Interstate Competition in Higher Education and the Allocation of Financial Aid

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April 2022

Abstract

I present theoretical and empirical evidence that interstate competition causes socially costly distortions to American financial aid policy. In a tractable model, I demonstrate that business-stealing incentives lead state-controlled university systems to provide less need-based and more merit-based aid than a national planner. Measuring competition from out-of-state institutions with both geographic distance and time-varying university rankings, I validate the model and show that a heightened threat of student outmigration shifts aid dollars away from need-based grants and low-income families. Quantitatively, need-based awards would be 27% larger, merit-based awards 14% smaller, and low-income college-attendance rates 8 percentage points higher under optimal policy. (JEL: H71, H75, H77, I22, I23, I28)

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1 Introduction

The rising economic returns to higher education are among the most well-documented labor market trends of the last fifty years. The rapid growth in the college wage premium (Autor, 2014) and the erosion of middle-skill employment opportunities (Autor, Katz, and Kearney 2006; Acemoglu and Autor 2011) have made postsecondary education an ever more important determinant of individuals' lifetime earnings. But as college graduates' economic fortunes have accelerated, so too have the financial costs of obtaining a four-year degree. Sustained growth in tuition has widened gaps in college-attendance rates between high- and low-income households (Belley and Lochner 2007, Lochner and Monge-Naranjo 2012) and led to a sharp increase in student debt, with attendant long-run effects on borrowers' financial security, occupation choices, and even family-formation decisions (Lochner and Monge-Naranjo 2016, Mueller and Yannelis 2017, Mezza et al. 2020, Rothstein and Rouse 2011, Luo and Mongey 2019, Gicheva 2016).

The parallel increases in the benefits and costs of college attendance make financial aid a key public policy tool. By reducing tuition and debt burdens for low-income households, aid programs can help ensure that the earnings boost provided by a four-year degree remains broadly accessible to students of all socioeconomic backgrounds. Much of the aid disbursed to American undergraduates is not, however, awarded on the basis of financial need: in 2016, 51% of grant aid from public four-year institutions was merit-based, and 48% went to the top half of the student income distribution.[1] In an environment where many students struggle to afford the economic security conferred by a college degree, it is important to understand the causes and social desirability of aid policies that increasingly divert tuition subsidies away from those with the least ability to pay.

I propose interstate competition as one such potential cause. The American higher education system is unique among developed countries in its fragmentation: public universities are funded and operated separately by state governments, each with an incentive to maintain enrollment levels and retain high-skilled workers in its labor force. State-level control of higher education thus inserts competitive considerations into financial aid policy decisions. Rather than targeting the neediest students who risk being priced out of college attendance altogether, aid dollars may instead serve protectionist purposes and flow to the students who are most likely to migrate to a university in another state.

The goal of this paper is to demonstrate that interstate competition does indeed distort the allocation of financial aid among undergraduate students. I develop a model that formalizes the competitive interactions between state university systems and show that business-stealing incentives lead states to provide less need-based and more merit-based aid than a

[1] Based on grant aid from state and institutional sources in the 2016 survey wave of the National Postsecondary Student Aid Study.

national social planner who seeks to maximize aggregate college attendance. To permit empirical tests of the model, I derive additional theoretical results relating interstate migration costs to equilibrium aid allocation: when migration is easier and states can compete more intensely for each other's students, they move further from socially optimal policy by decreasing need-based and increasing merit-based funding. Using both geographic distance and time-varying university rankings to proxy for students' migration costs, I find broad confirmatory evidence that heightened competition shifts aid dollars away from need-based grants and low-income students. Calibrated model simulations show that the distortionary effects of interstate competition are quantitatively important, with socially optimal policy raising college-attendance rates by substantial amounts relative to the decentralized equilibrium.

In the model, two states set tuition prices in order to maximize enrollment in their respective university systems, subject to a budget constraint. As in the framework used by Knight and Schiff (2019) (whose basic modeling setup I apply and expand), students can choose to attend college at home or incur a travel cost and migrate across state lines. To create scope for need- and merit-based aid within the model, I extend the base Knight-Schiff setup by adding student heterogeneity in terms of income and pre-college achievement (and allowing states to condition tuition on these characteristics). Low-income students' choices are more sensitive to tuition prices (thus rationalizing need-based aid), and high-achieving students receive a larger weight in states' enrollment objective functions (thus rationalizing merit-based aid). I also introduce an outside option of non-attendance, which allows aid distortions to generate social welfare costs by pricing some students out of college attendance altogether. Reasonable parameter conditions ensure that, as is true empirically, high-income and high-achieving students have higher college-attendance rates in equilibrium (i.e., choose the outside non-attendance option less often).

I show first that the competing states provide less need-based and more merit-based aid to resident students than a national social planner who seeks to maximize aggregate enrollment *across* the two states. There are two margins through which states can boost resident enrollment in their university systems: by converting students from the outside non-attendance option, or by drawing them away from nonresident attendance in the opposing state. The first margin is socially valuable, but the second, business-stealing margin merely shifts enrollment across state lines and is irrelevant to the planner. The business-stealing margin also exerts more downward pressure on high-income and high-achieving students' tuition prices, since they have higher attendance rates and provide more nonresident enrollment for states to lure back home. As a result, the competing states treat high-income and high-achieving students more favorably than the social planner does, causing need-based aid to be lower and merit-based aid to be higher in equilibrium than in the social optimum. Because the planner places the same weight on high-achieving enrollment as the states do, this distortionary policy gap is not driven by any a priori assumption that states value high achievers too much. The theoretical mechanism at work is more fundamental: business-stealing incentives are more pronounced for student groups with more enrollment for the states to compete over, and draw equilibrium funding away from the lower-income and lower-achieving students for whom marginal aid dollars primarily reduce non-attendance rates.

The model's primary purpose is to compare equilibrium and socially optimal financial aid policy, but since the social optimum is not empirically observable, this comparison is not directly testable. In order to generate empirically testable predictions that can be used to validate the model, I derive additional theoretical results relating the travel-cost parameter to states' equilibrium financial aid choices. In particular, I show that financial aid outcomes for resident students exhibit monotone comparative statics, with need-based aid strictly increasing and merit-based aid strictly decreasing in the travel-cost parameter. These comparative statics are essentially a continuous version of the untestable comparison to the social optimum. As travel costs increase, migration becomes less attractive and nonresident enrollment rates decrease. States therefore have a weaker business-stealing incentive to subsidize high-income and high-achieving tuition, causing need-based aid to rise and merit-based aid to fall. In the limit, as travel costs become infinite and migration goes to zero, distortionary business-stealing incentives completely disappear from the model and the states make socially optimal financial aid choices.

