Estimating the Causal Impact of Tutoring on Student Success Using Machine Learning–Based Propensity Score Matching

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Alamo Colleges District

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Conceptual Framework & Key Definitions

Tutoring (Intervention):
Tutoring is defined as an institutional academic support intervention delivered outside the classroom and modeled as a binary treatment (received tutoring vs. not).

Student Success (Broad Construct):
Student success is a broad, multidimensional concept encompassing academic progress, persistence, completion, and other indicators of positive student outcomes.

Outcome Measurement in This Study:
In this analysis, student success is measured using Fall-to-Fall persistence, a clear and policy-relevant indicator of continued enrollment.

The Evaluation Challenge:
Because participation in tutoring is non-random, observed differences in persistence cannot be interpreted as causal effects.

Analytic Requirement:
A quasi-experimental framework is required to isolate the effect of tutoring from pre-existing student characteristics.

Methodology & Operationalization

- **Time Frame:** Fall 2024 entry cohort tracked through Fall 2025.
- **Sampling:** Full population used to derive a matched analytic sample of 2,322 students.
- **Outcome Measurement:** Fall-to-Fall persistence measured as a binary indicator (PERSIST_F2F).
- **Baseline Controls:** Rich pre-treatment student characteristics used to capture baseline differences prior to tutoring exposure.

The Multi-Dimensional Control Framework

Demographic Characteristics:
Gender, age, and race/ethnicity.

Neighborhood & Life Context:
High school ZIP code (neighborhood proxy), single-parent status, marital status, and county of residence.

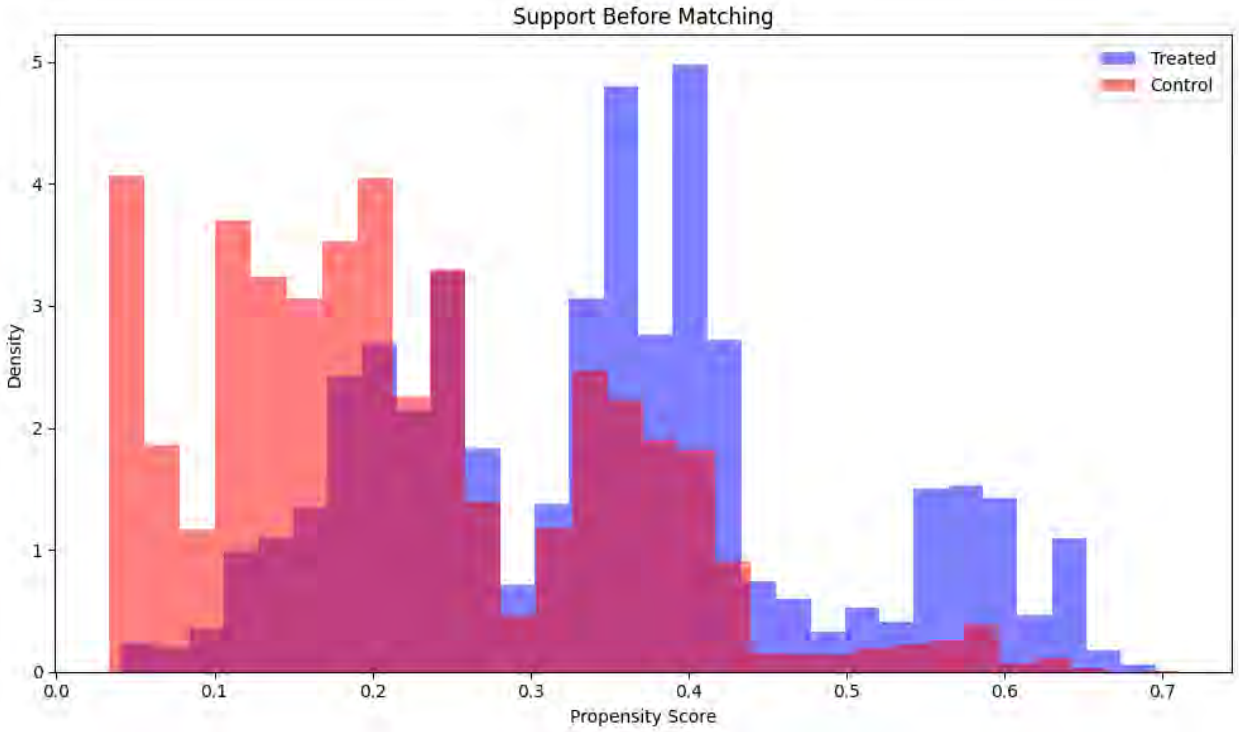
Academic Momentum:
Course load, major type (academic vs. technical), and enrollment intensity (full-time vs. part-time).

