A Passage to America: University Funding and International Students, John Bound, Breno Braga, Gaurav Khanna, Sarah Turner, Online Appendix.

Table A1: Appropriations and Chinese Enrollment

Panel A - Effects of log state appropriations on Chinese F-1 Visa Recipients, 2004-12 - Instrumental Variable Specification

	Dependent Variable: Ln 1st Year Enrollment, 2004-2012 (China)								
	Research			AAU			Non-Research		
Explanatory Variable	Bachelor	Masters	PhD	Bachelor	Masters	PhD	Bachelor	Masters	PhD
Log(State Appropriations)	-2.606	-1.394	0.269	-3.303	-1.154	0.389	-0.653	-0.061	0.353
	(1.515)	(0.480)	(0.270)	(1.811)	(0.933)	(0.277)	(0.610)	(0.582)	(0.551)
Log(Population 18)	-1.797	2.011	1.854	-6.447	2.636	1.167	-4.343	-1.061	0.524
	(2.849)	(0.694)	(0.519)	(2.506)	(1.548)	(0.913)	(1.665)	(1.709)	(1.474)
Partial R-squared	0.123	0.133	0.130	0.156	0.158	0.158	0.299	0.291	0.234
F- Statistic	62.98	64.64	62.82	27.35	27.28	27.28	37.94	31.26	33.89
Observations	1,065	1,151	1,145	303	305	305	1,090	1,084	253
Number of Universities	130	132	133	34	34	34	197	188	50

Panel B – Funding of Chinese Students

	Research			AAU			Non-Research		
Statistic	Bachelor	Masters	PhD	Bachelor	Masters	PhD	Bachelor	Masters	PhD
Share of F1 Undergraduates Receiving Institutional Funding	6.6%	26.4%	86.4%	3.6%	22.0%	85.6%	21.6%	23.1%	81.6%
Median Funding Received	$5,000	$19,640	$33,994	$4,000	$19,825	$38,000	$4,700	$8,280	$22,191

Notes: Overall state appropriations to higher education minus own appropriation are used as an instrument for institution-level state appropriations. All regressions include institution and year fixed effects. Institution-year observations are weighted by the undergraduate population at baseline (1996). Robust standard errors reported in parentheses are clustered at the state level. Research universities are those classified as having high or very high research activity by the Carnegie 2010 classifications. AAU institutions are also research universities. Non-Research includes both Doctoral granting low-research activity universities, and Masters universities. Population 18 is the number of people in the state aged 18, as projected by the US Census Bureau. Enrollment and funding data are from United States Citizenship and Immigration Services (USCIS) F1 Administrative Data. State level appropriations are from the State Higher Education Executive Officers Association. University level appropriations are from IPEDS.

Table A2: Effects of log state appropriations on level and share first-time foreign undergraduate enrollment, 1996-2012

Panel A	**Dependent Variable:** Number of Foreign 1st Year Enrollment					
	Research		AAU		Non-Research	
Explanatory Variable	OLS	IV	OLS	IV	OLS	IV
Log(State Appropriations)	-171.121	-376.571	-342.709	-298.365	1.406	10.291
	(62.716)	(111.438)	(130.484)	(240.723)	(6.113)	(12.300)
Log(Population 18)	-15.380	59.450	-460.115	-475.350	16.272	13.868
	(64.504)	(73.518)	(198.852)	(198.210)	(12.328)	(21.133)
R-squared	0.293		0.578		0.053	

Panel B	**Dependent Variable:** Log(Share of Total Freshmen that are Foreign)					
	Research		AAU		Non-Research	
Explanatory Variable	OLS	IV	OLS	IV	OLS	IV
Log(State Appropriations)	-0.684	-1.830	-0.693	-1.858	-0.022	0.566
	(0.178)	(0.632)	(0.268)	(0.842)	(0.156)	(0.434)
Log(Population 18)	-0.280	0.137	-1.435	-1.034	-0.694	-0.844
	(0.327)	(0.449)	(0.682)	(0.650)	(0.389)	(0.589)
R-squared	0.266		0.593		0.090	

Notes: Overall state appropriations to higher education minus own appropriation are used as an instrument for institution-level state appropriations in the IV regressions. For the first-stage of the IV regression, see Table 2. All regressions include institution and year fixed effects. Institution-year observations are weighted by the undergraduate population at baseline (1996). Robust standard errors reported in parentheses are clustered at the university level in the OLS and at the state level in the IV. Enrollment data are from the Annual Survey of Colleges (ASC). University level appropriations are from IPEDS. State level appropriations are from the State Higher Education Executive Officers Association. Research universities are those classified as having high or very high research activity by the Carnegie 2010 classifications. AAU institutions are also research universities. Non-Research includes both Doctoral granting low-research activity universities, and Masters universities. Population 18 is the number of people in the state aged 18, as projected by the US Census Bureau.

Table A3: Effects of log state level appropriations on log first-time foreign undergraduate enrollment, Private Universities, 1996-2012

	Dependent Variable: Ln Foreign 1st Year Enrollment		
Explanatory Variable	Research	AAU	Non-Research
Log(Overall State Appropriations)	0.452	0.766	-0.084
	(0.304)	(0.405)	(0.243)
Log(Population 18)	-1.151	0.788	1.151
	(0.869)	(1.037)	(0.546)
R-squared	0.338	0.587	0.087
Observations	789	396	4,315
Number of Universities	52	26	370
	Foreign 1st Year Enrollment		
	Research	AAU	Non-Research
Log(Overall State Appropriations)	95.577	182.444	-3.419
	(98.818)	(152.834)	(8.921)
Log(Population 18)	-115.121	55.610	64.742
	(143.309)	(241.831)	(42.505)
R-squared	0.338	0.495	0.053
Observations	789	396	4,378
Number of Universities	52	26	370

Note: All regressions include institution and year fixed effects. Institution-year observations are weighted by the undergraduate population at baseline (1996). Robust standard errors reported in parentheses are clustered at the state level. Enrollment data are from the Annual Survey of Colleges (ASC). State level appropriations are from the State Higher Education Executive Officers Association. Research universities are those classified as having high or very high research activity by the Carnegie 2010 classifications. AAU institutions are also research universities. Non-Research includes both Doctoral granting low-research activity universities, and Masters universities. Population 18 is the number of people in the state aged 18, as projected by the US Census Bureau.