The equilibrium comparative statics yield clear empirical hypotheses. When travel costs are low and competition for migrating students is more intense, the model predicts that the equilibrium should feature less need-based and more merit-based aid, with the overall income progressivity of financial aid awards falling as a result. I test these predictions using data from the National Postsecondary Student Aid Study (NPSAS), a repeated, nationally representative survey containing detailed information about students' demographics, household income, tuition costs, and financial aid received from need- and merit-based sources. In the main empirical analysis, I interpret the model's travel-cost parameter as physical distance and determine whether variation in the geographic proximity of state university systems shifts financial aid allocation among resident students in line with the theoretical results. Using state-level variation in a series of geographic proximity measures, I find broad evidence in support of the model. For instance, as one state-level variable measuring the extent of proximate interstate competition, I sum undergraduate enrollment at public out-of-state universities within 500 miles of the state's population centroid. A one-standard-deviation increase in this measure lowers the probability of need-based aid receipt by 3.1 percentage points (or 13%), raises the probability of merit-based aid receipt by 3.5 percentage points (or 24%), and lifts the merit share of total grant aid by 7.6 percentage points (or 21%). The same one-standard-deviation increase raises total grant aid for the top income quartile by

$419 relative to the bottom income quartile.

To supply more robust evidence in support of the model predictions, I supplement the geographic analysis with an additional proxy for interstate competition: U.S. News and World Report (USNWR) annual university rankings. When nearby out-of-state institutions receive higher USNWR rankings, students' out-of-state options are more attractive, they face lower effective travel costs, and outmigration becomes more likely. Because USNWR rankings are time-varying (unlike geography), they also allow me to control for state fixed effects and make use of the temporal variation in the NPSAS data. The USNWR analysis again confirms the model's theoretical predictions: a one-standard-deviation increase in a regional measure of USNWR rankings raises the merit share of total grant aid by 3.3 percentage points and lifts top-income-quartile grant aid by $158 relative to the bottom quartile.

Having verified its empirically testable predictions, I conduct calibrated simulations of the model in order to make quantitative statements about the effects of interstate competition. After using a series of aggregate moments to identify the model's full parameter vector, I can directly compare equilibrium financial aid outcomes and college-attendance rates to those that would occur under socially optimal policy. I find competition-induced policy distortions to be large. By reallocating funding from merit- to need-based aid (with the former falling by 14% and the latter increasing by 27%), socially optimal policy raises low-income college attendance by 8 percentage points, without any cost to the overall attendance rate.

By studying the distortionary effects of interstate competition on financial aid policy at public universities, I draw on the insights of the established tax competition literature. Wilson (1986) and Zodrow and Mieszkowski (1986) first demonstrated that inter-jurisdictional competition for mobile capital can depress tax rates below socially efficient levels and lead to the underprovision of public goods. The literature has since evolved to study how a range of policy decisions – from income redistribution (Wildasin, 1991) to national corporate tax rates (Devereux, Lockwood, and Redoano, 2008) and state and local business subsidies (Slattery 2020, Slattery and Zidar 2020) – are influenced by fiscal authorities' business-stealing incentives. I identify financial aid policy as another setting where interstate competition for a mobile factor (students) causes socially costly distortions to public subsidies.

I also add to a body of research that studies the distinctive properties of need- and merit-based financial aid. Recent theoretical work demonstrates that equity, efficiency, and insurance-value considerations combine to make optimal financial aid policy strongly need-based (Colas, Findeisen, and Sachs 2021; Fan, Fisher, and Samwick 2021). A longer-standing series of empirical studies shows that merit-based grants tend to regressively redistribute aid dollars from low- to high-income students (Baum and Schwartz 1988; Price 2001), widen income and racial gaps in college-attendance rates (Dynarski, 2000), exert small marginal effects on the educational attainment of high-achieving students (Angrist, Autor, and Pallais, 2020), and suboptimally redirect students from high- to low-quality institutions (Cohodes and Goodman, 2014). However, despite the theoretical and empirical evidence establishing the relative strengths of need-based aid, state and institutional merit aid programs have proliferated widely in recent years (Dynarski 2004, Frisvold and Pitts 2018, Doyle 2010). I contribute by offering a formal model where the overprovision of merit-based and underprovision of need-based aid result from interstate business-stealing activities that are individually rational but not socially valuable. My emphasis on business-stealing incentives aligns with papers showing that a robust property of state merit aid programs is their ability to decrease outmigration and raise retention of resident students (Cornwell, Mustard, and Sridhar 2006; Hickman 2009; Zhang and Ness 2010; Sjoquist and Winters 2014; Harrington et al. 2016).

My analysis also relates to a recent body of work that specifies competitive equilibrium models of the American college market. With its focus on financial aid allocation at public universities, the model I develop emphasizes features of the college market that have received less attention in these prior studies. Epple, Romano, and Sieg (2006) allow financial aid policy to be an endogenous choice in their model, but only characterize the behavior of selective private colleges and use data exclusively from private schools in their estimation process. Fu (2014) takes the distribution of financial aid among students as exogenous, letting colleges choose only their gross tuition prices. Cai and Heathcote (2022) allow colleges' quality to depend on the average ability of their student bodies and therefore endogenize merit-based aid, but again take need-based aid as an exogenous calibration input (resident tuition discounts and the share of students choosing to migrate out of state are also taken as fixed). By fully endogenizing financial aid policy, modeling the resident-nonresident attendance choice, and tailoring the setup to the public universities that account for 70% of four-year enrollment,[2] I complement these previous papers, which generally are best suited to describe quality (rather than aid or geographic) competition among more selective schools.

Finally, given its modeling framework and its emphasis on the geographic fragmentation of the American higher education system, this paper relates most closely to Knight and Schiff (2019). I adopt the same discrete-choice setup for students' college-attendance decisions and make a similar effort to compare equilibrium tuition policy to the preferences of a national social planner. But while Knight and Schiff examine the gap between resident and nonresident tuition, my aim is to show that competitive pressures can also affect the allocation of tuition subsidies *within* a given state's resident student population. The changes I make to the base Knight-Schiff setup – most importantly, adding student heterogeneity in income and pre-college achievement – allow me to study states' internal allocation of need- and merit-based aid among resident students.

[2] Based on total fall enrollment in public and private non-profit four-year colleges, as reported in the most recent edition of the NCES Digest of Education Statistics.

2 Model and Theoretical Results

2.1 Model Setup

2.1.1 Student Populations and Financial Aid Outcomes

There are two states, indexed by $s \in \{E, W\}$, who interact in a static model. Each state has a population of resident students who are graduating from high school and making college-attendance decisions. Besides their state of residence, students differ in two dimensions. The first source of student heterogeneity is income, which I index with $i \in \{H, L\}$: each state's population is composed of high-income ($i = H$) and low-income ($i = L$) subpopulations, each of measure 1. The second source of heterogeneity is achievement level, which I index with g (for "grade") $\in \{A, B\}$: of each income subpopulation i, a share ϕ_i is high-achieving with $g = A$, and the complementary share $1 - \phi_i$ is low-achieving with $g = B$.

States can observe and condition tuition prices on residence status, income (as is the case empirically, e.g., FAFSA applications), and achievement (as is the case empirically, e.g., high-school GPAs and standardized test scores). As a result, states set eight distinct tuition rates: resident tuition $r_{i,g}$ and nonresident tuition $n_{i,g}$ for each combination of the binary income type i and binary achievement type g. Because my goal is to study the effect of interstate competition on tuition distortions within states' resident populations, I focus on the resident tuition values $r_{i,g}$ and largely omit discussion of the nonresident tuition values $n_{i,g}$. When discussing tuition values, I sometimes add a superscript $r^s_{i,g}$ and $n^s_{i,g}$ to emphasize the choices made by one state versus the other.

