

Appendix D. Technical Appendix: Tennessee Student-Level Analysis

Introduction

Over the course of nearly two years, Research for Action (RFA) worked closely with the Tennessee Higher Education Commission (THEC) to clean, and analyze Tennessee's Statewide Longitudinal Data System (SLDS). During this iterative process, RFA worked to ensure the dataset was as accurate and complete as possible. We shared early results of our analyses with Tennessee to ensure that we avoided any inadvertent errors in assumptions, coding, or analysis. This process, while time-consuming, allowed us to produce analyses that are accurate and complete. Our study utilizes data for first-time undergraduate students who entered Tennessee's postsecondary education system during academic years 2006 through 2014, a time period that consists of 169,966 students in the four-year sector and 190,320 students in the two-year sector. We first examined descriptive trends in enrollment and completions (bachelor's degrees, associate's degrees, and certificates) and credit milestones. We then conducted multivariate logit regression analyses on the same outcomes.

The following outlines our methodological approach using data from Tennessee's SLDS.

Research Questions

1. Has the implementation of OBF impacted student outcomes, such as attaining a bachelor's or associate's degree?
2. How has the number of years of student exposure to OBF policies impacted student outcomes?
3. Has the implementation of OBF benefited underserved students (e.g. students who are eligible for the Pell grant)?

Data

Working closely with THEC, we obtained the Tennessee SLDS data of all public university and community college students who entered Tennessee's postsecondary education system in academic years 2006 through 2014, providing us five years of pre-OBF implementation and four years of post-OBF implementation data. While outcomes are analyzed through academic year 2014 (e.g. accumulating 48 credits within two years for the 2013 cohort), the 2014 cohort is not utilized in this analysis due to incomplete Pell eligibility data.

Study Samples

Our data for the four-year sector consists of 169,966 students and our data for the two-year sector consists of 190,320 students from academic year 2006 through academic year 2013 (see Table 1D). These complete samples, however, were only used to analyze descriptive trends in enrollment, e.g. how the enrollment of Pell-eligible students changed over time.

African-American	18%	19%	19%	18%	18%	20%	19%	19%
Hispanic	1%	2%	2%	2%	2%	2%	3%	3%
White	76%	75%	75%	75%	73%	67%	68%	71%
Other Race	4%	4%	5%	5%	6%	11%	10%	7%
Adult	3%	3%	2%	2%	3%	3%	2%	2%
ACT Score	22.5	22.6	22.6	22.7	22.9	22.6	22.6	22.8
Professional Major	43%	43%	45%	46%	46%	47%	51%	52%
STEM Major	16%	17%	17%	18%	19%	19%	19%	20%
Liberal Arts Major	36%	35%	34%	32%	31%	30%	27%	25%

- The proportion of students who were Pell-eligible increased over time, particularly during the Great Recession.
- The proportion of students who were white declined over time. The proportion of students reporting as “other race” conversely increased.
- ACT scores remained mostly flat over our period of study.
- The proportion of students declaring a professional or STEM major increased over time, while the proportion of students declaring a liberal arts major declined.

Table 4D. Characteristics of Full-Time Student Sample for the Two-Year Sector Analyses

	2006	2007	2008	2009	2010	2011	2012	2013
Pell Eligible	53%	50%	51%	51%	61%	71%	70%	67%
Female	58%	58%	56%	57%	56%	58%	58%	57%
African-American	22%	16%	15%	14%	15%	19%	19%	16%
Hispanic	2%	2%	2%	2%	3%	2%	3%	3%
White	72%	80%	80%	78%	76%	70%	72%	74%
Other Race	4%	3%	4%	6%	6%	9%	6%	7%
Adult	10%	10%	8%	9%	15%	15%	15%	13%
ACT Score	18.6	19.1	19.2	19.1	19.5	18.7	18.7	19.0
Professional Major	31%	29%	29%	29%	30%	34%	34%	32%
STEM Major	5%	5%	5%	5%	5%	5%	5%	5%
Liberal Arts Major	63%	65%	65%	65%	64%	59%	60%	63%

- The proportion of students who were Pell eligible increased over time, particularly during the Great Recession.
- The racial makeup of our sample fluctuated throughout our period of study, but did not show any particular trends.
- The proportion of students who were adults spiked during the Great Recession.
- ACT scores slightly increased over time.