Table A4: Effects of log state level appropriations on log first-time foreign undergraduate enrollment, 1996-2012. Additional Specifications

Panel A: Additional Controls	**Dependent Variable:** Ln Foreign 1st Year Enrollment		
Explanatory Variable	Research	AAU	Non-Research
Log(State Appropriations)	-2.059	-2.234	0.672
	(0.863)	(0.799)	(0.509)
Log(Population 18)	0.776	-0.937	0.549
	(0.427)	(0.569)	(0.553)
Additional Controls	Yes	Yes	Yes
C&H P-value	0.0288	0.0051	0.2035
Partial R-squared	0.0441	0.134	0.184
F-statistic	9.808	18.01	46.63
Panel B: Unweighted	**Dependent Variable:** Ln Foreign 1st Year Enrollment		
Explanatory Variable	Research	AAU	Non-Research
Log(State Appropriations)	-0.855	-1.553	0.616
	(0.524)	(0.701)	(0.478)
Log(Population 18)	0.388	-0.566	-0.280
	(0.420)	(0.756)	(0.604)
Unweighted	Yes	Yes	Yes
C&H P-value	0.1014	0.0215	0.1882
Partial R-squared	0.0919	0.176	0.230
F-statistic	15.90	14.69	65.74
Observations	2121	547	3,158
Number of Universities	136	34	281
Panel C: Reduced Form	**Dependent Variable:** Ln Foreign 1st Year Enrollment		
Explanatory Variable	Research	AAU	Non-Research
Log(Overall State Appropriations to Higher Education minus Own Appropriations)	-0.483	-0.904	0.432
	(0.181)	(0.320)	(0.274)
Log(Population 18)	0.071	-0.545	0.340
	(0.484)	(0.757)	(0.646)
R-squared	0.345	0.639	0.067
Observations	2121	547	3162
Number of Universities	136	34	285

Note: Panel A: Additional controls include the state unemployment rate (BLS), the share of the population below the poverty line (UKCPR National Welfare Data), an indicator whether the governor is a democrat (UKCPR National Welfare Data), the rate of non farm employment growth (BLS), the population at age 18 for all neighboring states (Census), the state level personal income of per capita (BEA), Median wages of employed workers with at least a bachelors degree for ages 23-35 , for ages 36-49 , and for ages 50-60 (author's calculations using March CPS). Overall state appropriations to higher education minus own appropriations are used as an instrument for institution-level state appropriations in the IV regressions in Panels A and B. All regressions include institution and year fixed effects. Institution-year observations are weighted by the undergraduate population at baseline (1996). Robust standard errors reported in parentheses are clustered at the university level in the OLS and at the state level in the IV. C&H P-value are the Chernozhukov and Hansen (2008) p-values from reduced form regressions. Enrollment data from ASC. University level appropriations are from IPEDS. State level appropriations are from the State Higher Education Executive Officers Association (SHEEO). Research universities are those classified as having high or very high research activity by the Carnegie 2010 classifications. AAU institutions are also research universities. Non-Research includes both Doctoral granting low-research activity universities, and Masters universities. Population 18 is the number of people in the state aged 18, as projected by the US Census Bureau.

Table A5: Effects of log state appropriations on log first-time foreign undergraduate enrollment, Alternative Instrumental Variables, 1996-2012

Panel A- IV: Log (State Level Appropriations) interacted with University Revenue Dependence on Appropriations at Baseline

	Dependent Variable: Ln Foreign 1st Year Enrollment		
Explanatory Variable	Research	AAU	Non-Research
Log(State Appropriations)	-1.824	-2.653	0.650
	(0.511)	(1.023)	(0.467)
Log(Population 18)	0.436	-0.863	0.259
	(0.360)	(0.572)	(0.675)
Partial R-squared	0.208	0.194	0.177
F- Statistic	69.86	33.80	40.31
Observations	1,987	492	2,955
Number of Universities	134	32	273

Panel B - IV: Log (Disposable Revenue in State)

	Dependent Variable: Ln Foreign 1st Year Enrollment		
Explanatory Variable	Research	AAU	Non-Research
Log(State Appropriations)	-1.344	-3.074	0.551
	(0.601)	(1.479)	(0.567)
Log(Population 18)	0.392	-0.358	0.308
	(0.488)	(0.814)	(0.749)
Partial R-squared	0.117	0.0757	0.145
F- Statistic	34.22	6.153	29.01
Observations	2,121	547	3,158
Number of Universities	136	34	281

Panel C - IV: Log (State Level Appropriations)

	Dependent Variable: Ln Foreign 1st Year Enrollment		
Explanatory Variable	Research	AAU	Non-Research
Log(State Appropriations)	-1.171	-1.704	0.557
	(0.431)	(0.703)	(0.380)
Log(Population 18)	0.329	-0.828	0.306
	(0.431)	(0.647)	(0.704)
Partial R-squared	0.270	0.284	0.285
F- Statistic	65.55	26.66	66.04
Observations	2,121	547	3,158
Number of Universities	136	34	281

Note: All regressions include institution and year fixed effects. Institution-year observations are weighted by the undergraduate population at baseline (1996). Robust standard errors reported in parentheses are clustered at the state level. **Panel A:** Instrumental variable is Log(Appropriations at the State Level) in the current period interacted with appropriations at the university level as a share of university total revenue in 1996. We only use 1997-2012 observations and do not use observations of universities with missing revenue in 1996. Panel B: Instrumental variable is Log(Disposable Revenue), where disposable revenue is defined as state general revenue minus entitlement spending. Panel C: Instrumental variable is Log(State Level Appropriations), where we use the appropriations assigned to all university in the state.

Enrollment data are from the Annual Survey of Colleges (ASC). University level appropriations are from IPEDS. State level appropriations are from the State Higher Education Executive Officers Association. Disposable Revenue is from the U.S. Census - State and Local Government Finance. Research universities are those classified as having high or very high research activity by the Carnegie 2010 classifications. AAU institutions are also research universities. Non-Research includes both Doctoral granting low-research activity universities, and Masters universities. Population 18 is the number of people in the state aged 18, as projected by the US Census Bureau.