As the key endogenous outcomes of the model, I define resident need-based aid (for achievement group g) as

$$r_{H,g} - r_{L,g} \tag{1}$$

and resident merit-based aid (for income group i) as

$$r_{i,B} - r_{i,A}. \tag{2}$$

Higher values of (1) indicate that high-income students pay more relative to low-income students and therefore that more need-based aid is being provided. Similarly, higher values of (2) indicate that low-achieving students pay more relative to high-achieving students and therefore that more merit-based aid is being provided. I also analyze the overall income progressivity of resident tuition, which I define as

$$\phi_H r_{H,A} + (1 - \phi_H) r_{H,B} - \big[\phi_L r_{L,A} + (1 - \phi_L) r_{L,B}\big]. \tag{3}$$

The expression in (3) gives the difference in average resident tuition between high- and low-income students, with the averages computed across achievement groups using the ϕ_i population shares. Higher values indicate that high-income students (after accounting for the incidence of both need- and merit-based aid) pay higher average tuition relative to low-income students, and therefore that the overall tuition schedule is more progressive.

2.1.2 Student Choices

Students choose one of three discrete options, indexed with l (for "location") $\in \{r, n, x\}$: they can attend college in their home state as a resident student ($l = r$), attend college in the other state as a nonresident ($l = n$), or not attend college at all ($l = x$). This choice follows a standard logit setup. Letting k index individual students, define $u^l_{i,g,k}$ as the utility to student k of income group i and achievement group g of making attendance choice l:

$$u^r_{i,g,k} = \gamma - \beta_i r^{s(k)}_{i,g} + \frac{\epsilon^r_k}{\psi}, \tag{4}$$

$$u^n_{i,g,k} = \gamma - \beta_i n^{-s(k)}_{i,g} - \delta + \frac{\epsilon^n_k}{\psi}, \tag{5}$$

$$u^x_{i,g,k} = \frac{\epsilon^x_k}{\psi}. \tag{6}$$

In (4)-(6), $\gamma > 0$ is the utility benefit from attending college (which applies in both states and ensures a symmetric equilibrium); $\beta_i > 0$ is a tuition-sensitivity parameter that differs by income group, with $\beta_L > \beta_H$; $\delta > 0$ represents travel costs associated with attending college away from home; ϵ^l_k are idiosyncratic preference shocks following a type 1 extreme value distribution; and $\psi > 0$ is a dispersion parameter controlling the variance of the idiosyncratic preference shocks. Students choosing to attend college as residents pay the relevant resident tuition price charged by their home state. Alternatively, students choosing to attend college as nonresidents[3] pay the relevant nonresident tuition price charged by their non-home state and incur travel costs. Finally, students choosing not to attend college do not pay any tuition and receive a utility benefit normalized to zero.[4] Because the idiosyncratic preference shocks follow a type 1 extreme value distribution, the student choice probabilities have the familiar closed-form logit expression. Let $p^{l,s}_{i,g}$ denote the probability that a student

[3]Private-school attendance is not an explicit option for students. But since private schools charge a substantial premium over resident public tuition and enroll a much higher share of out-of-state students, from the perspective of a state university system considering the options available to its students and choosing resident financial aid policy, private attendance can be grouped together with nonresident public attendance without much loss of accuracy (Cai and Heathcote 2022 make this approximation in their setup as well).

[4]The outside option here could also be interpreted as attendance in the public two-year sector, where the vast majority of students are in-state. The utility parameter γ would then represent the incremental benefit of 4-year attendance and the tuition prices $r_{i,g}$ and $n_{i,g}$ would be normalized relative to two-year tuition, which averaged just \$3,000 in gross terms in 2016 (see this federal report).

of income group i and achievement group g residing in state s makes attendance choice l.

2.1.3 Equilibrium and Social Optimum

I assume that each state chooses its tuition prices in order to maximize a weighted sum of enrollment in its university system, subject to a budget constraint. The assumption that states act to maximize enrollment has several potential justifications, the most natural of which is fiscal externalities. Since college graduates earn higher wages, provide more income tax revenue, and are more likely to live and work in a given state after attending college there (Groen 2004, Sjoquist and Winters 2014, Winters 2020), state governments have a direct fiscal interest in attracting students to their university systems. Maintaining high enrollment levels is also inherently important to the prestige of public universities and to popular political support for higher-education budgets. Finally, an enrollment objective provides the most reasonable justification for tuition discrimination within resident student populations (e.g., states use merit scholarships because they value the quality that high achievers add to their student bodies, and probably not because high-achieving students' welfare is more important to them than lower-achieving students' welfare).

The objective function is a weighted sum because I allow states to have preferences for enrolling resident (relative to nonresident) and high-achieving (relative to low-achieving) students. Let $\alpha_r \geq 1$ and $\alpha_A > 1$ represent states' preferences for resident and high-achieving students, respectively. State s's enrollment objective is then

$$E_s \equiv \sum_{i \in \{H,L\}} \phi_i \alpha_A (\alpha_r p^{r,s}_{i,A} + p^{n,-s}_{i,A}) + (1-\phi_i)(\alpha_r p^{r,s}_{i,B} + p^{n,-s}_{i,B}). \tag{7}$$

Enrollment in state s is composed of s residents who choose to attend college at home (the $p^{r,s}_{i,g}$ choice probabilities) as well as $-s$ residents who choose to migrate (the $p^{n,-s}_{i,g}$ choice probabilities). The α_r and α_A weights reflect states' enrollment preferences by allowing resident and high-achieving students to contribute more heavily to the objective function.

Let c be the constant resource cost of educating a single student. I impose a budget constraint requiring each state – in expectation across all of the students enrolling in its university system – to recoup this cost through tuition receipts. Formally, state s must choose tuition prices to satisfy

$$B_s \equiv \sum_{i \in \{H,L\}} \phi_i \big[p^{r,s}_{i,A}(r^s_{i,A} - c) + p^{n,-s}_{i,A}(n^s_{i,A} - c)\big] + (1-\phi_i)\big[p^{r,s}_{i,B}(r^s_{i,B} - c) + p^{n,-s}_{i,B}(n^s_{i,B} - c)\big] = 0. \tag{8}$$

Again, the sum is taken over s residents choosing to attend college at home and $-s$ residents choosing to migrate. The state is free to subsidize or mark up individual tuition prices, but must break even by collecting average tuition revenue of c across its entire student body.

Combining the objective in (7) and the budget constraint in (8) gives the state's optimization problem. Each state s takes the other's tuition choices as given, then solves:

$$\max_{\{\{r_{i,g}^s\},\{n_{i,g}^s\}\}} \quad E_s$$
$$\text{s.t.}$$
$$B_s = 0. \tag{9}$$

In the two-state game, equilibrium occurs when the states choose tuition profiles that are mutual best responses. Restricting attention to the symmetric case where the states act identically, I can give the following formal definition of equilibrium:

Definition 1 *An equilibrium is a tuition profile* $\{\{r_{i,g}^{eq}\},\{n_{i,g}^{eq}\}\}$ *that solves the state optimization problem in (9), given that the opposing state is employing the same tuition profile.*

In defining the socially optimal tuition profile, I take the perspective of a national social planner who seeks to maximize aggregate college attendance, without any preference for enrollment in one state versus the other. I continue to assume, however, that the social planner has a preference for high-achieving enrollment, so the α_A parameter remains in the objective function. The social planner thus acts to maximize

$$E_{planner} \equiv \sum_{s\in\{E,W\}} \sum_{i\in\{H,L\}} \phi_i \alpha_A (p_{i,A}^{r,s} + p_{i,A}^{n,s}) + (1-\phi_i)(p_{i,B}^{r,s} + p_{i,B}^{n,s}). \tag{10}$$

The key difference between the states' objective in (7) and the social planner's objective in (10) is the presence of business-stealing incentives. Whereas each competing state perceives a benefit from increasing its enrollment at the expense of the other state's, the social planner – whose objective function sums enrollment across the two states – fully internalizes the resulting business-stealing externality and perceives no such benefit.