Table 5D. Characteristics of Part-Time Student Sample for the Two-Year Sector Analyses

	2006	2007	2008	2009	2010	2011	2012	2013
Pell Eligible	61%	60%	60%	60%	70%	79%	79%	78%
Female	60%	62%	63%	59%	61%	60%	61%	61%
African-American	27%	21%	19%	21%	25%	31%	35%	35%
Hispanic	2%	2%	2%	3%	3%	2%	3%	3%

White	67%	73%	75%	71%	62%	59%	56%	55%
Other Race	4%	4%	4%	5%	10%	7%	6%	7%
Adult	41%	40%	42%	40%	44%	43%	35%	32%
ACT Score	17.9	18.4	18.7	18.3	18.2	17.6	17.3	17.2
Professional Major	39%	36%	35%	38%	39%	43%	43%	45%
STEM Major	6%	7%	6%	7%	4%	6%	6%	7%
Liberal Arts Major	50%	52%	53%	52%	55%	48%	51%	47%

- The proportion of students who were Pell eligible increased over time, particularly during the Great Recession.
- The proportion of students who were African-American increased over time, while the proportion of students who were white conversely decreased.
- The proportion of students who were adults remained flat over the majority of our period of study; however, it dropped off in academic years 2012 and 2013.
- ACT scores first increased, then substantially decreased.
- The proportion of students who were a professional major increased over time, while the proportion of students who declared a STEM or Liberal Arts major remained flat.

Outcome Measures

Our study examined the effects of OBF on the probability of completing a degree, as well as the probability of accumulating enough credits to remain “on track” to graduate. The outcomes that we analyzed differed for each sample. Table 6D below summarizes the studied outcome measures.

Table 6D. Outcomes of Interest

TWO-YEAR SECTOR STUDENT OUTCOMES	FOUR-YEAR SECTOR STUDENT OUTCOMES
Full-Time Students	Full-Time Students
<ul style="list-style-type: none"> • Associate Degree Completion within Two Years • Associate Degree Completion within Three Years • Earning a Certificate within Two Years • Accumulating 12 Credits within the First Semester • Accumulating 24 Credits within the First Two Semesters • Accumulating 36 Credits within the First Three Semesters • Transferring within Three Years 	<ul style="list-style-type: none"> • Bachelor’s Degree Completion within Four Years • Accumulating 24 Credits within the First Year • Accumulating 48 Credits within the First Two Years • Accumulating 72 Credits within the First Three Years • Crossing the Finish Line
Part-Time Students	
<ul style="list-style-type: none"> • Associate Degree Completion within Three Years • Associate Degree Completion within Four Years • Earning a Certificate within Two Years • Accumulating 12 Credits within the First Year • Accumulating 24 Credits within the First Two Years 	

- **Accumulating 36 Credits within the First Three Years**
- **Transferring within Three Years**

Analytical Model

Using the repeated cross-sectional data of the incoming four-year college student cohorts, we conducted an interrupted time series analysis to estimate the effect of OBF (implemented in academic year 2011) on each of the student outcome measures listed above. We conducted separate analyses for three analytical samples described above.

Since all student-level outcome measures were binary variables (1=completed; 0=not completed), a logit regression model was used to estimate the effect of OBF on an outcome measure. For example, the logit of the probability of accumulating 24 credits within the first year for a full-time student i in year t can be written as follows:

$$\text{logit}(\pi_{it}) = \beta_0 + \beta_1 \text{Time}_{it} + \beta_2 \text{POST1_OBF}_{it} + \beta_3 \text{POST2_OBF}_{it} + \beta_4 \text{POST3_OBF}_{it} + \sum_{k=1}^K \beta_{k+4} X_{kit} + \varepsilon_{it},$$

where:

π_{it} = probability of achieving a given binary outcome, $\Pr(Y_{it} = 1)$, given the values of all explanatory variables. And, $\text{logit}(\pi_{it}) = \log\left(\frac{\pi_{it}}{1-\pi_{it}}\right)$.

Y_{it} = One of the binary outcome measures listed above for student i in year t (e.g., 1 if a full-time student completed a BA degree and 0 otherwise.)