Table A6 - Estimates of the effect of enrollment and cohort size on in-state and out-of-state enrollment levels, 1996-2012

	Dependent Variable: In-State 1st Year Enrollment		
Explanatory Variable	Research	AAU	Non-Research
Out-of-State 1st Year Enrollment	0.153	0.017	0.060
	(0.122)	(0.147)	(0.278)
Foreign 1st Year Enrollment	-0.550	-0.557	1.265
	(0.198)	(0.259)	(0.501)
Log(Population 18)	2,084.228	1,775.804	1,426.968
	(397.636)	(321.166)	(261.543)
R-squared	0.403	0.360	0.322
Observations	2,184	550	3,194
Number of Universities	137	34	288

Notes: All regressions include institution and year fixed effects. Institution-year observations are weighted by the undergraduate population at baseline (1996). Robust standard errors reported in parentheses are clustered at the university level. Enrollment data are from the Annual Survey of Colleges (ASC). Research universities are those classified as having high or very high research activity by the Carnegie 2010 classifications. AAU institutions are also research universities. Non-Research includes both Doctoral granting low-research activity universities, and Masters universities. Population 18 is the number of people in the state aged 18, as projected by the US Census Bureau.

Table A7: Effects of log state appropriations on university financial variables, 1996-2012

Expenditure Variables			
Panel A1	Log(Instructional - salaries and wages)		
Log(State Appropriations)	0.110	0.068	0.226
	(0.083)	(0.046)	(0.031)
Log (Population)	0.091	0.023	-0.082
	(0.097)	(0.232)	(0.090)
Log (FTE)	0.437	0.035	0.344
	(0.107)	(0.143)	(0.054)
R-squared	0.780	0.944	0.861
Panel A2	Log(Expenditures for institutional support)		
Log(State Appropriations)	0.301	0.221	0.404
	(0.092)	(0.109)	(0.054)
Log (Population)	-0.613	-0.881	-0.518
	(0.176)	(0.310)	(0.168)
Log (FTE)	0.526	0.309	0.199
	(0.127)	(0.219)	(0.075)
R-squared	0.677	0.766	0.693
Panel A3	Log(Total education and general expenditures)		
Log(State Appropriations)	0.132	0.025	0.252
	(0.095)	(0.041)	(0.027)
Log (Population)	0.053	0.171	-0.009
	(0.073)	(0.156)	(0.063)
Log (FTE)	0.278	-0.141	0.307
	(0.100)	(0.130)	(0.045)
R-squared	0.880	0.952	0.908
Observations	1,656	432	3,637
Number of Universities	126	32	265
Revenue Variable			
Panel B1	Log (Total Tuition Revenue)		
Log(State Appropriations)	-0.185	-0.269	-0.075
	(0.052)	(0.070)	(0.047)
Log (Population)	0.084	0.062	0.120
	(0.091)	(0.143)	(0.125)
Log (FTE)	0.668	0.267	0.571
	(0.089)	(0.133)	(0.088)
R-squared	0.841	0.891	0.555
Observations	2,139	521	4,116
Number of Universities	136	34	290

Notes: All regressions include institution and year fixed effects. Institution-year observations are weighted by the undergraduate population at baseline (1996). Data on appropriations, revenues and expenditures are from IPEDS. Enrollment data are from ASC. Research universities are those classified as having high or very high research activity by the Carnegie 2010 classifications. AAU institutions are also research universities. Non-Research includes both Doctoral granting low-research activity universities, and Masters universities. Population 18 is the number of people in the state aged 18, as projected by the US Census Bureau.

Table A8: Effect of Log Foreign First Year Enrollment on Log Tuition Revenues, Research Universities 1996-2012

	Dependent Variable: Ln (Tuition Revenue)		
Explanatory Variable	Research	AAU	Non-Research
Ln Foreign 1st Year Enrollment	0.018	0.070	0.045
	(0.010)	(0.017)	(0.014)
Log(Population 18)	0.306	0.108	0.510
	(0.122)	(0.151)	(0.341)
R-squared	0.808	0.891	0.733
Observations	2,184	529	1,143
Number of Universities	136	34	230

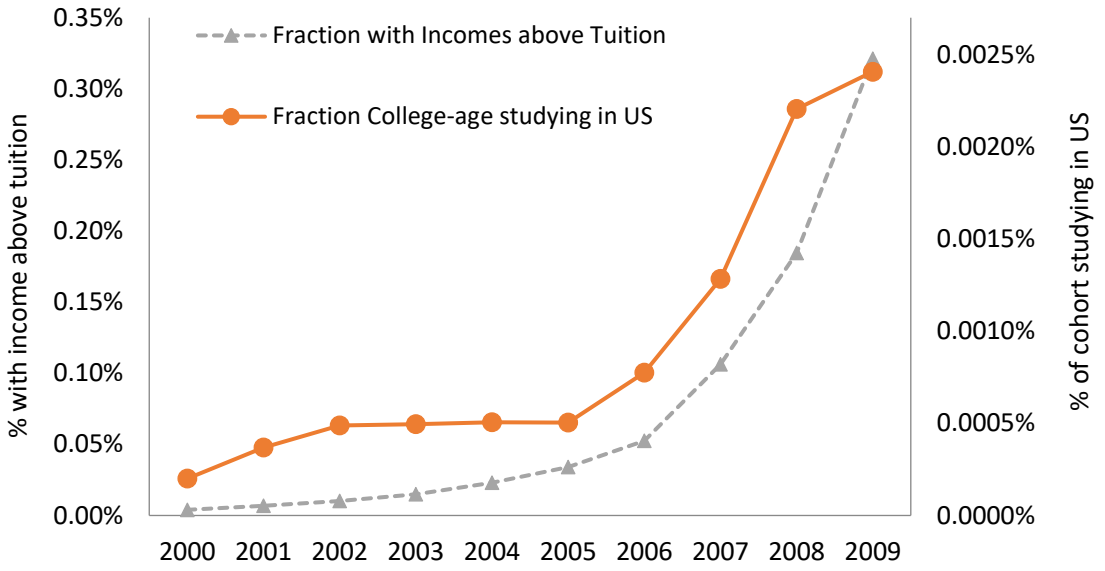
Notes: All regressions include institution and year fixed effects. Institution-year observations are weighted by the undergraduate population at baseline (1996). Robust standard errors reported in parentheses are clustered at the university level. Enrollment data are from ASC, tuition revenue are from IPEDS. Research universities are those classified as having high or very high research activity by the Carnegie 2010 classifications. AAU institutions are also research universities. Non-Research includes both Doctoral granting low-research activity universities, and Masters universities. Population 18 is the number of people in the state aged 18, as projected by the US Census Bureau.

