} includes:

- student i's lagged math and reading test scores in cubic polynomials, ethnicity, gender, English limited proficiency status, disability status, eligibility for free/reduced-price lunch, academically gifted status, and indicators for repeating/skipping grade
- classroom-level and school-grade level means of lagged math and reading scores in cubic polynomials, classroom and school-grade means of student body characteristics
- teachers' years of experience and education level
- dummies for grade and year

The unobserved part includes a teacher value-added μ_{jt}, a classroom effect θ_c, and an idiosyncratic shock ϵ_{it}

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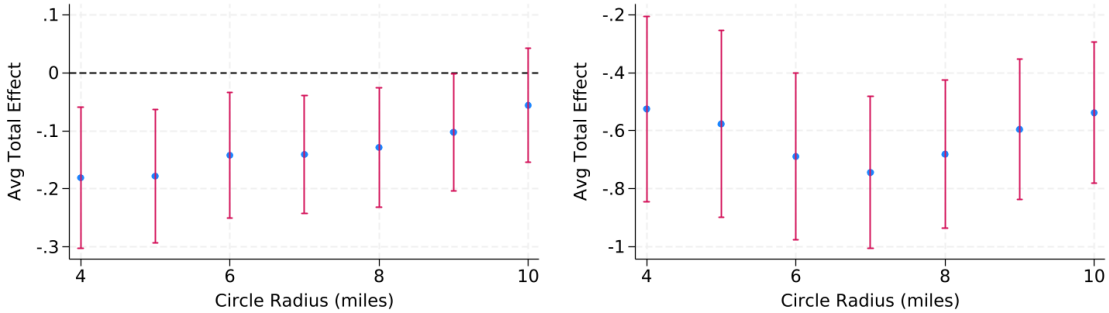
Appendix: Robustness Check by Varying Circle Size



(a) All TPS

(b) Low-Income TPS

Figure: Avg Total Treatment Effect on Avg Teacher Experience

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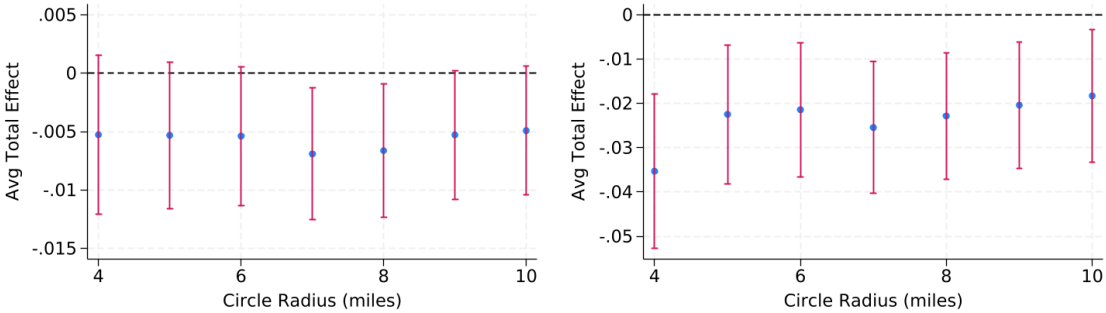
Appendix: Robustness Check by Varying Circle Size



(a) All TPS

(b) Low-Income TPS

Figure: Avg Total Treatment Effect on Avg Teacher VA

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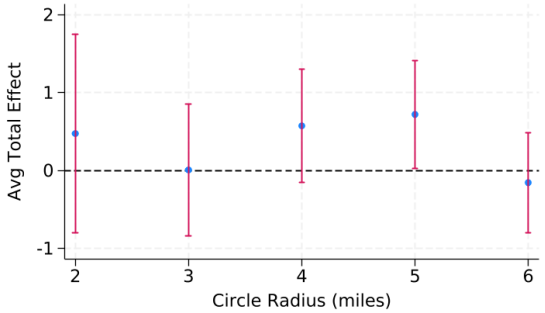
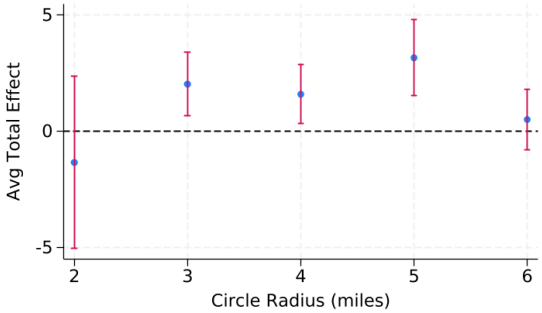
Appendix: Robustness Check by Varying Circle Size



(a) All TPS



(b) Low-Income TPS

Figure: Avg Total Treatment Effect on % Low-Inc Students

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Appendix: Optimal Solution to School's Problem

