Teacher Compensation and Structural Inequality

Evidence from Centralized Teacher School Choice in Peru

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Motivation

Sizable urban-rural disparities in schooling outcomes in many developing countries

- Inherited from persistent underinvestment in remote areas $\Longrightarrow$ structural inequalities
- Can we provide equal opportunities despite these barriers?

Mobile input that we can leverage through policy: teachers

- Largely contribute to student outcomes (Rivkin et al, 2005; Chetty et al, 2014b)
- Efficiency gains from teacher-student match effects (Ahn et al 2023, Graham et al 2023)
- Problem: rigid wages $\Longrightarrow$ sorting on non-pecuniary benefits exacerbates inequalities

Can teacher compensation design be effective at mitigating structural inequalities?

Evaluation Wage Policy

Unique dataset on nation-wide allocation of public teachers in Peru

- Structural inequalities very salient
- Large urban-rural gap in schooling inputs, teacher quality and student achievement
- Survey evidence of compensating differentials $\Longrightarrow$ rigid wages induce unequal sorting

Causal evaluation of teacher compensation reform

- 13% wage bonus in very remote schools attributed through cutoff rules $\Longrightarrow$ RDD
- 0.42σ increase in teacher competency $\Longrightarrow$ 0.21-0.27σ increase in student test scores
- Entirely driven by selection of new recruits, not by effort of incumbents

Counterfactual Analysis

Build joint model of teacher school choice and value added

- Goal: quantify equity/efficiency gains from counterfactual compensation policies
- Key features: horizontal/vertical preferences, absolute/comparative advantage, correlation between preferences and effectiveness
- Identification: panel data on choices, choice sets, outcomes + policy variation

Teacher sorting remains highly unequal but large potential gains in efficiency/equity

- Residual 0.14σ urban-rural gap in teacher value-added ($\approx 1/4$ of achievement gap)
- Reallocating teachers to exploit match effects: rural $+0.17\sigma$, urban -0.02σ
- Attracting high-effectiveness applicants into public teaching (extensive margin): $+0.11\sigma$

Optimal Wage Policy Design

Framework to design cost-effective wage policy leveraging information on preferences and effectiveness

- Matching with contracts: let schools bid for teachers (Hatfield & Milgrom, 2005)
- Generalized DA converges to wage policy that reaches objective at minimal cost

Results

- Status quo bonus is poorly targeted: large gains attainable at no additional cost
- Budget-neutral policy raises teacher value-added by 0.12σ in rural schools
- Gains come from the extensive margin of recruitment $\implies$ more cost-effective than inducing sorting on comparative advantage

Outline

1. Context, Data, and Descriptive Evidence
2. The Causal Effects of Teachers' Wage Incentives
3. Empirical Model of Teacher Sorting and Student Achievement
4. Estimation Results
5. Counterfactual Analysis

Context, Data, and Descriptive Evidence

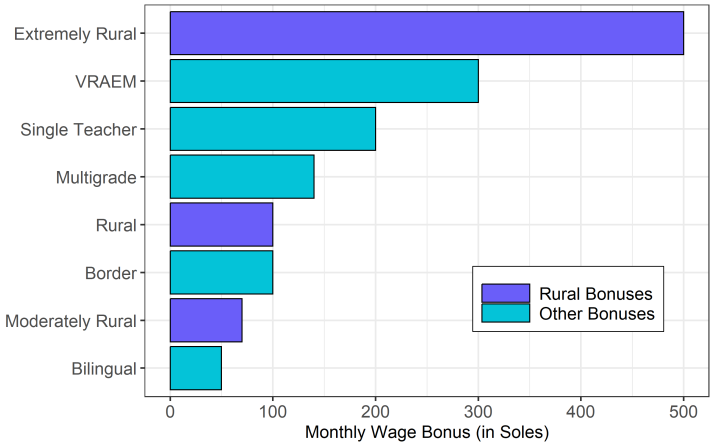
Contracts, Assignment Mechanism, and Wages

- Two types of teacher contracts: Permanent and Contract Teachers
- New assignment mechanism introduced in 2015-16. Two rounds of the centralized recruitment drive (2016 and 2018)
- Contract teachers: serial dictatorship $\implies$ applicants ranked by competency test score choose sequentially among open vacancies
- Flat wage structure + the introduction of wage bonuses

Contracts, Assignment Mechanism, and Wages

- Fixed wage + bonuses to certain types of schools (bilingual, single teacher,...)