Table A9: Estimates of the effect of state appropriations on university financial variables, 1996-2012, Heterogeneous Effects for Research Universities

	Effect on Expenditures and Tuition Rates			
	Early Period (1996-2004)		Late Period (2005-2012)	
Explanatory Variable	In State Tuition	Log(Total Expenditure)	In State Tuition	Log(Total Expenditure)
Log(State Appropriations)	-0.297	0.221	-0.153	0.098
	(0.069)	(0.046)	(0.060)	(0.034)
Log(Population 18)	-0.060	0.024	1.258	-0.015
	(0.068)	(0.046)	(0.222)	(0.141)
Log (FTE)	-0.042	0.146	-0.130	0.218
	(0.047)	(0.048)	(0.118)	(0.093)
R squared	0.861	0.664	0.836	0.872
Observations	1,097	972	1,006	932
Number of Universities	136	126	135	125

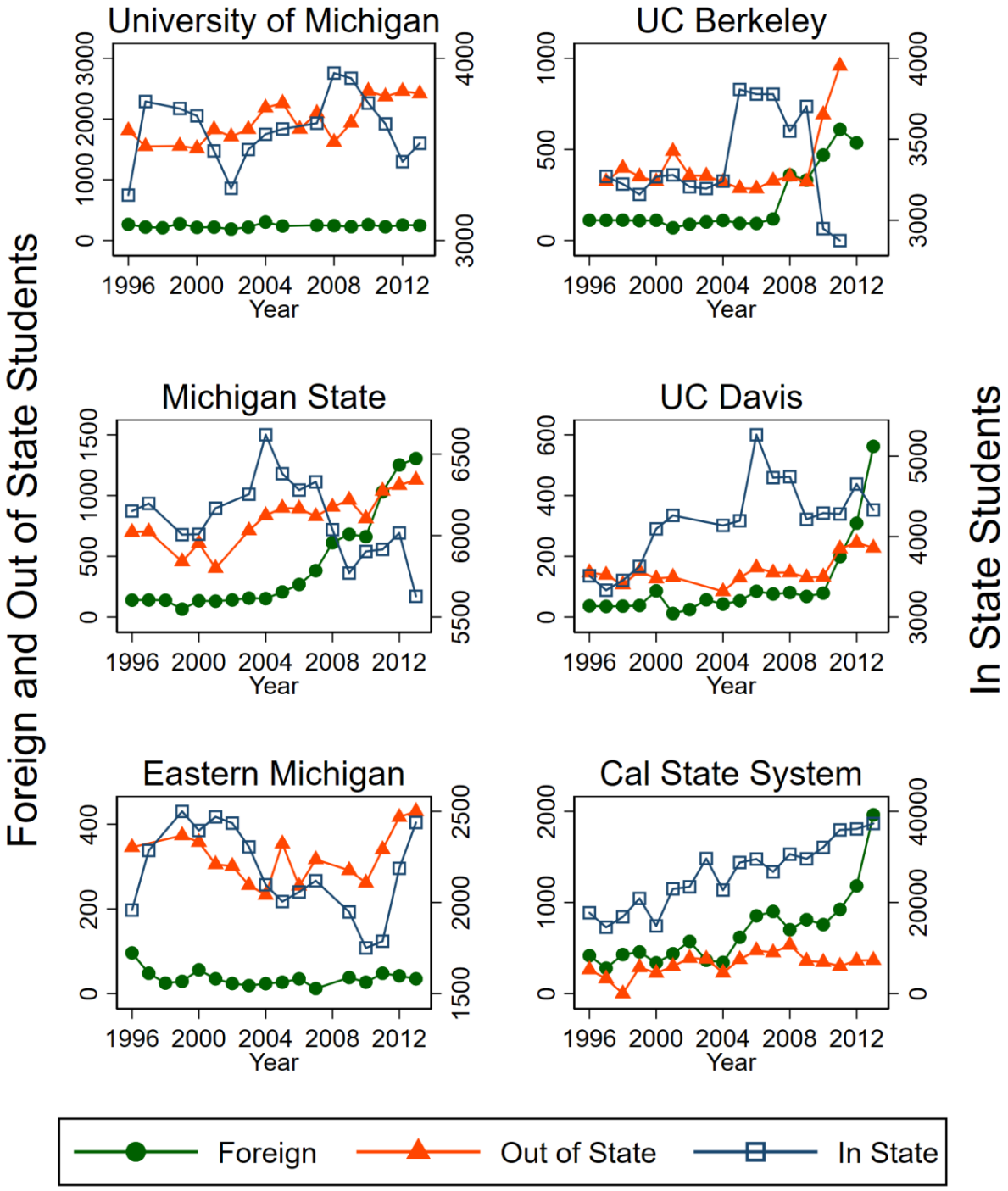
Note: All regressions include institution and year fixed effects. Institution-year observations are weighted by the undergraduate population at baseline (1996). Robust standard errors reported in parentheses are clustered at the university level. Tuition, expenditure and appropriations data are from IPEDS. Enrollment data are from ASC. State level appropriations are from the State Higher Education Executive Officers Association (SHEEO). Research universities are those classified as having high or very high research activity by the Carnegie 2010 classifications. AAU institutions are also research universities. Non-Research includes both Doctoral granting low-research activity universities, and Masters universities. Population 18 is the number of people in the state aged 18, as projected by the US Census Bureau.

Figure A1: Fraction of Chinese college-age population studying abroad and financial capacity, 2000-2009