Time_t = A continuous variable indicating year t from the start of the observation period (academic year 2006)

POST1_OBF_{it} , POST2_OBF_{it} & POST3_OBF_{it}

= Dummy variables indicating 1st, 2nd, and 3rd year after the implementation of OBF,

respectively

X_{kit} = A vector of student-level covariates including gender, Pell eligibility, race/ethnicity, age, gender, ACT score, and major.

ε_{it} = Random errors

In this logit regression model, β_1 estimates the slope of the baseline trend in the log odds of achieving student outcome Y before OBF. And, β_2 , β_3 , and β_4 estimate deviations from the pre-OBF baseline trend (i.e., OBF impacts) that occurred in Years 1, 2, and 3 after the implementation of OBF, respectively. Note that this model estimates the impact of OBF as the change in the log odds of achieving the outcome in a given post-OBF year, which is not easily-interpretable for a lay audience. Thus, we converted all log odds to predicted probabilities (in percent) using mean values of all covariates.

In addition to estimating the impact of OBF for the overall full-time sample, we also examined whether the estimated OBF effect varies across two specific student populations: economically disadvantaged student groups, as defined by Pell eligibility, and underrepresented minority (black

and Hispanic) students. We conducted these subgroup analyses by segmenting the above regression equation between Pell and non-Pell groups or between underrepresented minority (URM) and non-URM groups. In these analyses, the differential impact of OBF was evaluated between two student subgroups by examining the significance of interaction terms between a student subgroup dummy (e.g., a dummy indicator for Pell and non-Pell students) and the three post-OBF dummies.

A full set of parameter estimates are reported in Tables 7D, 8D, and 9D below. Not all three treatment variables were used in every regression because some outcomes were on a time frame that precluded more recent cohorts from analysis. For example, attaining a bachelor's degree within four years was only possible for the 2011 cohort, thus only one post-OBF dummy was used in that regression. We should also note that a few students may be used in one analysis but not in another due to missing data on the outcomes of interest.

Model Limitations

An interrupted time series analysis with no control group is susceptible to threats to internal validity caused by history. For example, there may have been another program related to college completion implemented in Tennessee at the same time as OBF, which could lead us to overestimate the positive effects of OBF.

Our analysis is also susceptible to omitted variable bias. For example, our logit regression model did not control for institutional level covariates because we could not assign each student to a single institution. Many students moved from their starting institution to another within the Tennessee's public university system over time.

A key component of an interrupted time series analysis is having an accurate pre-OBF trend line. To this end, a longer pre-OBF period is always desired. Due to data constraints, however, we must base our pre-OBF trend line on only five pre-OBF periods (cohorts 2006 through 2010). For one outcome – “crossing the finish line” – we must base our pre-OBF trend line on only three pre-OBF periods. As such, there is the possibility that our pre-OBF trend line does not provide a valid counterfactual.

Data Limitations

A small portion of observations had missing data on their ACT score, age, and major. For these observations, missing values were imputed. Some students had missing data related to their Pell eligibility status. Because we conducted subgroup analyses for Pell and non-Pell students, students with missing Pell eligibility data were dropped. We initially intended to analyze post-graduation job placement for the two-year sector, but were unable to do so due to the quality of the data.