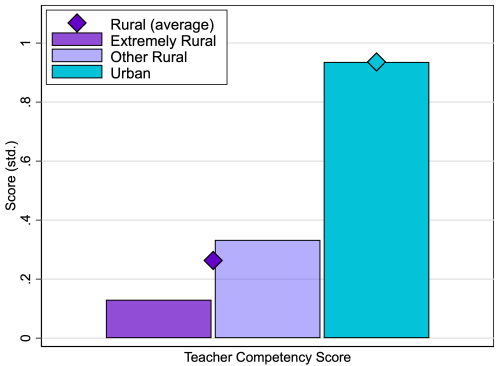
Figure: Wage Bonuses for Teachers in Disadvantaged Schools



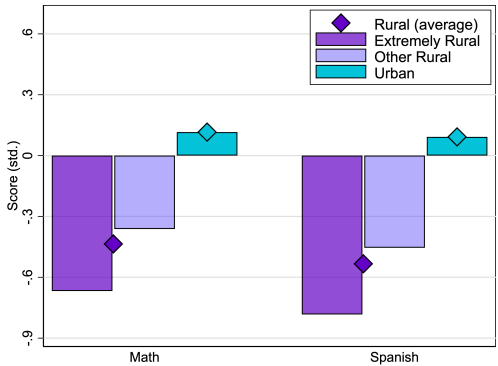
Data

- Centralized assignment: universe of job postings and applicants (w/characteristics, including scores in competency test for 2016 and 2018)
- Matched teacher-classroom data with student standardized test scores (yearly, since 2014)
- Ministry of Education administrative records: all employed public-sector teachers from 2012 to 2020
- Auxiliary data:
  - school census
  - household census
  - survey on teachers' preferences
- Analysis samples:
  - Choice sample: 22,743 vacancies and 50,319 applicants
  - Outcome sample: 4,834 teachers matched to 96,508 fourth-grade students

Descriptive evidence: unequal teacher sorting and inequalities in student achievement



a) Teachers



b) Students

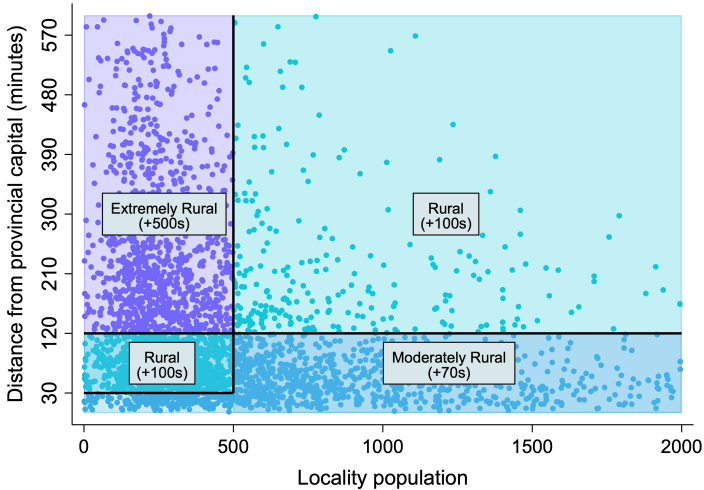
Descriptive evidence: survey on compensating differentials

Table: Applicant Survey (Choice Attributes)

	Rank			
	1st	2nd	3rd	In Top 3
Close to House	44.17	11.66	8.00	63.83
Safe	10.66	24.19	19.25	54.10
Well Connected	9.69	20.62	20.20	50.51
Prestige	17.92	14.12	12.29	44.33
Cultural Reasons	10.61	9.67	12.31	32.59
Good Infrastructure	2.02	8.40	12.86	23.28
Good Students	1.24	4.52	6.08	11.84
Possibility other Jobs	1.93	3.72	4.90	10.55
Career	1.76	3.10	4.09	8.95