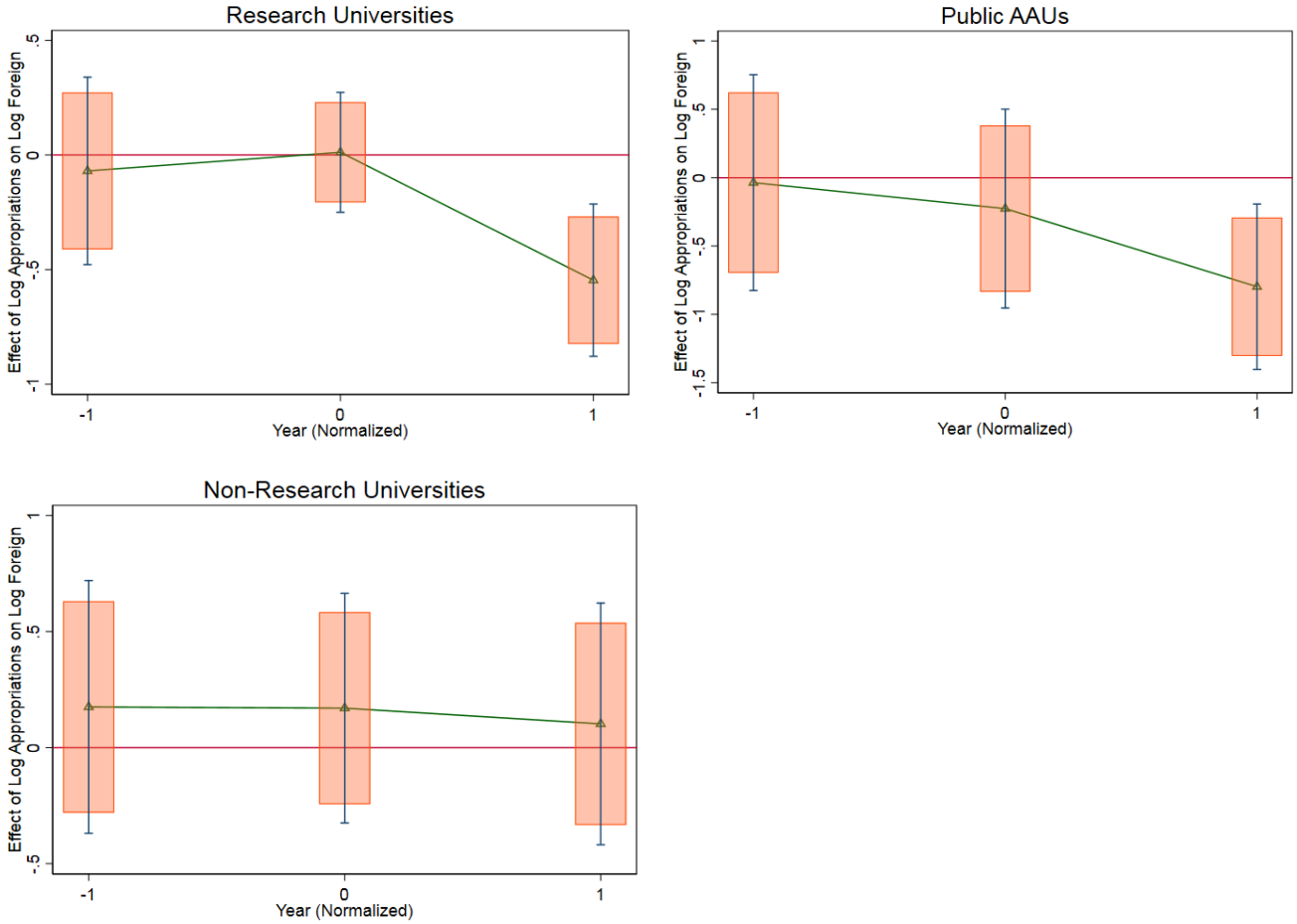
Source: Authors' calculations, based on income distribution data from the World Bank and average tuition, room and board charges for out-of-state students at public universities recorded in IPEDS. We derived the income distribution (assumed to be log-normal) following the approach of Pinkovskiy and Sala-i-Martin (2009). With the mean from GDP-per capita, we calibrate the standard deviation using income shares received by each quintile of the income distribution (available from the World Bank). Using the currency exchange rate, we convert to constant U.S. dollars and compute the expected share of households with incomes greater than the average public tuition, room and board for out-of-state students.

Figure A2: Trends in Enrollment by Institution –Michigan and California



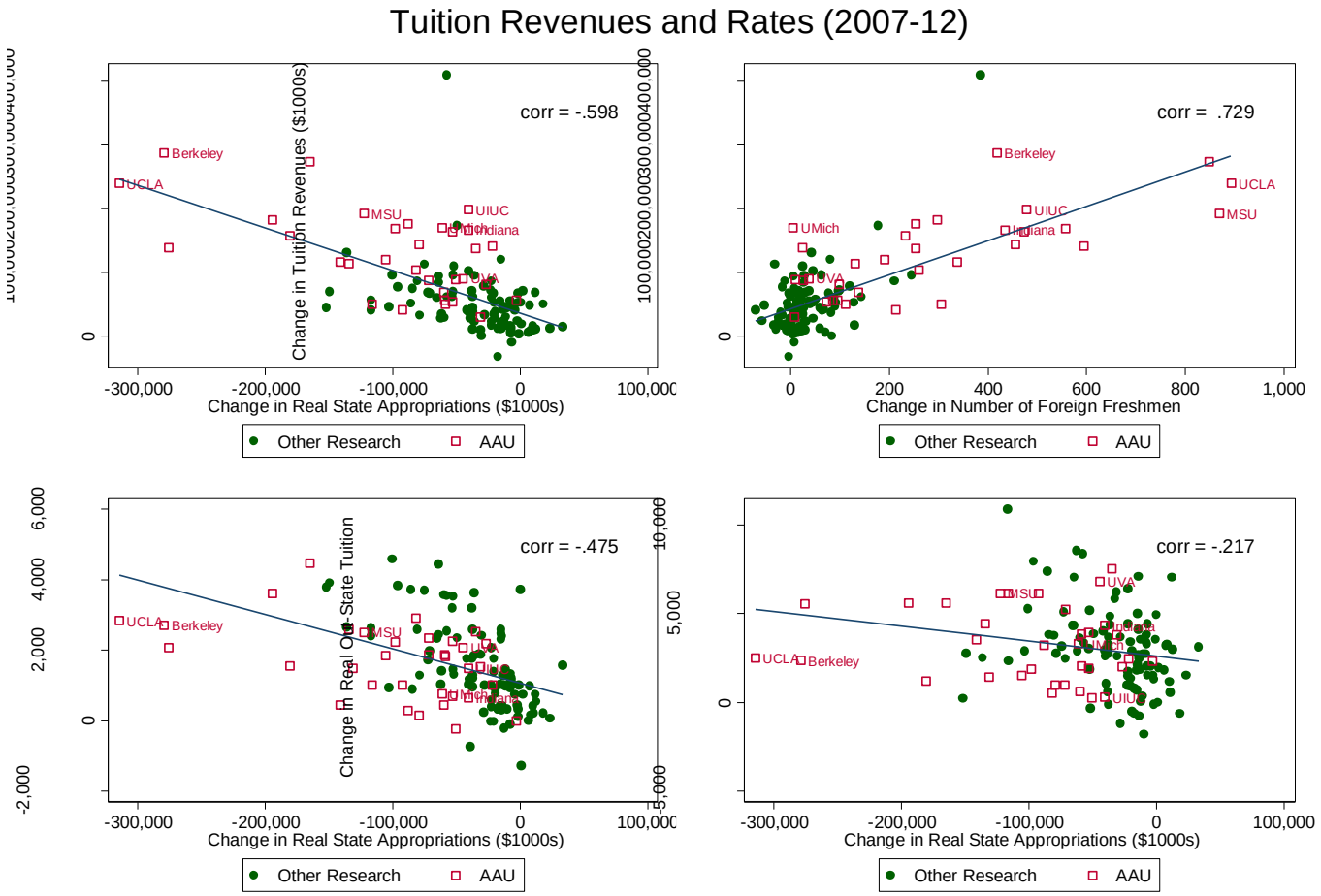
Note: Enrollment numbers from ASC data 1996 to 2012. Figures show number of full time first year students by residency and visa status. As Ohio has a tuition reciprocity agreement Michigan, many of the out-of-state students at Eastern Michigan University come from northern Ohio.