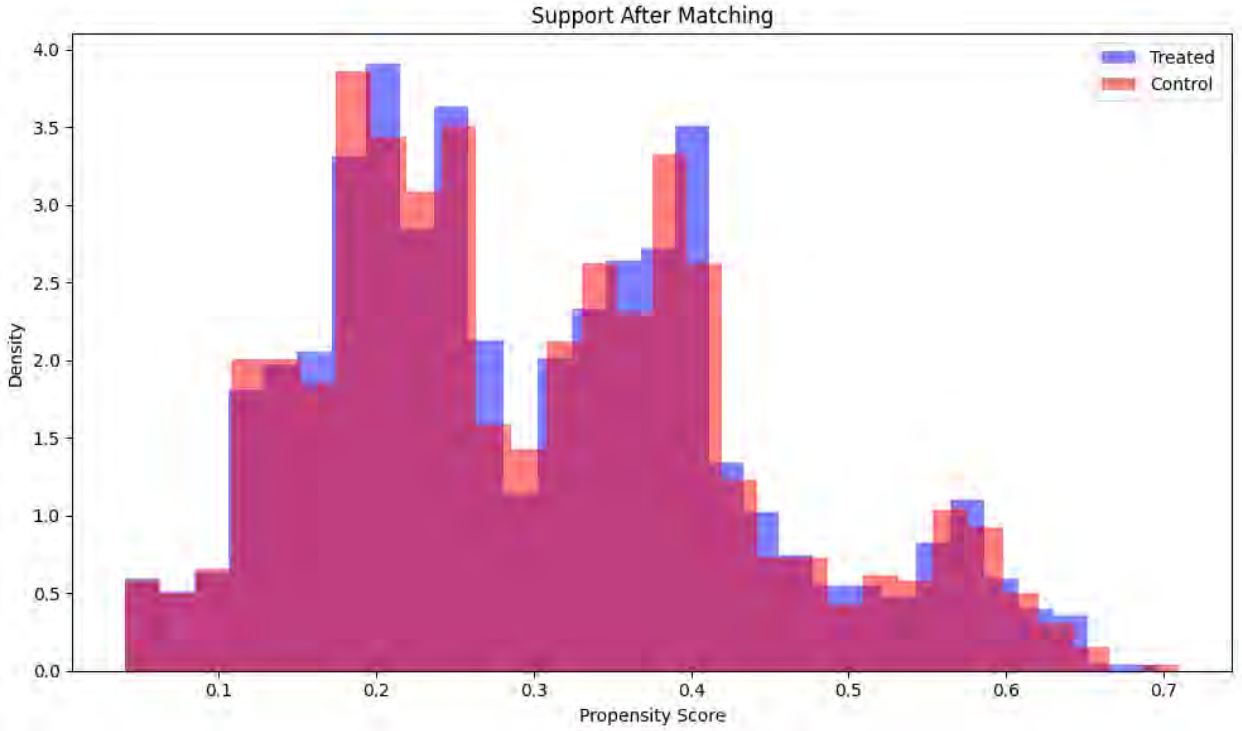
Institutional Context:
College location and tuition status to account for institutional-level differences.

Model Quality & Matching Performance

- **Propensity Model:**
  Gradient Boosting Classifier used to flexibly model non-linear relationships and interactions among baseline covariates.
- **Model Quality:**
  Area Under the Curve (AUC) = 0.731, indicating good separation between tutored and non-tutored students.
- **Matching Criterion:**
  Strict caliper of 0.05 applied to ensure close matches in estimated propensity scores.
- **Matching Outcome:**
  1,161 matched pairs retained (40% of treated students), prioritizing match quality over sample size.

Common Support Before and After Matching





Covariate Balance Diagnostics

Purpose:
To verify that treated and control students are statistically comparable across all observed baseline characteristics.

Balance Assessment:
Standardized Mean Differences (SMDs) were examined for all baseline covariates before and after matching.

Key Result:
After matching, SMDs across all covariates were reduced to near zero and well below conventional imbalance thresholds.

Interpretation:
The matched groups are statistically indistinguishable across observed characteristics, isolating tutoring as the primary remaining difference.

Core Findings: The 17.1% Persistence Lift

Matched Sample Results (n = 2,322):
Tutored students: **72.5%** Fall-to-Fall persistence
Matched control students: **55.4%** Fall-to-Fall persistence

Estimated Causal Effect:
+17.1 percentage point increase in persistence

Relative Difference:
Tutored students were **30.8% more likely to persist** than their matched peers

Limitations & Scope of Inference

Local Scope of the Estimated Effect:
The estimated impact applies to students within the matched sample—those similar to current tutoring participants and within the region of common support.

Generalizability Considerations:
Students in the matched sample may be more predisposed to academic success than the broader student population, as reflected in baseline indicators such as prior academic performance.

Unobserved Factors:
Although extensive baseline controls were used, unmeasured characteristics (e.g., motivation or help-seeking orientation) may still influence both tutoring participation and outcomes.

Outcome Focus:
Student success is measured using Fall-to-Fall persistence; other dimensions of success remain important but are beyond the scope of this analysis.

Institutional Implications & Advising

Identifying Actionable Risk:
Among students comparable to tutoring participants, those who did not receive tutoring persisted at a substantially lower rate (55.4%), identifying a group currently underutilizing support services.

Proactive Advising Strategy:
The matching framework can be used to proactively identify students who resemble high-risk matched controls and prioritize early outreach and structured connection to tutoring.

Institutional Takeaway:
Tutoring emerges as a high-impact lever for improving persistence among students who are otherwise positioned to succeed.

Thank you.

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