Financial Aid and Student Retention

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Gauging Causality in Discrete-Choice Propensity Score-Matching Models

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Limitations of Higher Education Studies

• Descriptive data
• Inferential data
  – Insufficient covariate controls
  – Sample selection bias (restricted observation in dependent variable)
  – Endogeneity bias (choice variable correlated with error term)
• Theory development
  – Lack of disciplinary integration
  – Lack of evaluative research
Limitations of Higher Education Studies

- Research on financial aid:
  - Inconsistent findings
  - Unbalanced literature review
  - Methodological and data problems

- Advocacy vs. scholarship? (examples)
  - Congressional Advisory Committee on Student Financial Aid
  - The Education Trust

Addressing endogeneity bias in observational studies on treatment effects

Assumptions:
1) Normal distribution of error terms in selection and outcome model
2) At least one predictor uncorrelated with outcome

- **Heckman correction** (the two-stage method, Heckman's lambda, Inverse Mill's ratio)
- **Instrumental variable (IV)** estimation (predictor related to treatment but not outcome)
Gauging the Financial Aid-Student Success Nexus

• Estimating the influence of aid on freshmen retention at moderately expensive public university
  – Expanding covariate controls
  – Correcting selection bias in aid status via propensity score-matching
  – Decomposing treatment effect of aid via counterfactual analytical framework
  – Underpinning findings with a plausible paradigm central to other disciplines

Estimating the Influence of Aid on Freshmen Retention

• Analytical process
  1. Identify pre-treatment variables that explain financial aid support to freshmen
  2. Estimate propensity for aid support via multinomial logit/probit model
  3. Match aided vs. unaided on propensity score (identify common support, check for score balance across all variables)
  4. Estimate impact of aid status/propensity for aid on retention via binary logit models with unmatched and matched freshmen (at $\alpha \leq 0.05$)
Data Sources, Cohorts, Model Specifications

- Panel data from institutional student information system, ACT Student Profile Section, CIRP Trends File
- Spring-retained freshmen who entered in fall 2001 through 2005 (N=6,048 or 71%, excl. foreign/athlete students, missing cases)
- Models specified for typical aid packages:
  - Grants/scholarships package vs. no aid (N=3,109)
  - Package with loans vs. no aid (N=2,176)
  - Millennium aid-only students (N=1,226) not tested
- Separate estimates by student capacity to afford cost of attendance (EFC), controlling for net remaining cost and academic experience with hierarchical variable entry.

Propensity Score Matching

- Score estimation via multinomial logit model: \( \ell^{(r)} = u^{(r)} + \omega^{(r)} \delta + \varepsilon^{(r)} = \eta^{(r)} + \varepsilon^{(r)} \), \( r = 1, \ldots, k \), with covariate vector \( \omega^{(r)} \) consisting of income, gender, age, ethnicity/race, prep index, un/declared, test date, AP credits, credit load, housing, facilities use, where \( r \) is a finite choice set
- Unconfoundedness assumption: Treatment (aid) is random conditional on set of observed pre-treatment characteristics (\( \omega^{(r)} \)), i.e., ignorability of aid selection
- \( \mathbb{P}(\omega_i | A_i=1, p(\omega)) = \mathbb{P}(\omega_i | A_i=0, p(\omega)) = \mathbb{P}(\omega_i | p) \)
  where distribution of \( \omega_i \) is equal for aided and unaided with matched propensity scores \( p \)
- \( A \perp y(0), y(1) | p(\omega) \), where balance in \( p(\omega) \) is checked for each covariate after matching on \( p \)
Propensity Score Matching

- Matching aided with unaided using stratification with minimum of 5 groups
  - Estimated to remove 90% in bias
  - Preferred if unobservables are suspected
  - Generates more matches with sufficiently large control group (unaided)
  - Alternatives: nearest neighbor, radius, kernel, Mahalanobis-metric matching
- Exclude cases outside common support area, check for balance within stratum, split stratum if unbalanced, repeat until balanced
- Estimate standard errors via bootstrap replications (min. 500-1000)

The Common Support Area

91-97% of students matched (depending on model)
The Common Support Area

83-93% of students matched (depending on model)