Figure A3: Impact of Appropriations on Foreign Enrollment – Leads and Lags.



Note: This figure presents estimates and 95 percent confidence intervals from a regression of Ln Foreign 1st Year Enrollment on lags and leads of Log(State Appropriations) for Public Research, AAU and Non-Research universities. Overall state appropriations to higher education minus own appropriation are used as an instrument for institution-level state appropriations. All regressions include institution and year fixed effects. Institution-year observations are weighted by the undergraduate population at baseline (1996). Robust standard errors reported in parentheses are clustered at the university level in the OLS and at the state level in the IV. Data on enrollment are from the Annual Survey of Colleges (ASC). University level appropriations and expenditures data are from IPEDS. State level appropriations are from the State Higher Education Executive Officers' office (SHEEO). Research universities are those classified as having high or very high research activity by the Carnegie 2010 classifications. AAU institutions are also research universities. Non-Research includes both Doctoral granting low-research activity universities, and Masters universities.

Figure A4: Change in Appropriations, Tuition, and Foreign Freshmen - 2007 to 2012



Note: Changes are defined as the difference between the 2012 value and the 2007 value. All monetary units are deflated by Higher Education Price Index (HEPI) 2012. State appropriations, tuition levels and tuition revenue data from IPEDS, foreign freshmen from ASC. Research universities are those classified as having high or very high research activity by the Carnegie 2010 classifications. AAU institutions are also research universities.

Appendix 2: Data Sources and Preparation

Sources

The data assembled for this project are organized at the university and academic year and draw on multiple sources including the Department of Education's IPEDS survey modules, the American Survey of Colleges assembled by the College Board, and administrative data from the Department of Homeland Security on F-visa recipients. In addition, we assembled annual state-level data on demographics and economic conditions.

We use the 2010 Carnegie Classification to form groups of public universities. The Carnegie Classification taxonomy classifies institutions by the highest level of degrees awarded and research intensity, measured by factors such as research expenditures, doctorates awarded, and number of research-focused faculty. Among institutions awarding doctorate degrees, there are three categories: (1) Very high research activity, (2) High research activity, and (3) Doctoral universities. In all, there are 177 public doctorate-granting universities across eighteen years (1997 to 2014) of which 138 universities are in the first two categories. There are an additional 265 Master's institutions. We focus our analysis on "Research Universities" defined as the combination of (1) and (2) and create a comparison group of "Non-Research" institutions as the aggregate of (3) and the Master's institutions.

Enrollment Measures

The enrollment measure we employ is first-time undergraduate enrollment; fall enrollment is recorded in both the IPEDS "Fall Enrollment" module and the Annual Survey of Colleges (ASC), which is assembled by the College Board. We follow the coding of the surveys, which distinguish between temporary visa holders and U.S. residents to record counts of "Temporary Residents" in identifying foreign students. By definition, any student holding a temporary visa is a foreign-born person who is "not a citizen or national of the United States and who is in this country on a visa or temporary basis and does not have the right to remain indefinitely." Nearly all non-resident students at U.S. colleges and universities hold an F-type ("student") visa.

To distinguish domestic students by in- or out-of-state status, we use data from the American Survey of Colleges (ASC). The ASC has more detail on the characteristics of admitted and matriculating students than IPEDS measures. When this information is missing in the ASC, we complement the dataset with institutional sources (see below). In addition to total enrollment, the ASC reports the number of foreign freshmen and the fraction of domestic first year students who are from out-of-state on an annual basis. Given the fraction of out-of-state, the number of foreign students, and the total enrollment, we compute in-state enrollment for first-year students. We have verified this approach with the examination of independent reporting at the university level.

Data on the enrollment of foreign students by country of origin are more limited in their availability. The Institute for International Education (IIE) provides a long series of enrollment by country of origin in the *Open Doors* series. These data are not publicly available by institution. The most accurate source of data on country of origin for temporary residents comes from an individual-level file of F-1 visa recipients (2004-2015) obtained from the U.S. Immigration and Customs Enforcement group of the Department of Homeland Security through a Freedom of Information Request. These data identify each student's intended degree, subject of study, post-secondary institution in the U.S., city and country of origin, along with variables indicating cost of attendance, financial support, and the period of study.

Finance Variables and University Characteristics

The "Finance" module of the IPEDS data collection contains detailed financial information on revenues and expenditures by source and use. These data are the source of our measures of total tuition revenue, expenditures by purpose and state appropriations measures. For 2010 and prior, we employ the harmonized files assembled as part of the Delta Cost Project and add the subsequent years from the annual IPEDS files. The "Institutional Characteristics" module contains data on in-state and out-of-state tuition charges. We do not use data on University of Texas' tuition prior to 2004 because the Texas Legislature had the regulatory authority to set tuition rates, generally mandating that the same statutory and designated tuition rate be charged across the state.[1] State level data on total appropriations comes from the State Higher Education Finance report (SHEF) provided by the State Higher Education Executive Officers' (SHEEO) in the website <http://www.sheeo.org/projects/shef-%E2%80%94-state-higher-education-finance>.

All the monetary variables (including state appropriations, tuitions and expenditures) are deflated by the Higher Education Price Index (HEPI). Since most of our regression formulations include the logged monetary variable and fixed effects, the method of deflation for these regressions is inconsequential, and the deflation only affects the figures and levels regressions.