Full Parameter Estimates

Table 7D. Full-Time, Four-Year Sector Students

	Bachelor's Degree Within 4 Years	Accumulated 24 Credits in First Year	Accumulated 48 Credits in First Two Years	Accumulated 72 Credits in First Three Years	"Crossing the Finish Line"
Time	0.0297*** (0.00642)	0.000702 (0.00564)	-0.00179 (0.00553)	-0.00242 (0.00550)	0.0244 (0.0164)
Post Year 1	0.125*** (0.0278)	0.0433 (0.0247)	0.0193 (0.0242)	0.0162 (0.0241)	0.00661 (0.0413)
Post Year 2	- -	0.0256 (0.0287)	0.0522 (0.0282)	0.0462 (0.0280)	0.0904 (0.0549)
Post Year 3	- -	0.116*** (0.0334)	0.123*** (0.0327)	- -	0.185** (0.0698)
Pell Eligible	-0.588*** (0.0193)	-0.438*** (0.0133)	-0.514*** (0.0131)	-0.562*** (0.0140)	-0.367*** (0.0219)
Adult	-1.174*** (0.0959)	-0.680*** (0.0406)	-0.901*** (0.0449)	-0.975*** (0.0504)	-0.591*** (0.109)
ACT Score	0.137*** (0.00221)	0.132*** (0.00179)	0.141*** (0.00175)	0.135*** (0.00184)	0.0879*** (0.00252)
Hispanic	-0.319*** (0.0641)	-0.0283 (0.0414)	-0.0462 (0.0408)	-0.0857 (0.0449)	-0.285*** (0.0723)
Black	-0.373*** (0.0277)	-0.0822*** (0.0172)	-0.0976*** (0.0172)	-0.131*** (0.0186)	-0.355*** (0.0309)
Other Race	-0.0597 (0.0345)	0.0253 (0.0248)	0.0475 (0.0244)	0.0289 (0.0260)	-0.0657 (0.0390)
Female	0.691*** (0.0170)	0.427*** (0.0126)	0.445*** (0.0124)	0.445*** (0.0132)	0.559*** (0.0191)
Professional Major	-0.0117 (0.0179)	0.0440** (0.0138)	0.0521*** (0.0135)	0.0892*** (0.0144)	-0.0621** (0.0203)
STEM Major	-0.157*** (0.0238)	-0.124*** (0.0179)	-0.126*** (0.0176)	-0.122*** (0.0188)	-0.104*** (0.0271)
Constant	-4.613*** (0.0609)	-2.437*** (0.0476)	-2.936*** (0.0468)	-2.926*** (0.0491)	-2.677*** (0.0746)
Observations	94,377	127,115	127,235	110,295	52,380

Standard errors in parentheses

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

Table 8D. Full-Time, Two-Year Sector Students

	Associate Degree Within 2 Years	Associate Degree Within 3 Years	Certificate Within 2 Years	Accumulated 12 Credits in First Semester	Accumulated 24 Credits in First 2 Semesters	Accumulated 36 Credits in First 3 Semesters	Transferred Within 3 Years
Time	-0.00743 (0.0167)	-0.0147 (0.0115)	0.0578 (0.0400)	-0.0188* (0.00803)	-0.0238** (0.00853)	-0.0136 (0.00922)	-0.0300** (0.0115)
Post Year 1	-0.183** (0.0699)	-0.0613 (0.0470)	1.683*** (0.129)	0.0797* (0.0317)	0.0363 (0.0340)	-0.0716 (0.0371)	-0.00597 (0.0470)
Post Year 2	0.0220 (0.0807)	0.137* (0.0550)	1.553*** (0.165)	0.113** (0.0381)	0.0390 (0.0407)	-0.00349 (0.0442)	0.0661 (0.0557)
Post Year 3	0.107 (0.0939)	- -	1.320*** (0.202)	0.182*** (0.0451)	0.131** (0.0479)	0.0575 (0.0519)	- -
Pell Eligible	-0.673*** (0.0375)	-0.504*** (0.0273)	-0.489*** (0.0495)	-0.433*** (0.0176)	-0.475*** (0.0184)	-0.456*** (0.0199)	-0.527*** (0.0273)
Adult	-0.0695 (0.0642)	0.00212 (0.0436)	0.229*** (0.0676)	0.105*** (0.0245)	0.109*** (0.0269)	-0.0314 (0.0306)	-0.884*** (0.0597)
ACT Score	0.170*** (0.00476)	0.115*** (0.00357)	0.101*** (0.00638)	0.0754*** (0.00234)	0.0882*** (0.00248)	0.104*** (0.00269)	0.113*** (0.00360)
Hispanic	-0.0773 (0.130)	-0.141 (0.0964)	0.0594 (0.151)	0.0308 (0.0531)	-0.0349 (0.0577)	-0.0174 (0.0634)	0.202* (0.0887)
Black	-0.827*** (0.0915)	-0.933*** (0.0576)	-0.787*** (0.0985)	-0.583*** (0.0241)	-0.701*** (0.0298)	-0.760*** (0.0357)	-0.188*** (0.0473)
Other Race	-0.103 (0.0764)	-0.0535 (0.0547)	-0.404*** (0.105)	-0.0343 (0.0332)	-0.00562 (0.0354)	-0.0290 (0.0389)	0.0893 (0.0540)
Female	0.482*** (0.0372)	0.452*** (0.0276)	0.0934 (0.0495)	0.416*** (0.0168)	0.364*** (0.0181)	0.322*** (0.0198)	0.0295 (0.0265)
Professional Major	-0.691*** (0.0461)	-0.526*** (0.0315)	0.393*** (0.0510)	-0.0979*** (0.0177)	-0.247*** (0.0193)	-0.354*** (0.0216)	-0.907*** (0.0344)
STEM Major	0.361*** (0.0756)	0.466*** (0.0553)	1.160*** (0.0809)	0.146*** (0.0378)	0.232*** (0.0401)	0.264*** (0.0429)	-1.043*** (0.0811)
Constant	-5.978*** (0.119)	-3.904*** (0.0864)	-6.839*** (0.199)	-1.212*** (0.0561)	-2.134*** (0.0597)	-2.819*** (0.0651)	-3.414*** (0.0855)
Observations	69,956	58,125	69,953	68,175	68,035	67,854	58,127