Propensity Score Balance

Within-Stratum Statistics of New Full-Time Freshmen, 2001-2005

<table>
<thead>
<tr>
<th>With Grants and/or Scholarships (No loans)</th>
<th>Matched Size (N)</th>
<th>Percent Retained</th>
<th>Sig. Diff. in Propensity Score (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Matched Size (N)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>With Loans in Aid Package</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>86</td>
<td>199</td>
<td>81</td>
</tr>
<tr>
<td></td>
<td>109</td>
<td>458</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>63</td>
<td>290</td>
<td>83</td>
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<tr>
<td></td>
<td>32</td>
<td>290</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>327</td>
<td>83</td>
</tr>
</tbody>
</table>

* Number of variables based on Bonferroni adjusted t-test level

6.6% (8/120) and 9% (9/100) of t-tests at α ≤ .05
First-Year Financial Aid Profile

Average Aid and Need ($) by Estimated Family Contribution for New FT Fresh., 2001-2005

<table>
<thead>
<tr>
<th>Estimated Family Contribution (EFC)*</th>
<th>All (N=2,541)</th>
<th>&gt; $4,016 - 9,768 (N=371)</th>
<th>&gt; $9,769 (N=873)</th>
<th>Unknown (N=758)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-income federal grants</td>
<td>469 (N=539)</td>
<td>2,212</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Low-income state grants</td>
<td>119 (N=371)</td>
<td>223</td>
<td>471</td>
<td>9</td>
</tr>
<tr>
<td>Low-income institutional grants</td>
<td>77 (N=873)</td>
<td>129</td>
<td>287</td>
<td>22</td>
</tr>
<tr>
<td>Other grants</td>
<td>189 (N=873)</td>
<td>146</td>
<td>117</td>
<td>215</td>
</tr>
<tr>
<td>Millennium scholarship</td>
<td>2,003 (N=758)</td>
<td>1,881</td>
<td>2,132</td>
<td>1,965</td>
</tr>
<tr>
<td>Other merit-based aid</td>
<td>2,146 (N=758)</td>
<td>2,270</td>
<td>2,471</td>
<td>2,280</td>
</tr>
<tr>
<td>Need after EFC*</td>
<td>4,226 (N=758)</td>
<td>11,945</td>
<td>9,019</td>
<td>1,075</td>
</tr>
<tr>
<td>Need after all awarded aid*</td>
<td>2,007 (N=758)</td>
<td>6,053</td>
<td>4,179</td>
<td>309</td>
</tr>
</tbody>
</table>

With Loans in Aid Package

<table>
<thead>
<tr>
<th>All (N=1,563)</th>
<th>&gt; $4,016 - 9,768 (N=428)</th>
<th>&gt; $9,769 (N=689)</th>
<th>Unknown (N=12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-income federal grants</td>
<td>809 (N=434)</td>
<td>2,910</td>
<td>5</td>
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<tr>
<td>Low-income state grants</td>
<td>243 (N=428)</td>
<td>370</td>
<td>475</td>
</tr>
<tr>
<td>Low-income institutional grants</td>
<td>241 (N=689)</td>
<td>320</td>
<td>398</td>
</tr>
<tr>
<td>Other grants</td>
<td>164 (N=12)</td>
<td>130</td>
<td>222</td>
</tr>
<tr>
<td>Millennium scholarship</td>
<td>1,397 (N=12)</td>
<td>1,365</td>
<td>1,474</td>
</tr>
<tr>
<td>Other merit-based aid</td>
<td>1,024 (N=12)</td>
<td>1,154</td>
<td>974</td>
</tr>
<tr>
<td>Unsubsidized loans</td>
<td>3,560 (N=12)</td>
<td>1,284</td>
<td>2,483</td>
</tr>
<tr>
<td>Subsidized loans</td>
<td>1,760 (N=12)</td>
<td>2,812</td>
<td>2,532</td>
</tr>
<tr>
<td>Need after EFC*</td>
<td>8,115 (N=12)</td>
<td>15,320</td>
<td>10,198</td>
</tr>
<tr>
<td>Need after all awarded aid*</td>
<td>2,895 (N=12)</td>
<td>5,787</td>
<td>3,778</td>
</tr>
</tbody>
</table>

* Based on total cost of attendance per federal aid application information (FAFSA), *constant 2005-$