I subject the social planner to the same resource cost and budget constraint as the states, so the budget-balance condition is the same as in (8). The social planner's problem is thus to maximize aggregate achievement-weighted enrollment, with each state breaking even:

$$\max_{\{\{r_{i,g}\},\{n_{i,g}\}\}} \quad E_{planner}$$
$$\text{s.t.}$$
$$B_s = 0 \ \ \forall s \in \{E, W\}. \tag{11}$$

Again restricting attention to the symmetric case where the same tuition profile is employed in both states, I can define the social optimum as the solution to the planner's problem:

Definition 2 *The social optimum is the symmetric tuition profile* $\{\{r^*_{i,g}\},\{n^*_{i,g}\}\}$ *that solves the social planner's problem in (11).*

2.1.4 Parameter Assumptions

I make several parameter assumptions whose purpose and justification are worth discussing in more detail. First, by positing that $\alpha_r \geq 1$ and $\alpha_A > 1$, I assume that states have a weak preference for resident enrollment and a strict preference for high-achieving enrollment. The preference for resident enrollment reflects the fact that state-run public university systems are primarily financed by and operated for the benefit of the state's taxpayers, and accords with the empirical reality that public universities generally charge lower tuition for resident than nonresident students (Knight and Schiff, 2019). The $\alpha_r > 1$ case is thus realistic, but all theoretical results comparing equilibrium and socially optimal financial aid policy hold even in the empirically unrealistic case where $\alpha_r = 1$ and the states have the same (non-)preference for resident enrollment as the social planner.

The preference for high-achieving enrollment is more consequential, since $\alpha_A > 1$ is necessary to ensure that equilibrium merit aid is nonzero. But again, the $\alpha_A > 1$ assumption reflects empirical reality, since state and institutional merit aid programs are widespread. Institutions value the positive peer effects exerted by high-achieving students (Sacerdote 2001; Carrell, Fullerton, and West 2009; Cai and Heathcote 2022) and the boost they provide to closely-watched university rankings. State governments value the additional tax revenue generated by higher-skilled workforces, since high-achieving students earn higher expected wages and are more likely to live and work in their home state when induced by merit scholarships to stay home for college (see, e.g., Hickman 2009, Sjoquist and Winters 2014, and Harrington et al. 2016). High-achieving students also have higher graduation rates and are more likely to earn their degrees and realize the college wage premium, conditional on enrolling (Hendricks, Koreshkova, and Leukhina, 2018). By assuming that the social planner uses the same α_A weight to value high-achieving enrollment, I am able to isolate the distortionary role of competitive business-stealing incentives: interstate competition makes merit-based aid higher in equilibrium, not any a priori assumption that the states value high-achieving enrollment more than the social planner.

Second, I assume that high- and low-income students are distinguished by their tuition sensitivity, with $\beta_L > \beta_H$ and tuition imposing a larger utility cost for the low-income group. This assumption is intended as a reduced-form representation of credit or liquidity constraints that raise tuition sensitivity and depress college-attendance rates among students from lower-income households. Although there is some disagreement in the literature, a substantial body of prior work finds empirical evidence of credit constraints and a positive relationship between family income and college attendance that has strengthened over time (Belley and Lochner 2007, Kane 2007, Lochner and Monge-Naranjo 2011, Lovenheim 2011, Lochner and Monge-Naranjo 2012). The $\beta_L > \beta_H$ assumption reflects this empirical evidence and creates the scope for need-based financial aid within the model.

The assumption that $\beta_L > \beta_H$ is not, however, sufficient to guarantee that college-attendance rates are higher for high-income students in equilibrium. To ensure that the model reflects empirical reality and generates a positive relationship between income and college-attendance rates, I must also place a restriction on ψ, which controls the dispersion of students' idiosyncratic preference shocks.

Proposition 1 *Fix all other model parameters at arbitrary values (with $\beta_L > \beta_H$). There exists a $\bar{\psi}$ such that for all $\psi > \bar{\psi}$, all resident and nonresident enrollment values are strictly higher for high-income students in equilibrium, i.e.,*

$$p^r_{H,g} > p^r_{L,g}, \quad p^n_{H,g} > p^n_{L,g}, \quad \forall g \in \{A, B\}.$$

Conversely, for $\psi \leq \bar{\psi}$, $p^l_{H,g} \leq p^l_{L,g}$ for at least one combination of $g \in \{A, B\}$ and $l \in \{r, n\}$.

The proof of Proposition 1 is given in Appendix A.1. Intuitively, there are two competing forces determining the relative attendance rates of high- and low-income students. Since $\beta_L > \beta_H$, a tuition cut of a given size does more to increase low-income enrollment than high-income enrollment, so states are naturally incentivized to provide need-based aid and low-income students face lower tuition prices. These lower tuition prices tend to increase low-income enrollment relative to high-income enrollment. However, the fact that $\beta_L > \beta_H$ also mechanically implies that if high- and low-income students faced the same tuition prices, low-income students would have lower mean utility values and lower enrollment rates. The condition on ψ, by making the choice probabilities sufficiently responsive to tuition, ensures that states do not provide so much need-based aid that the first force outweighs the second.

For the remainder of this section, I maintain the empirically realistic assumption that high-income students have higher equilibrium attendance rates:

Assumption 1 *The dispersion parameter ψ is sufficiently large to ensure that in equilibrium, $p^r_{H,g} > p^r_{L,g}$ and $p^n_{H,g} > p^n_{L,g}$, $\forall g \in \{A, B\}$.*

2.2 Theoretical Results

2.2.1 Welfare Costs of Interstate Competition

I begin by establishing the model's primary result: competitive business-stealing incentives distort equilibrium state behavior away from socially optimal financial aid policy.

Proposition 2 *For any set of parameter values, there exists a unique equilibrium and a unique social optimum. Relative to the social optimum, the equilibrium features strictly lower need-based aid for both achievement types,*

$$r^{eq}_{H,g} - r^{eq}_{L,g} < r^*_{H,g} - r^*_{L,g} \ \ \forall g \in \{A, B\},$$

and strictly higher merit-based aid for both income types,

$$r^{eq}_{i,B} - r^{eq}_{i,A} > r^*_{i,B} - r^*_{i,A} \ \ \forall i \in \{H, L\}.$$

The proof of Proposition 2 is given in Appendix Sections A.2-A.4. The main intuition, which I summarize briefly here, comes from a simple comparison of the optimality conditions that govern competing states' and the social planner's tuition choices.