The Causal Effects of Teachers' Wage Incentives

Wage Bonus Policy



Wage Bonus Policy

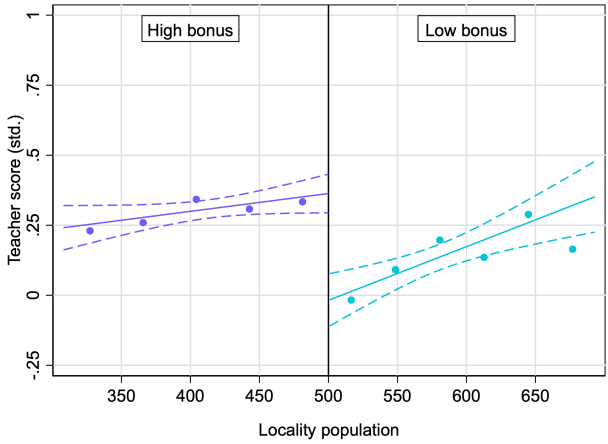
- Two thresholds (population + time-to-travel) determine the Extremely Rural Bonus
- Evidence of manipulation on time-to-travel
- RD design using population threshold only:

$$y_{ijt} = \gamma_0 + \gamma_1 1(pop_j < pop_c) + g(pop_j, pop_c) + \delta_t + \varepsilon_{ijt}, \quad (1)$$

$\Longrightarrow$ 13% wage increase Table

- Validity assumptions:
  - Assumption 1: continuity of potential outcomes Manipulation charts
  - Assumption 2: SUTVA Teacher Flows

Threshold Crossing Effects: Teacher Selection



0.42σ increase in teacher competency score

Threshold Crossing Effects: Teacher Selection

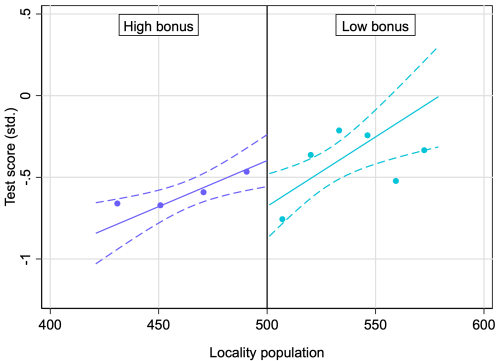
Table: Teacher Choices and Sorting

	(1) Vacancy filled	(2) Preferences	(3) Teacher Score (Std.)
High Bonus	0.063	0.108	0.418
	(0.048)	(0.031)	(0.106)
Bandwidth	190.896	162.270	193.380
Schools	1478	1157	1388
Observations	3524	2575	3068

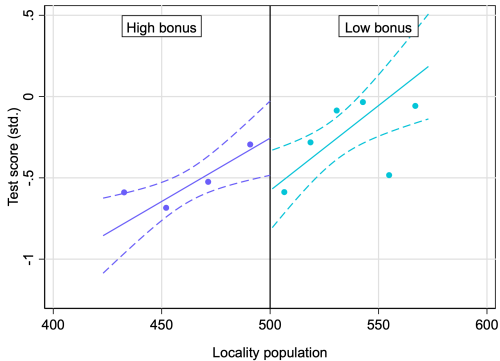
0.42σ increase in teacher competency score

Threshold Crossing Effects: Student Achievement

Figure: Wage Bonus and Student Achievement (Newly Recruited Teachers)



a. Spanish



b. Math

Threshold Crossing Effects: Student Achievement

Table: Wage Bonus and Student Achievement

Panel A: Dependent Variable is Spanish Test (z-score)			
	(1)	(2)	(3)
	New teacher	No vacancy	All
High Bonus	0.340	-0.080	0.206
	(0.174)	(0.124)	(0.084)
Bandwidth	92.657	143.045	114.510
Schools	221	436	931
Observations	3830	6578	18828
Panel B: Dependent Variable is Math Test (z-score)			
	(1)	(2)	(3)
	New teacher	No vacancy	All
High Bonus	0.543	-0.040	0.265
	(0.221)	(0.143)	(0.099)
Bandwidth	79.168	144.756	110.039
Schools	192	442	889
Observations	3408	6699	18083

Summary

Wage policy triggered large increase in local labor supply in treated schools

- $\Longrightarrow$ higher competition for these positions increases teacher quality
- $\Longrightarrow$ translates into better student outcomes

Additional results

- No evidence of other mechanisms at play
  - Effort: No detectable effect in schools with no open vacancies (de Ree et al., 2018)
  - No change in size or composition of the teaching staff
  - No effects on teacher retention
  - No quality losses in nearby low-bonus schools Diff-in-disc

Next: quantify equity/efficiency gains attainable through alternative compensation policies

Empirical Model of Teacher Sorting and Student Achievement

Preferences, Outcomes and Equilibrium

Teacher i's utility from being matched with school j + outside options:

$$U_{ijt} = \underbrace{\alpha_i w_{jt}}_{\text{wage}} + \underbrace{u(x_i, z_{jt}, d_{ijt}) + \kappa_{c(j)} + \eta_{ijt}}_{\text{non-pecuniary utility}}, \qquad u_{i0t} = \beta_1 \mathbb{1}\{t = 2018\} + \beta_i,$$