State-Level Demographic and Labor Market Variables

In order to control for changes to the local economy, we compile historical Census estimates of the population at age 18 by state, and Bureau of Labor Statistics (BLS) data on the state unemployment rate and rate of non-farm employment growth for every year in our data. Median wage of employed workers with at least a bachelor degree at ages 23-35, 36-49, and age 50-60 comes from the March Current Population Survey (CPS), the share of the population below the poverty line and an indicator whether the governor is a Democrat comes from the UKCPR

[1] In 2004, the 78th Legislature passed House Bill (HB) 3015, amending Texas Education Code §54.0513 to allow governing boards of public universities to set different designated tuition rates. Tuition deregulation became effective September 1, 2003, and universities began increasing designated tuition in spring 2004. More information can be found at the Overview: Tuition Deregulation and Tuition Set Asides Report.

National Welfare Data. Finally, state level personal income come from US Bureau of Economic Analysis.

Missing Data

When data elements related to enrollment, tuition and finances were missing from standard institutional surveys, we attempted to locate the missing elements from the universities' Common Data Sets (CDS) available on their Institutional Research webpages and the University of California System available at <http://universityofcalifornia.edu/uc-system>. In addition, we consulted the annual university financial statements (Annual Financial Reports) to locate institutional data on appropriations and revenues when missing from IPEDS. By using the complementary data on enrollment and state appropriations, we add 139 observations (at the level of the year-university) to the Research University sample, 84 to the Flagship, 49 to the AAU and 4 to the Non-Research. Our main results are robust to excluding the hand-coded data.

Appendix 3: Detailed Derivations for the Model

In our model, the behavior of public universities and state legislators, each with different objective functions, reflects a principal-agent problem. Universities maximize the quality of education provided, while legislators focus on the enrollment of in-state students and the provision of other government services within a budget constraint. In this appendix, we supplement the main text presentation with additional derivation of the primary relationships among appropriations from the state, in-state tuition determination and enrollment of students from different points of origin.

The Optimization Problem of the University

University administrators have an objective function focused on the quality of the education provided by the public university defined as: $q = q(I, \theta) = \alpha I + \theta$, where I is the per-student educational resources, and θ is a measure of academic ability of the undergraduate student body, and the positive parameter α alpha reflects the rate at which the university can tradeoff purchased educational inputs and student quality in determining the quality of the college education.[2]

While the basic optimization of the generalized form yields the intuition that universities trade revenue for the direct cost and monetized change in quality of students of different types, assuming a functional form of θ allows for a closed form solution. The quality of the student body (θ) depends on the supply of college applicants from each type of student to the university and in-state tuition:

$$\theta = T - \frac{\mu_s}{2}K_s^2 - \frac{\mu_o}{2}K_o^2 - \mu_f K_f + \frac{\pi(c - p_s)^2}{2},$$

where K_s , K_o , K_f are the number of enrolled in-state, out-of-state domestic, and foreign undergraduate students and p_s is the in-state tuition. The salient properties of the parameterized properties of θ are the faster decline in quality of domestic applicants compared to foreign applicants, and the decline in quality as tuition charges are increased.

The in-state tuition is given by p_s and the out-of-state tuition by p_o, which is paid by both foreign and out-of-state domestic students. We assume that public universities take out-of-state tuition as given, but do set the in-state tuition price p_s. The university's revenue is:

$$Rev(K_s, K_o, K_f) \; = \; R(K_s) \; + p_s K_s \; + p_o(K_o + K_f) \, ,$$

where $R(.)$ denotes the non-tuition income of the public university. In our framework, it corresponds to state appropriations $R(K_s)$, which represent a contract set by the state legislature as a function of the enrollment of in-state students. We focus on contracts in which the state appropriation is a fixed piece-rate of in-state enrollment: $R(K_s) = \gamma K_s$.

[2] Epple, Romano, Sarpça and Sieg (2017) present a general equilibrium model of the market for undergraduate higher education, modeling both public and private colleges, in which they use a similar framework. Unlike the existing literature, we describe the relationship between the university and state legislature as a principal-agent problem and incorporate foreign enrollment decisions the university's set of choices.

The cost function $c\left(K_s + K_o + K_f \right) + \frac{\rho}{2} I^2$ captures the cost of expanding enrollment, and is strictly increasing in all arguments, with marginal cost *c* of enrollment being the same for all students. $\rho > 0$ is a constant associated with costs of per-student resources.

To maximize its objective function, the public university makes choices on the in-state tuition, the number of in-state, out-of-state, and foreign students to enroll and, correspondingly, how much to invest in education. The choices must satisfy a budget constraint, and a condition of non-negativity of its inputs. Given a constant *T*, the university's problem is defined as:

$$max_{I,K_s,K_o,K_f,p_s}\ \alpha I + \left[T - \frac{\mu_s}{2} K_s^2 - \frac{\mu_o}{2} K_o^2 - \mu_f K_f + \frac{\pi (c - p_s)^2}{2} \right]$$

Subject to the budget constraint: $\gamma K_s + p_s K_s + p_o K_o + p_o K_f = c\left(K_s + K_o + K_f \right) + \frac{\rho}{2} I^2$

And non-negativity constraints: $K_s, K_o, K_f, I, p_s \geq 0$

Based on the set-up above, we can rewrite the university's behavior as a system of equations defined by the first-order conditions (FOC):[3]

a) FOC with respect to in-state students: $\gamma + p_s = c + \frac{\mu_s K_s}{\lambda}$

b) FOC with respect to out-of-state students: $p_o = c + \frac{\mu_o K_o}{\lambda}$

c) FOC with respect to foreign students: $p_o = c + \frac{\mu_f}{\lambda}$

d) FOC with respect to educational resources: $\frac{\alpha}{\lambda} = \rho I$

e) FOC with respect to in-state tuitions: $K_s = \frac{\pi (c - p_s)}{\lambda}$,

where λ is the Lagrangian multiplier associated with the budget constraint.

The FOCs provide some intuition regarding the decision of the public university. In all equations, the left hand side represents the marginal benefit of increasing the input and the right hand side represents the marginal cost of increasing the input.