Statistical Results: Reference Example

Parameter Estimates of Second-Year Enrollment of New Full-Time Freshmen with Grants/Scholarships (No Loans), 2001-2005

| Parameter                                              | Unmatched Matched Avg Effect Matched Avg Treated Matched Avg untreated |
|--------------------------------------------------------|---------------------------|----------------|----------------|----------------|
| Percentage change in probability of second-year enrollment | Δ-ρ Sig | Δ-ρ Sig | Δ-ρ Sig | Δ-ρ Sig |
| All (Unmatched N = 3,109)                              |              |              |              |              |
| Received grant/scholarship (unmatched); propensity score (matched) | NS | 2.94 *** | 3.06 *** | 2.76 ** |
| Controlling for first-year GPA and math experience     |              |              |              |              |
| Received grant/scholarship (unmatched); propensity score (matched) | -3.99  | * NS         | NS         | NS         |
| GPA (1/10 of one letter grade increment)               |              |              |              |              |
| Math experience                                       | 4.58 * Adv    | 5.20 ** Adv  | 4.73 *      |
| % of cases matched                                    |              |              |              |              |

Percentage change in second-year retention probability using a linear transformation of the log odds (ρ*(1-ρ)*β)
Estimating Impact of Grants/Scholarships Pckg

- Propensity to receive gift aid has no bearing on retention, net of academic experience (no significant GPA/prop score interaction).
- No significant correlation with amount and type of aid.
- Positive correlation with advanced math (10%) and GPA.

Unmatched | Matched Avg | With aid | No aid

After matching
- Propensity to receive gift aid has no bearing on retention.
- Negative endogeneity bias net of first-year academic experience. **But, no statistical control for student ability to pay and assume unmet need!**
Estimating Impact of Grants/Scholarships Pckg

% Change in Retention for Freshmen with a $4-10K EFC

- Propensity to receive gift aid has no bearing on retention, net of academic experience
- No significant correlation with amount and type of aid
- Positive correlation with advanced math ($\alpha < .10$) and GPA

Estimating Impact of Grants/Scholarships Pckg

% Change in Retention for High-Income Freshmen (> $10K EFC)

- Propensity to receive gift aid shows a positive correlation, net of academic experience
- Overall and endogeneity bias detected, largely unaffected by the amount of aid (3.26 vs. 3.01)
- Remedial math students exhibit greater persistence (12%)
Estimating Impact of Aid Package with Loans

% Change in Retention for Low-Income Freshmen (EFC<$4K)

- Propensity to receive aid and amount/type of aid shows no correlation after factoring in academic experience.
- Remedial math students and those not completing math in the first year face elevated dropout risk ($\alpha < .05$ and $<.10$, respectively).
- Similar results for other EFC students as with gift aid-only pkg.

Estimating Impact of Grants/Scholarships Pckg

% Change in Retention by Remaining Need after EFC

- Gift aid benefit for those ineligible for need-based aid.
- No gift aid benefit, but math-related benefit, for the needy.
Findings

• Pattern of correlations suggests:
  – Financial aid-retention nexus depends on need level and academic experience
  – Endogeneity associated with aid status biases results from non-randomized data
  – Had aided high-EFC students not received gift aid, their retention would be less likely
  – Low-income/EFC students accrue retention benefits from academic success
  – High-income/EFC students accrue retention benefits from financial aid

Thus:

– Allocating more aid to higher-income freshmen (EFC >$4K) coupled with better preparation of, academic assistance to low-income freshmen would maximize overall retention

• Results are consistent with theory of moral hazard in economics
  – Utility maximization is compromised under uncertainty arising from asymmetry of information between benefactor and beneficiary
Moral Hazard Theory

• Motivation to excel academically is undermined due to:
  – Low cost of potential failure (i.e., investment risk)
  – Financial aid that is ascribed, not earned (e.g., need-based vs. merit-based)
  – Lack of effective monitoring of academic progress (e.g., by supportive parents)

• Intellectual foundation:

Corroborating research

Propensity Score-Matching

• Aim is to control for confounding when evaluating treatment effect (e.g. impact of aid, advising, learning communities) to approximate randomization
• Preferred with infrequent outcome, common treatment, and many covariates
• Scalar summary of pre-treatment observables allows shrinkage of high-dimensional model
• Over-parametrization is not an issue in score estimation
• Distributional balance of covariates within strata, subclasses, or pairs is key (e.g., check interaction and quadratic terms in scoring model)
• Principal limitation: omitted variables strongly related to outcome and uncorrelated with propensity score

Propensity Score-Matching

• Intellectual foundation:
Standards of Evidence

• Analytical level of “researcher”
• Familiarity with other disciplines
  – Education
  – Economics
  – Medicine
  – et al.
• Money and education

Link to presentation and paper:
http://www.unr.edu/ia/research/