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Student l's potential outcome when matched with teacher i:

$$Y_{\ell i} = \underbrace{\delta_{0i}}_{\text{teacher ATE}} + \underbrace{X'_{\ell 1}\delta_{1i}}_{\text{match effects}} + \underbrace{X'_{\ell 2}\delta_2}_{\text{student/class/school controls}} + \epsilon_{\ell i},$$

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Equilibrium: serial dictatorship $\implies$ discrete choice with observed choice sets

$$D_{it} = \underset{j \in \Omega(s_{it}) \cup \{0, J+1\}}{\arg\max} U_{ijt}$$

Identification

Assumptions

- η_{ijt} iid and extreme value type I distributed
- Correlated random coefficients: $\theta_i = (\log \alpha_i, \beta_i)$, $\theta_i | x_i \sim \mathcal{N}(\mu_\theta' x_i, \Sigma_\theta)$
- Exclusion restrictions: distance to home, wages (no direct effect absent recruitment)

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Preferences: mixed logit MLE on the panel of matching histories

- Observing two choices per teacher + variation in choice sets identifies $(\mu_\theta, \Sigma_\theta)$

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Teacher value-added: relax selection on observables (Abdulkadiroglu et al, 2020)

- Control function from choice model corrects for selection on teachers' unobserved preference for their school assignment + Empirical Bayes shrinkage
- δ_i correlates with $\theta_i \implies$ captures selection on unobserved quality in response to counterfactual compensation policies

Estimation Results

Estimates and Model Fit

Teacher value added estimates

- Very large variance: 1 SD in average effectiveness = 0.38σ in math, 0.33σ in Spanish
- 22-38% of total variance explained by match effects: scope for efficiency gains
- Teachers more responsive to wages or with better outside options are less effective

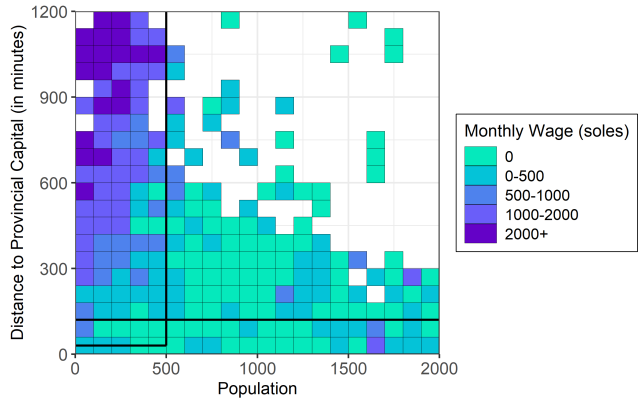
Preference estimates

- Compensating differentials: large average WTP for distance, amenities, cultural fit
  - Median WTP to avoid teaching in multi-grade, single-teacher or bilingual schools ranges from 43% to 103% of the base wage Table
  - Large heterogeneity across teachers + large spatial differences in the utility of each job

Model validation

- Replicate threshold crossing effects on teacher sorting in simulated data
- Replicate urban-rural gaps in teacher value-added and competency scores

Rural vs. Urban Non Pecuniary Utility Differences



Need 2 to 4x amount of rural wage bonus to compensate for urban/rural utility differences

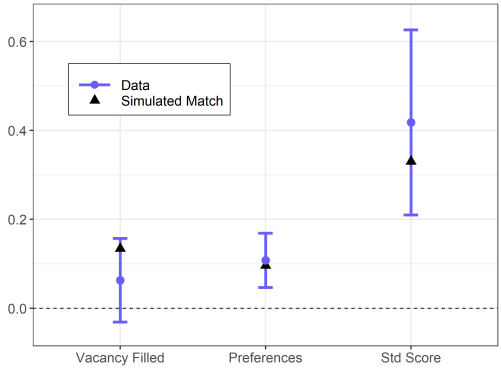
Teacher Sorting and Inequality in the Status Quo

	ATE Math	Match Effects Math
	(1)	(2)
Urban	0.112	0.004
Rural	-0.029	0.003
Other Rural	0.001	0.002
Extremely Rural	-0.085	0.005
Total	0.052	0.003