- *In-state students*: The marginal benefit of in-state students is the tuition they pay as well as the increase in state appropriations associated with higher in-state enrollment. The marginal cost is the expense of enrolling an additional in-state student as well as the monetized cost of the (potential) decrease in the quality of the current student body associated with expanding the enrollment of in-state students. A public university enrolls in-state students until their marginal benefit is equal to their marginal cost. State legislators will take this behavior in consideration when setting their state appropriations contract.
- *Out-of-state and foreign students*: The marginal benefit of foreign and out-of-state students is the tuition they pay, which is higher than the tuition paid by in-state students. The marginal cost is the expense associated with their enrollment as well as the monetized cost of the (potential) decrease in the quality of the student body associated with expanding enrollment of out-of-state and foreign students.

[3] We only evaluate interior solutions for the university problem.

- *Resource investment*: The marginal benefit of additional purchased instructional inputs is the monetized benefit of an increase in the quality of education provided by the university. The marginal cost is the expense associated with the investment.
- *In-state tuition:* The marginal benefit is the increased revenues, and the marginal cost is the lower the quality of in-state students.

Overall, a public university enrolls in-state, out-of-state, and foreign students until their marginal benefit is equal to their marginal cost. As a result, the relative tuition, marginal costs, state appropriations contract, and quality of the marginal applicant between in-state, out-of-state, and foreign students will determine the share of each type of student that will be enrolled at a public university.

State Legislature's Decision Problem

The determination of the appropriations-rule from the state $R(K_s) = \gamma K_s$ follows from the legislature's maximization of its objective function which weighs the number of in-state students enrolled in a public university against the provision of other public goods (g). When making their appropriation decisions, a state legislature must consider the optimal strategy of university administrators and the university's budget constraint.

The state legislature chooses a state appropriation contract γ and provides public good g:

$$max_{\gamma,g} K_s^{\beta} g^{1-\beta},$$

subject to the state budget constraint: $Y = \gamma K_s + p_g g$,
incentive compatibility constraint (from the university problem): $K_s = \Omega\gamma$,
and non-negativity constraints: $K_s, K_o, K_f, I, p_s \geq 0$,
where $\Omega = \frac{\pi(p_o - c)\mu_f}{\mu_f^2 + \pi\mu_s(p_o - c)^2}$ is derived from the first order conditions of the university maximization problem.

Based on the set-up above, we can rewrite the university's behavior as a system of equations defined by the first-order conditions (FOC) of the legislature's decision problem:

FOC with respect to appropriation contract: $\beta\Omega^{\beta} g^{1-\beta}\gamma^{\beta-1} = \sigma 2\Omega\gamma$

FOC with respect to public goods: $(1-\beta)\Omega^{\beta} g^{-\beta}\gamma^{\beta} = \sigma p_g$,

where σ is the Lagrangian multiplier associated with the budget constraint of state legislators.

Equilibrium Appropriations

From the FOC of state legislature's decision problem, we obtain the optimal piece-rate parameter of the state appropriations contract:

$$\gamma^* = \left(\frac{\beta Y}{(2-\beta)\Omega}\right)^{\frac{1}{2}},$$

and state appropriations as a function of the parameters of the model:

$$R^*(Y) = \frac{\beta}{2-\beta} Y ,$$

which is an increasing function of exogenous state (disposable) revenues and the state legislature's preference for higher education. The intuition is that, in equilibrium, states spend more on higher education if they have higher revenues or if they have stronger preferences for higher education over other public goods.[4]

Equilibrium Enrollment

Using the expressions above and the incentive compatibility constraint of university administrators, we derive the equilibrium in-state enrollment as a function of the parameters of the model:

$$K_s^* = \left(\Omega \frac{\beta}{2-\beta} Y\right)^{\frac{1}{2}},$$

which is an increasing function of exogenous state (disposable) revenues and a decreasing function of μ_s, which measures the decrease in quality of the student body associated with the marginal enrollment of an in-state student.[5]

Using the FOC of the university maximization problem, we can demonstrate that the optimal enrollment of out-of-state students is:

$$K_o^* = \frac{\mu_f}{\mu_o},$$

which is a negative function of the ability of the marginal foreign students. The intuition is that foreign and out-of-state students generate the same (net) revenue to the university. As a result, universities will enroll out-of-state students until their ability is equal to the ability of the marginal foreign student enrolled.

Finally, we derive equilibrium foreign enrollment from the first order conditions, and the closed form solutions for in-state tuition, and in-state enrollment:

$$K_f^* = \frac{p_o - c}{2\rho}\left(\frac{\alpha}{\mu_f}\right)^2 - \frac{\mu_f}{\mu_0} - \frac{\pi\mu_s(p_o - c)}{\mu_f^2 + \pi\mu_s(p_o - c)^2} \frac{\beta}{2-\beta} Y$$

A fall in state revenue Y is associated with a decline in appropriations which consequentially leads to a rise in foreign enrollment. This result follows from the fact that additional tuition revenue provided by foreign students to finance operations works as a substitute for the subsidies from the state government. Drops in appropriations will increase the relative value of foreign students.

In addition, our model predicts that over this period, as the supply of high quality foreign students increased (a fall in μ_f), the response of foreign enrollment to appropriation shocks also increases (the magnitude of $\frac{dK_f^*}{dR}$ is larger). In the same way, we expect that non-research universities, which have limited access to foreign student applicants (high μ_f), do not increase foreign enrollment much when faced with budget shocks.

Equilibrium Tuition and Resource Investments

[4] We explore this relationship empirically in a two-state least square estimation.

[5] It is also indirectly negatively related to the supply of foreign applicants through λ^*.

From the optimal in-state tuition equation, we can derive the inverse demand curve from in-state students, and show that tuitions are a decreasing function of state appropriations:

$$p_s^* = c - \frac{\mu_f}{\pi(p_o - c)} \; K_s^* = c - \frac{\mu_f}{\pi(p_o - c)} \left(\Omega \frac{\beta}{2 - \beta} Y \right)^{\frac{1}{2}}$$

This result is consistent with the empirical patterns which shows that a fall in state revenue Y is associated with declines in appropriations which consequentially lead to a rise in in-state tuition, and that this relationship is stronger for schools that have less access to foreign students, or in periods where the supply of foreign students is lower (higher μ_f)

Finally, Using the FOC of the university maximization problem, we derive the optimal investment decision of a university:

$$I^* = \left(\frac{p_o - c}{\mu_f} \right) \frac{\alpha}{\rho},$$

which is an increasing function of the net revenue generated by foreign students and out-of-state students, and not a function of state appropriations R. In this setup, the revenue generated by foreign students provides the resources that a university can use to invest in better education.