The expressions determining equilibrium and socially optimal need-based aid – obtained by taking first-order conditions in (9) and (11) – can be written, respectively, as:

$$r^{eq}_{H,g} - r^{eq}_{L,g} = \frac{1}{\psi}\left(\frac{1}{\beta_H(p^x_{H,g} + p^n_{H,g})} - \frac{1}{\beta_L(p^x_{L,g} + p^n_{L,g})}\right), \tag{12}$$

$$r^*_{H,g} - r^*_{L,g} = \frac{1}{\psi}\left(\frac{1}{\beta_H p^x_{H,g}} - \frac{1}{\beta_L p^x_{L,g}}\right). \tag{13}$$

In both (12) and (13), the left-hand side gives resident need-based aid for achievement group g. This is equated with an inverse-elasticity expression on the right-hand side: resident need-based aid is rationalized by the difference between L and H students' elasticities of resident enrollment with respect to tuition.

The competing states and social planner differ in the enrollment elasticities they use to compute optimal need-based aid. The tuition-sensitivity parameters β_i determine the responsiveness of enrollment to tuition, so they appear on the right-hand side of both expressions. But in (12), the β_i parameters multiply $p^x_{i,g} + p^n_{i,g}$, while in (13), the β_i parameters multiply only $p^x_{i,g}$. This difference in optimality conditions is intuitive. The competing states aim to increase resident enrollment by any means; an additional resident enrollee is always equally valuable, whether converted from non-attendance $p^x_{i,g}$ or drawn away from nonresident attendance $p^n_{i,g}$. When states assess the value of a marginal cut in resident tuition, the relevant pool of persuadable students is thus represented by the sum $p^x_{i,g} + p^n_{i,g}$ (and the logit error assumption ensures that the elasticity of resident enrollment with respect to resident tuition is exactly proportional to this sum).

The social planner, however, internalizes business-stealing effects and does not perceive a benefit from increasing one state's resident enrollment at the expense of the other's nonresident enrollment. The planner therefore does not count nonresident enrollees $p^n_{i,g}$ among the pool of persuadable students whose choices might be favorably changed by a cut in resident tuition. All tuition choices made by the planner are instead geared solely toward reducing the non-attendance rates $p^x_{i,g}$, which are the only choice probabilities appearing on the right-hand side of (13).

The business-stealing wedge between the right-hand sides of (12) and (13) ensures that need-based aid is lower in equilibrium than the social optimum. Because all equilibrium enrollment rates are higher for high-income students and $p^n_{H,g} > p^n_{L,g}$ (recall the discussion in Section 2.1.4), the effect of business-stealing incentives on equilibrium tuition is more consequential for H than for L students. Concretely, since $p^n_{H,g} > p^n_{L,g}$, the inclusion of nonresident enrollment rates in (12) increases the H elasticity relative to its counterpart in (13) more so than for the L elasticity. As a result, competing states have a weaker incentive to give relative tuition subsidies to L students than the social planner does, and resident need-based aid is strictly lower in equilibrium than in the social optimum.

The result for merit-based aid follows similar logic. Because $\alpha_A > 1$ and states have a strict preference for high-achieving enrollment, high-achieving students must face lower tuition rates in equilibrium, so $r_{i,A} < r_{i,B}$ and $n_{i,A} < n_{i,B}$. Since high- and low-achieving students in the same income group have the same tuition sensitivity, this in turn implies that high-achieving enrollment rates are higher, so $p^r_{i,A} > p^r_{i,B}$ and $p^n_{i,A} > p^n_{i,B}$. The fact that $p^n_{i,A} > p^n_{i,B}$ causes business-stealing incentives to be more pronounced for A than for B students, states give larger tuition subsidies to high achievers than the social planner does, and resident merit-based aid is strictly higher in equilibrium than in the social optimum.

The competitive distortions to equilibrium financial aid policy have social welfare costs, which are stated formally in the following corollary.

Corollary 1 *Achievement-weighted aggregate college enrollment (i.e., the social planner's objective function in (10)) is strictly lower in equilibrium than in the social optimum.*

Since the socially optimal tuition profile is unique and the equilibrium tuition profile is strictly different, the social planner's objective function must be strictly lower when evaluated at the equilibrium tuition values. By engaging in business stealing with no net social benefit, the states compete away some of the aggregate college enrollment that a national planner (facing the same budget constraint) would otherwise be able to achieve.

2.2.2 Empirically Testable Implications: Travel-Cost Comparative Statics

Since the socially optimal tuition profile is not observable, the statements in Proposition 2 cannot be directly tested. In order to generate empirically testable predictions that can be used to validate the model, I derive additional theoretical results about the relationship between equilibrium financial aid outcomes and the travel-cost parameter δ. The travel-cost comparative statics arise from the same business-stealing incentives that distinguish the competing states from the social planner, but since they refer only to equilibrium outcomes, they can be tested with financial aid data and empirical variation in measures of δ.

Proposition 3 *Equilibrium need-based aid (for both achievement types) is strictly increasing in δ,*

$$\frac{\partial}{\partial \delta}\left[r^{eq}_{H,g} - r^{eq}_{L,g}\right] > 0 \;\; \forall g \in \{A, B\},$$

and equilibrium merit-based aid (for both income types) is strictly decreasing in δ,

$$\frac{\partial}{\partial \delta}\left[r^{eq}_{i,B} - r^{eq}_{i,A}\right] < 0 \;\; \forall i \in \{H, L\}.$$

Furthermore, as $\delta \to \infty$, need- and merit-based aid approach their socially optimal values,

$$\lim_{\delta \to \infty}\left[(r^{eq}_{H,g} - r^{eq}_{L,g}) - (r^{*}_{H,g} - r^{*}_{L,g})\right] = 0 \;\; \forall g \in \{A, B\},$$
$$\lim_{\delta \to \infty}\left[(r^{eq}_{i,B} - r^{eq}_{i,A}) - (r^{*}_{i,B} - r^{*}_{i,A})\right] = 0 \;\; \forall i \in \{H, L\}.$$

The proof of Proposition 3 is given in Appendix Sections A.3-A.4. Again, the intuition comes from inspecting the optimality conditions governing states' tuition choices in equilibrium.

As δ increases, migration becomes less attractive and nonresident enrollment decreases. In the case of need-based aid, this causes both nonresident enrollment values $p^{n}_{H,g}$ and $p^{n}_{L,g}$ on the right-hand side of the equilibrium optimality condition in (12) to decrease. The reduction in nonresident enrollment, however, is larger for high-income students. To see why this is the case, consider the limiting behavior: the nonresident enrollment gap $p^{n}_{H,g} - p^{n}_{L,g}$ is always positive for any given δ, but as $\delta \to \infty$, migration becomes prohibitively costly and both nonresident enrollment terms (and thus their difference) go to zero. Since the nonresident enrollment gap is always positive but limits to zero, it must be shrinking as δ increases. The business-stealing incentives encapsulated in the $p^{n}_{i,g}$ terms thus decrease for both H and L students, but the magnitude of the change is larger for H students. An increase in δ therefore causes the H elasticity in (12) to decrease more than the L elasticity, states' incentive to give relative tuition subsidies to L students is strengthened, and need-based aid rises. And once again, using the fact that $p^{n}_{i,A} > p^{n}_{i,B}$ in equilibrium, similar logic establishes the result for merit-based aid: an increase in δ lowers business-stealing incentives more for A students than for B students, and merit-based aid falls as a result.