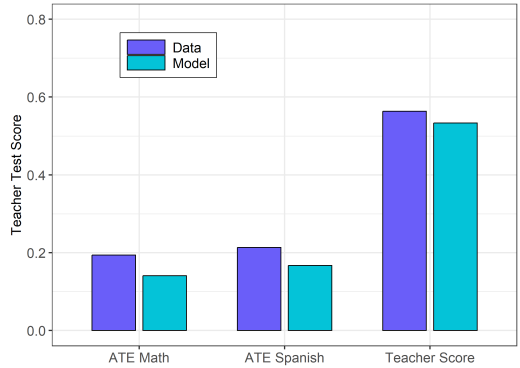
Residual 0.14σ urban-rural gap in teacher value-added ($\approx 1/4$ of the achievement gap)

Match effects $\approx 0 \implies$ teachers do not sort on their comparative advantage

Model Validation



a. Threshold-Crossing Effects



b. Urban-Rural Inequality

Counterfactual Analysis

Potential Efficiency/Equity Gains

Reallocation: reassign the observed pool of teachers to maximize total student achievement

	Data (1)	TVA Maximization (2)
Panel A: ATE Math		
Urban	0.112	0.053
Rural	-0.029	0.050
Panel B: Match Effects Math		
Urban	0.004	0.044
Rural	0.003	0.091

Rural schools gain $+0.17\sigma$ (mostly through match effects) while urban schools lose only 0.02σ

Potential Efficiency/Equity Gains

Extensive margin of recruitment

- Enlarge the pool with applicants who chose the outside option in the status quo
- Selecting those with highest average effectiveness $\Longrightarrow$ aggregate gains up to 0.11σ

Take-away: large equity and efficiency gains attainable by either

- reallocating existing teachers to exploit teacher-student match effects, or
- attracting applicants with higher average effectiveness into public teaching

Which margin can wage policy reach cost-effectively? $\Longrightarrow$ design optimal compensation

Teacher Compensation Design

Goal: solve following problem

$$\min_{w_1,\ldots,w_J} \sum_j w_j, \text{ s.t. } \begin{cases} \max_{\{i:D_i=j\}} Y_{ij} \geq \bar{c}, \ \forall j \in \mathcal{S} & \text{(C1)} \\ D_i \text{ is stable given } w \text{ and using } Y_{ij} \text{ as priorities} & \text{(C2)} \end{cases}$$

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Result: school-proposing Generalized DA converges to solution (Hatfield & Milgrom, 2005)

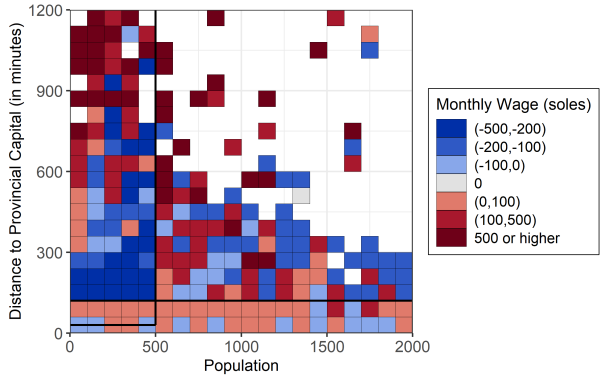
- Each school $j \in \mathcal{S}$ bids upward until (C1) is satisfied
- Outcome is a pair (D, w) that satisfies (C1)-(C2) while minimizing total cost
- Run for different $\bar{c}$ and select the budget-neutral policy relative to the status quo

Teacher Compensation Design

	Status Quo (1)	Optimal Policy (2)
Panel A: ATE Math		
Urban	0.112	0.138
Rural	-0.029	0.089
Other Rural	0.001	0.093
Extremely Rural	-0.085	0.079
Panel B: Match Effects Math		
Urban	0.004	0.005
Rural	0.003	0.009
Panel C: Monthly Wage Bonus (in Soles)		
Rural	235	227
Other Rural	86	153
Extremely Rural	500	365
Total	122	120

Budget-neutral policy raises rural TVA by 0.12σ, mostly via average effectiveness (extensive margin)

Optimal Wage Bonuses Relative to Status Quo



Status quo is poorly targeted: schools near the 120-minute threshold are over-subsidized, the most remote schools are under-subsidized

Conclusion

Leverage unique setting and very rich nation-wide admin data

- Causal policy evaluation of wage bonus policy using RD design
- Identify and estimate joint model of teacher school choice and student outcomes
- Build framework to design optimal wage policies