Standard errors in parentheses

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

Table 9D. Part-Time, Two-Year Sector Students

	Associate Degree Within 3 Years	Associate Degree Within 4 Years	Certificate Within 2 Years	Accumulated 12 Credits in First Year	Accumulated 24 Credits in First 2 Years	Accumulated 36 Credits in First 3 Years	Transferred Within 3 Years
Time	0.118* (0.0519)	0.0734 (0.0376)	0.0252 (0.112)	0.0458* (0.0199)	0.0476* (0.0217)	0.0464* (0.0235)	0.0697 (0.0536)
Post Year 1	-0.565** (0.191)	-0.417** (0.139)	1.011** (0.366)	-0.227** (0.0724)	-0.240** (0.0792)	-0.323*** (0.0864)	-0.634** (0.207)
Post Year 2	-0.559* (0.224)	- (-)	0.328 (0.477)	-0.399*** (0.0875)	-0.383*** (0.0956)	-0.474*** (0.104)	-0.579* (0.236)
Post Year 3	- (-)	- (-)	0.803 (0.566)	-0.519*** (0.105)	-0.491*** (0.115)	- (-)	- (-)
Pell Eligible	-0.590*** (0.112)	-0.396*** (0.0948)	-0.428** (0.161)	-0.191*** (0.0402)	-0.232*** (0.0440)	-0.220*** (0.0537)	-0.389** (0.123)
Adult	0.323** (0.110)	0.279** (0.0920)	0.507*** (0.153)	0.546*** (0.0359)	0.512*** (0.0398)	0.448*** (0.0492)	-0.577*** (0.133)
ACT Score	0.0781*** (0.0142)	0.0637*** (0.0119)	0.0418* (0.0203)	0.0152** (0.00489)	0.0224*** (0.00539)	0.0271*** (0.00662)	0.0552*** (0.0153)
Hispanic	-0.194 (0.345)	-0.0533 (0.293)	-0.0292 (0.423)	0.222* (0.100)	0.181 (0.109)	0.257 (0.138)	0.0238 (0.348)
Black	-0.998*** (0.190)	-0.862*** (0.152)	-1.309*** (0.259)	-0.525*** (0.0453)	-0.552*** (0.0522)	-0.494*** (0.0664)	0.0584 (0.156)
Other Race	-0.501 (0.261)	-0.307 (0.199)	-0.516 (0.347)	0.136* (0.0694)	0.211** (0.0746)	0.250** (0.0923)	0.331 (0.212)
Female	0.297* (0.117)	0.290** (0.0979)	-0.111 (0.158)	0.372*** (0.0375)	0.296*** (0.0418)	0.269*** (0.0520)	-0.117 (0.117)
Professional Major	0.104 (0.111)	0.103 (0.0944)	0.980*** (0.165)	-0.0674 (0.0364)	-0.145*** (0.0406)	-0.161** (0.0507)	-0.818*** (0.138)
STEM Major	0.000303 (0.252)	0.261 (0.191)	0.893** (0.289)	0.164* (0.0760)	0.151 (0.0830)	0.182 (0.103)	-0.999** (0.329)
Constant	-5.065*** (0.360)	-4.034*** (0.288)	-6.097*** (0.587)	-1.199*** (0.124)	-1.717*** (0.136)	-2.083*** (0.162)	-3.948*** (0.374)
Observations	13,011	8,996	17,042	16,326	16,268	12,389	13,014

Standard errors in parentheses
 *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$