Proposition 3 can be viewed as a continuous version of the discrete comparison made in Proposition 2: since increases in δ narrow the $p^{n}_{H,g} - p^{n}_{L,g}$ and $p^{n}_{i,A} - p^{n}_{i,B}$ nonresident enrollment gaps, the differential business-stealing incentives that drive a wedge between equilibrium and socially optimal policy gradually disappear as δ grows. We should therefore expect equilibrium and socially optimal financial aid to converge in the limit; the last statement in Proposition 3 demonstrates that this is indeed the case. As $\delta \to \infty$, all nonresident enrollment rates $p^n_{i,g}$ go to 0 and business-stealing incentives disappear for the competing states. Each state makes tuition choices solely to maximize achievement-weighted enrollment among its own resident students, without any threat of outmigration. This is the same problem that the planner solves as $\delta \to \infty$ (one can verify that with all nonresident enrollment rates $p^n_{i,g}$ fixed at 0, the state and planner optimization problems in (9) and (11) exactly coincide). The states and planner thus make identical resident tuition choices, and all functions of the resident tuition prices (including need- and merit-based aid) become equal.

The final theoretical result, concerning the income progressivity of resident tuition defined in (3), is a corollary that follows directly from Propositions 2 and 3.

Corollary 2 *If ϕ_H is sufficiently large relative to ϕ_L, then the equilibrium income progressivity of tuition is strictly increasing in δ,*

$$\frac{\partial}{\partial \delta}\Big[\phi_H r^{eq}_{H,A} + (1-\phi_H) r^{eq}_{H,B} - \big[\phi_L r^{eq}_{L,A} + (1-\phi_L) r^{eq}_{L,B}\big]\Big] > 0.$$

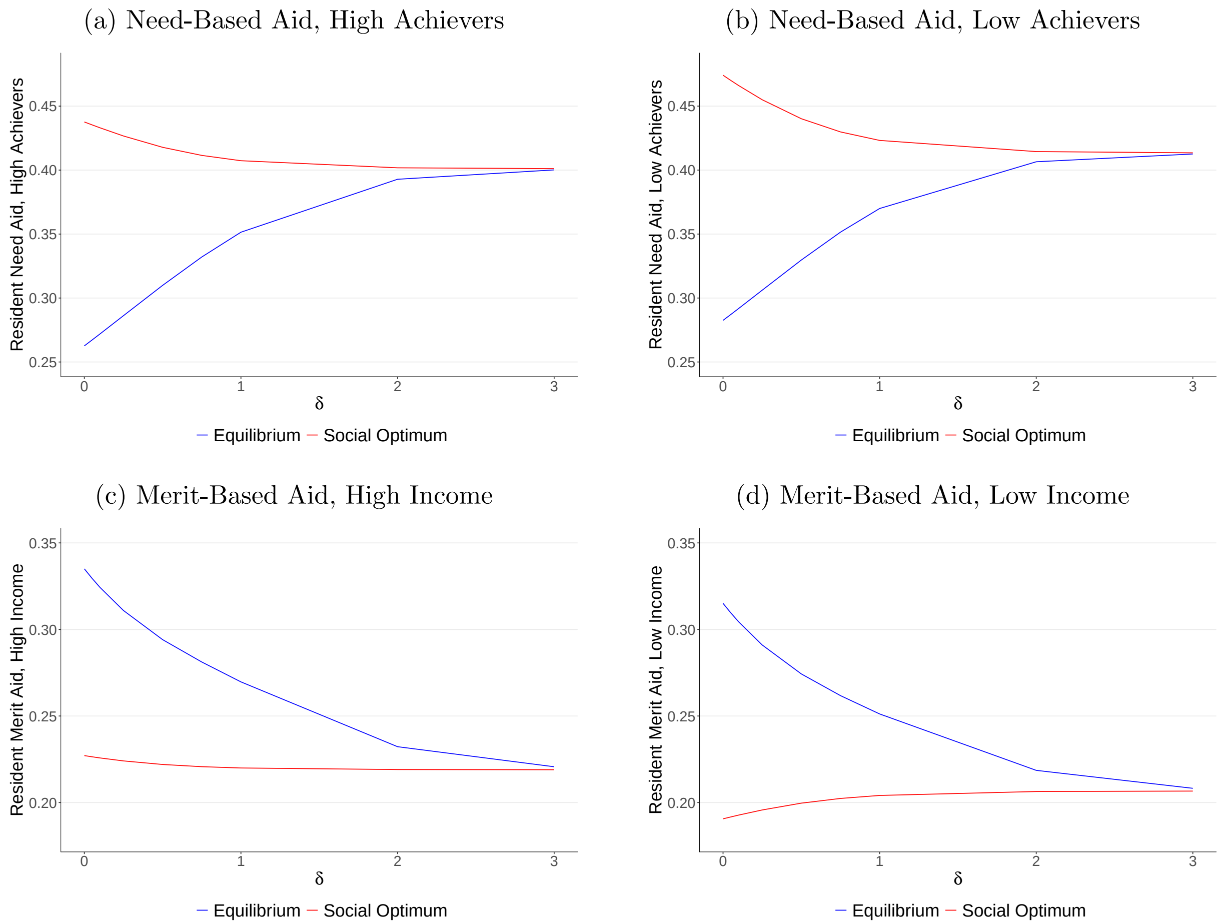
The proof of Corollary 2 is given in Appendix A.5. Given that equilibrium need-based aid is increasing in δ, it is reasonable to expect the overall income progressivity of tuition to be increasing in δ as well. But since merit-based aid (for both income groups) is decreasing in δ, the relationship between δ and the income progressivity of tuition is technically ambiguous: if the share of L students receiving merit-based aid is too large relative to the share of H students receiving merit-based aid, the decrease in merit-based aid could land most heavily on L students and cause average L tuition to rise relative to average H tuition. The condition that ϕ_H is sufficiently large relative to ϕ_L (recall that the ϕ_i parameters give the high-achieving share of income group i) rules out this possibility.

I do not derive explicit bounds on ϕ_H and ϕ_L that ensure Corollary 2 holds; I merely view the assumption that ϕ_H is large relative to ϕ_L as an empirically realistic condition that allows me to generate another testable prediction for the empirical analysis. The positive correlation between household income and academic achievement is well documented, and prior work has shown that rates of merit-based aid receipt are higher among high-income students (Price 2001; Ehrenberg, Zhang, and Levin 2006; Woo, Choy, and Weko 2011).[5]

Figure 1 gives a graphical depiction of the theoretical results established above. Using an illustrative set of parameter values, I solve numerically for the equilibrium and socially

[5]The positive correlation between income and merit-based aid receipt also holds in my NPSAS sample: the share of students with nonzero merit aid is monotonically increasing in household income quartile.

Figure 1: Equilibrium and Socially Optimal Financial Aid, as Functions of Travel Costs



Note: This figure shows numerical model results for the following set of illustrative parameter values: $\gamma = 1.5$, $\beta_H = 1$, $\beta_L = 1.5$, $\psi = 2.25$, $\phi_H = 0.3$, $\phi_L = 0.2$, $\alpha_r = 1.75$, $\alpha_A = 1.75$, $c = 1$. Note that since $c = 1$, the y-axis values can be interpreted as percentages of the resource cost of education.

optimal tuition profiles at a range of travel-cost values δ, then plot financial aid outcomes as functions of δ. At any given δ value, need-based aid is lower and merit-based aid is higher in the equilibrium than in the social optimum. As δ increases, the equilibrium outcomes change monotonically and gradually converge to the socially optimal values.