Take-away

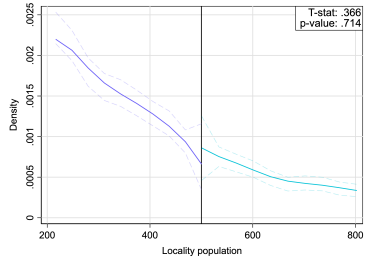
- Wage rigidity $\implies$ teacher sorting exacerbates inequalities in student achievement
- Large equity and efficiency gains from reallocation and from the extensive margin of recruitment
- Attracting higher-effectiveness applicants into public teaching is more cost-effective than inducing sorting on comparative advantage
- Achievable at no additional cost through smarter teacher compensation design

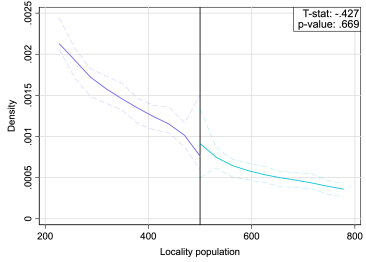
Wage increases around the population cutoff

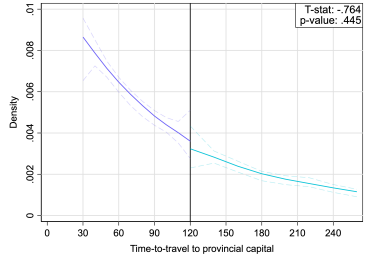
	(1) Overall	(2) Time < 120	(3) Time > 120
Bonus	244.205	26.503	410.654
	(26.528)	(12.818)	(22.795)
Mean dep. var. (Lower Bonus)	1844.006	1800.000	1901.101
Bandwidth	143.908	142.384	210.283
Schools	1081	671	715
Observations	2600	1301	1627

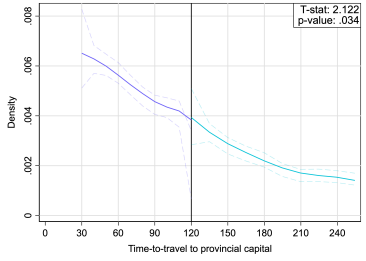
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Additional Results - Manipulation charts



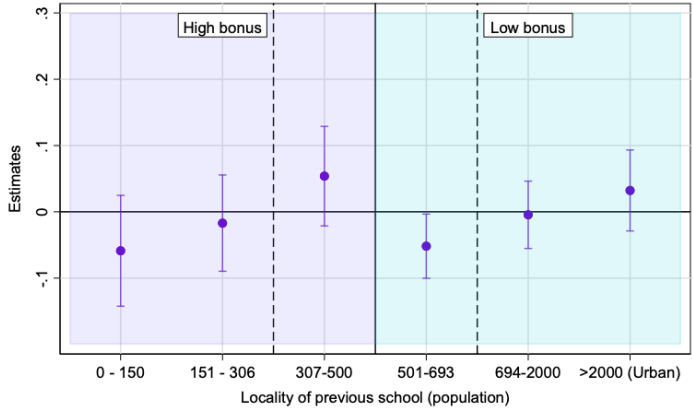






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Figure: Rural Bonus and the Origin of Newly Recruited Teachers



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Table: Teacher Score (Std.)–Difference-in-discontinuity

	(1) 2016	(2) 2018	(3) Pooled
Post-policy	-0.024	0.172	0.064
	(0.064)	(0.062)	(0.054)
Post-policy × High Bonus	0.214	0.272	0.254
	(0.079)	(0.079)	(0.068)
Bandwidth	158.717	221.494	173.569
Schools	1112	1776	1625
Observations	3997	5817	7279

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Willingness to Pay for Non-Pecuniary Job Attributes

	Bottom Decile	Median	Top Decile
	(1)	(2)	(3)
Amenity Index	0.028	0.114	0.450
Multigrade	-1.880	-0.435	-0.075
Single Teacher	-4.263	-1.031	-0.193
Bilingual	-3.270	-0.747	0.338
Share of Female Students	-0.790	-0.103	0.156
Share of Quechua Students	-4.011	-0.898	1.003
Average Math Score	-0.293	0.001	0.236
Average Spanish Score	-0.018	0.015	0.110
Distance Spline: 0-20km	-0.451	-0.124	-0.034
Distance Spline: 20-100km	-0.232	-0.065	-0.018
Distance Spline: 100km+	-0.039	-0.010	-0.003

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