FOC for each offer decision o_{kj}:

$$U_{kj}^{schl} = \lambda_\kappa$$

- λ_κ: Lagrangian multiplier for the adjusted capacity constraint

Optimal offer decision:

$$o_{kj} = \begin{cases} = 1 \text{ if } \ U_{kj}^{schl} > \lambda_\kappa \\ = 0 \text{ if } \ U_{kj}^{schl} < \lambda_\kappa \\ \in [0,1] \text{ if } \ U_{kj}^{schl} = \lambda_\kappa \end{cases}$$

The set of optimal offers $\{o_{kj}\}_j$ for each school k can be derived by the following algorithm:

1. Set $o_{kj} = 1$ for tenured teachers;
2. Rank other teachers by $U_{kj}^{schl} - \lambda_\kappa$;
3. Give offers to teachers from the top-ranked until the expected capacity constraint binds;
4. The associated offer decisions are the optimal ones.

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Appendix: First Stage Regression

IV#1: local demographics

- The share of households with annual income below the state median level living in census tracts from 2 to 5 miles
- Identification assumption: residential sorting only occurs for assigned schools

IV#2: local market structure

- The proportion of charter schools among all public schools located within 3 miles
- Identification assumption: charter school entry decisions are independent of ξ of nearby TPS

	% Low-Income Students
% Low-Income Households	1.931***
	(0.197)
Exposure to Charter Schools	0.360**
	(0.175)
Observations	104
R-Squared	0.637
F-stat on excluded instruments	45.280

Table: Excluded Instruments for Student Demand Estimation: First Stage

Appendix: Estimated Student Preferences

Panel A: Nonlinear Preferences	Notation	Coef	S.E.
Avg Teacher VA × High × White	β^v_{HW}	-0.3086	0.4270
Avg Teacher VA × Low × White	β^v_{LW}	-0.1965	0.6218
Avg Teacher VA × High × Non-White	β^v_{HN}	0.1943	0.3786
% Low-Inc Students× High × White	β^h_{HW}	-5.5609	0.2303
% Low-Inc Students× Low × White	β^h_{LW}	-1.7809	0.3026
% Low-Inc Students× High × Non-White	β^h_{HN}	-3.0779	0.1847
Charter × High × White	β^C_{HW}	2.1244	0.4220
Charter × Low × White	β^C_{LW}	0.1272	0.5108
Charter × High × Non-White	β^C_{HN}	1.7897	0.3501
Magnet × High	β^M_H	1.7159	0.1499
Assign	β^A_0	1.4952	0.0404
Assign × High	β^A_H	0.4442	0.0650
Distance	α_0	-2.1870	0.0259
Distance × High	α_H	0.4295	0.0401
Distance × Assign	α^A_0	1.6617	0.0470
Distance × Assign × High	α^A_H	-0.3718	0.0728
Distance × Magnet	α^M_0	1.3036	0.0515
Distance × Magnet × High	α^M_H	-0.7893	0.0811
σ^C	σ^C	3.7628	0.4679

Table: Estimated Student Preferences

Appendix: Estimated Student Preferences

Panel B: Linear Preferences (Low × Non-White)			
Avg Teacher VA	β_0^v	-0.1626	0.7700
% Low-Inc Students	β_0^h	0.5242	0.3633
Charter	β_0^C	-4.9976	0.3961
Magnet	β_0^M	-1.9003	0.2262

Table: Estimated Student Preferences (continued)

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Appendix: Estimated Teacher & School Preferences

Panel A: Teacher Preference	Notation	Coef.	S.E.
% Low-Inc Students	θ_1	-6.2784	0.0038
% High-Achieving Students	θ_2	-3.9565	0.0016
% Minority Students	θ_3	-3.0320	0.0024
Wage (10k)	θ_4	0.2276	2.3256
% Low-Inc Students×Value-Added	θ_5	0.2815	0.0617
% High-Achieving Students×Value-Added	θ_6	4.9940	0.1506
% Minority Students×Minority	θ_7	4.6972	0.0069
$\mathbb{1}(k \neq k_j^0)$	δ_0	-10.6224	0.0032
ln(Distance)	δ_1	-0.5523	0.0001
Panel B: School Preference	**Coef.**	**S.E.**	
Value-Added	β_1	1 (normalized)	-
Experience	β_2	0.1587	0.0001
Master's Degree+	β_3	0.1057	0.3602
% High-Achieving Students×Value-Added	β_4	3.9669	0.0704

Table: Estimated Teacher & School Preferences

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Appendix: Relocation Algorithm

I use the following procedure to choose the census tracts for relocation:

1. Keep census tracts that enroll more than 80% of low-income students under the baseline scenario;
2. Among these census tracts, withdraw the tract if it is located within 2 miles of any tracts that enroll less than 40% of low-income students.

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