3 Financial Aid Allocation and Geography

The paper's empirical analysis aims to test the theoretical predictions contained in Proposition 3 and Corollary 2. When competing out-of-state institutions are more proximate or otherwise impose smaller travel costs on migrating students, public university systems should award less need-based and more merit-based funding, with overall aid distributions that are less progressive with respect to income.

The most natural interpretation of the travel-cost parameter δ is as physical distance. My primary empirical strategy is therefore to construct variables measuring the proximity of competing out-of-state public institutions to a given state's population centroid, then determine whether these proximity measures predict the allocation of financial aid among the state's resident students.

3.1 Identification

In regressing financial aid outcomes on physical proximity measures, the clear identifying assumption is that the geographic distance between state population centers and out-of-state public institutions is uncorrelated with unobservable factors affecting financial aid policy.

The assumption that geographic distance measures are orthogonal to time-varying unobservables is highly plausible. The number of public four-year institutions in the United States has remained very stable over time, with openings and closings of public universities representing rare occurrences.[6] The case of operating institutions changing their physical location from one year to the next appears to be even rarer.[7] The result is an essentially constant group of public four-year colleges whose locations are fixed during my sample period.

Time-invariant unobservables are a more relevant concern. Given the geographic layout of the United States, the distance measures I construct are strongly correlated with region: western states are geographically larger and tend to have longer distances separating state population centroids from out-of-state universities, while smaller eastern states tend to have population centers that are closer to competing out-of-state institutions. If there are regional characteristics – e.g., ideology and partisan control of state government, higher-education governance structures, the demographic makeup of student populations – that are relatively stable over time but affect financial aid policy, then these regional characteristics would load onto the estimated effects of my geographic distance measures.

My primary identification solution is to divide the United States into regional higher-education markets, define the geographic distance measures within those regional markets, and include region fixed effects in my regression specifications. The effect of distance on financial aid allocation is then identified by variation in the proximity of competing out-of-state institutions, among states within the same regional market. To split the country into regional markets, I use the eight-region division established by the Bureau of Economic

[6] According to the 2016 Digest of Education Statistics, a total of six public four-year institutions closed between 1970 and 2016. During my sample period of 1993-2016, the total number of public four-year institutions increased from 600 to 710, though the NCES notes that this increase is partly due to an increase in the number of institutions reporting separate data for their branch campuses (without the actual opening of new branch campuses).

[7] In the Digest of Education Statistics and other NCES publications, I could not find any documentation of or statistics regarding location changes of (public or private) four-year institutions. I take this lack of information as an indication that such cases are exceedingly rare.

Analysis (BEA).[8] The National Center for Education Statistics itself uses the BEA definitions when reporting institution region in the NPSAS data, and similar regional divisions have been used to define higher-education markets in prior work.[9]

3.2 Data and Regression Specifications

3.2.1 Data

I implement my empirical strategy with the National Postsecondary Student Aid Study (NPSAS), a repeated, nationally representative survey conducted by the National Center for Education Statistics (an office of the federal Department of Education). The survey collects data from students across the American higher education system – undergraduates and graduates, public and private institutions, two-year and four-year institutions – once every four years. To maximize the sample size and introduce temporal variation, I use data from the 1993, 1996, 2000, 2004, 2008, 2012, and 2016 survey years. Because the model developed above describes the behavior of state-run public university systems and its primary theoretical predictions concern the allocation of financial aid to resident students, I restrict the NPSAS data to resident students enrolled at public four-year institutions. The full sample is comprised of about 174,000 students,[10] who are distributed roughly evenly over the survey years. Appendix Table B1 provides summary statistics for the NPSAS sample.

3.2.2 The Merit-Need Allocation of Aid

I employ two sets of regression specifications. The first set determines whether geographic distance measures (to be defined formally below) predict the allocation of resident financial aid between merit- and need-based grants. These specifications take the form

$$y_{it} = \beta g_{s(i)t} + \theta x'_{it} + \eta_r + \tau_t + \epsilon_{it}, \tag{14}$$

where i indexes resident students, $s(i)$ is the state of i's institution, and t indexes time (i.e., survey years of the NPSAS data). The independent variable of interest is $g_{s(i)t}$, which stands for one of the geographic distance measures. The specification includes fixed effects

[8] The eight BEA regions are: New England (CT, ME, MA, NH, RI, VT), Mideast (DE, MD, NJ, NY, PA), Great Lakes (IL, IN, MI, OH, WI), Plains (IA, KS, MN, MO, NE, ND, SD), Southeast (AL, AR, FL, GA, KY, LA, MS, NC, SC, TN, VA, WV), Southwest (AZ, NM, OK, TX), Rocky Mountains (CO, ID, MT, UT, WY), and Far West (AK, CA, HI, NV, OR, WA). In my geographic analysis, I drop students in Alaska and Hawaii and consider only the continental United States.

[9] Carneiro and Lee (2011) use a very similar nine-region division (established by the Census Bureau) when studying studying the effect of college-attendance rates on the college wage premium at the region level.

[10] The survey design gathers data from many students at each sampled institution (an average of about 70 to 100, depending on the survey year), so there are more students than institutions represented in the data.

for BEA regions η_r and NPSAS survey years τ_t. Ideally, the x_{it} vector would include controls for students' household income[11] and ACT/SAT scores[12] (the best measure of pre-college achievement available in the NPSAS) in order to mirror the model's theoretical predictions: merit-based aid is decreasing in travel costs for any given income category, and need-based aid is increasing in travel costs for any given achievement category. However, since standardized test scores are missing for many students, controlling for achievement would substantially reduce the sample size. I therefore control only for household income in the baseline analysis, but consider a robustness specification that includes an achievement control with a smaller sample.

As the dependent variable y_{it} in (14), I use several financial aid measures: an indicator for receiving merit-based aid, an indicator for receiving need-based aid, merit-based aid as a share of the student's cost of attendance (COA), need-based aid as a share of COA, and merit-based aid as a share of total (merit-based plus need-based) grant aid. The estimated β coefficients from (14) then provide a test of the predictions contained in Proposition 3: do resident students receive more merit-based and less need-based aid when competing out-of-state institutions are closer to their state's population center?

Because I view the model as capable of describing the financial aid allocation decisions of both state governments and individual institutions within state university systems,[13] I sum grant aid from state and institutional sources when computing y_{it} values in (14). Since the model's business-stealing incentives do not apply to national entities without vested interests in students' location decisions, I omit grant aid from federal sources (e.g., Pell Grants).[14] When measuring financial aid in relative terms, I divide by students' total COA – which is reported in the NPSAS data and includes tuition and fees, room and board, books and supplies, and other expenses budgeted by students' institutions – rather than tuition and fees alone. I do this because aid packages may compensate students for their total COA, so the reported COA values are the relevant upper bound on grant aid and provide a more accurate cost-normalized measure of students' aid awards.

[11]For dependent students, I define household income as the combined income of the students' parents; for independent students, I define household income as the combined income of the student and his/her spouse.

[12]For students who took the ACT, I use their score directly. For students who took the SAT, I convert their score to an ACT equivalent using official conversion tables.

[13]To the extent that intra-state competition exists, including institutional grants in my financial aid measures would only make it more difficult to verify my hypotheses (since the institutional component of grant aid would respond to the proximity of *all* institutions, and not just the out-of-state institutions I include in my geographic distance measures). Tables B8-B9 also show that the travel-cost comparative statics continue to hold when ignoring state grants and considering aid *only* from institutional sources.

[14]Since federal grant eligibility does not depend on students' state of residence or the location of their institution, the regression specifications in (14)-(15) would be fundamentally incapable of explaining cross-sectional variation in federal aid awards.

3.2.3 The Income Progressivity of Aid

The second set of regressions analyzes the overall income progressivity of financial aid awards. The essential content of the travel-cost comparative statics is that heightened geographic competition leads state universities to shift aid dollars from students on the college-attendance margin (who are low-income) toward students on the migration margin (who, because income increases enrollment both directly and indirectly through its correlation with achievement, are higher-income). An alternative empirical test is therefore to be agnostic about the binary merit-versus-need labeling of scholarships (thereby eliminating any noise from cross-state differences in labeling conventions), and simply determine whether heightened competition moves aid dollars from low- toward high-income students.

To measure the income distribution of financial aid, I define region- and survey-year-specific household income quartiles.[15] Let I_{it}^q be an indicator equal to 1 if student i belongs to regional household income quartile q in year t (with quartile 1 defined as the lowest). The second set of regression specifications then takes the form

$$y_{it} = \gamma_1 + \sum_{q=2}^{4} \gamma_q I_{it}^q + \beta_1 g_{s(i)t} + \sum_{q=2}^{4} \beta_q g_{s(i)t} I_{it}^q + \eta_r + \tau_t + \epsilon_{it}, \tag{15}$$

where η_r and τ_t are again region and survey-year fixed effects. The coefficients of interest are β_q, which allow the effect of the distance measure $g_{s(i)t}$ on the dependent variable to differ by income quartile (with the lowest quartile as the omitted group).

As the dependent variable y_{it} in (15), I use three measures of grant aid. The first is simply the summed dollar amount of all need- and merit-based grants from state and institutional sources. The second gives the summed grant amount net of demonstrated need, which is the difference between the student's COA and expected family contribution (EFC):[16]

$$\text{Grant Aid Net of Demonstrated Need} \equiv \text{Total Grant Aid} - (\text{COA} - \text{EFC}). \tag{16}$$

Finally, the third dependent variable is the summed grant amount divided by the student's COA. The regression specifications in (15) thus test the prediction of Corollary 2: does the overall distribution of grant aid to resident students – whether measured in raw dollars, relative to demonstrated need, or as a share of COA – become less progressive when competing out-of-state institutions are closer to the relevant state's population center?

[15] Ideally, I would define the income quartiles at the state-year level, but some state-year cells are too small to do this reliably.

[16] EFC values – computed with a uniform formula established by federal law – give the dollar amount that students' families can reasonably be expected to contribute toward college costs. They are reported directly in the NPSAS, so I do not need to compute them myself.

3.3 Geographic Distance Measures

For use as the main independent variable $g_{s(i)t}$ in (14)-(15), I construct three alternative measures of geographic proximity to out-of-state institutions. Each is defined at the state-survey-year level and in reference to the BEA region divisions. Let $U_t(s)$ be the set of public four-year universities in state s's regional market in year t, excluding institutions in state s itself. Additionally, let c_{st} be the location of state s's population centroid in year t, l_u be the location of university u, and e_{ut_0} be the total undergraduate enrollment of university u in the year just before the start of my sample period ($t_0 = 1992$). Finally, let $d(\cdot, \cdot)$ be a function returning the distance between its two arguments.[17]

The first state-specific geographic proximity measure I define is the enrollment-weighted average distance to regional competitors:

$$\text{Average Distance}_{st} \equiv \frac{\sum_{u \in U_t(s)} e_{ut_0} \cdot d(c_{st}, l_u)}{\sum_{u \in U_t(s)} e_{ut_0}}. \tag{17}$$

Larger values of of (17) indicate that the residents of state s have longer distances to travel to out-of-state institutions in their region. It is important to weight institutions by size when computing this average, since bigger schools with larger student bodies are more likely to attract migrating students and pose a greater competitive threat. I therefore weight schools by their total undergraduate enrollment, but fix the enrollment weights at the beginning of my sample period so that they are not endogenous to universities' financial aid policies. I also show that the empirical results continue to hold when ignoring enrollment sizes and giving all competing institutions equal weight.

The second measure is computed using the same formula as (17), but sums only over flagship institutions in state s's region:

$$\text{Average Flagship Distance}_{st} \equiv \frac{\sum_{u \in U_t^f(s)} e_{ut_0} \cdot d(c_{st}, l_u)}{\sum_{u \in U_t^f(s)} e_{ut_0}}, \tag{18}$$

where $U_t^f(s)$ is the set of flagship public universities[18] in state s's region (excluding state s's own flagship university). To the extent that migrating students are disproportionately drawn to prestigious flagship universities, the measure in (18) more precisely captures the

[17] I use the Integrated Postsecondary Education Data System (IPEDS) to obtain institutions' longitude-latitude coordinates and undergraduate enrollment totals. The coordinates of state population centroids come from the Census Bureau's decennial estimates. I use the 1990 centroids for the 1993 and 1996 NPSAS surveys; the 2000 centroids for the 2000, 2004, and 2008 surveys; and the 2010 centroids for the 2012 and 2016 surveys.

[18] A state's flagship university is the most prestigious public four-year institution in the state (usually the main campus of the state's largest university system). I use the list of flagship institutions in Mugglestone, Dancy, and Voight (2019).

average travel distances to those institutions for state s residents.

With the third and final distance measure, I aim to capture the density of competing out-of-state institutions in a smaller geographic band around state s (rather than averaging over the full set of out-of-state institutions in state s's region). To do so, I simply sum the the undergraduate enrollment at regional competitors within a strict distance cutoff around state s's population centroid,

$$\text{Enrollment Within } D \text{ Miles}_{st} \equiv \sum_{u \in U_t(s)} \mathbf{1}\{d(c_{st}, l_u) \leq D\} \cdot e_{ut_0}. \tag{19}$$

I use a distance cutoff of $D = 500$ miles in my baseline specifications, but examine robustness to other cutoffs as well. If the threat of student outmigration is not uniform throughout state s's region and is instead larger at the closest regional competitors, then the enrollment-proximity measure in (19) may provide a more accurate gauge of interstate competition than the comprehensive average-distance measures in (17)-(18).[19]

Given these definitions, we can see what gives rise to within-region variation in the geographic distance measures. States that are geographically smaller than others in their region (with shorter distances between their population centroids and borders) tend to have average-distance values in (17)-(18) below their region average, and enrollment-proximity values in (19) above their region average. This is also the case for states that are centrally located within their BEA region (rather than bordering a body of water or otherwise being on the periphery of the region). Finally, since the enrollment-proximity measure is a sum rather than an average, it also correlates with states' enrollment sizes. States with smaller shares of regional enrollment necessarily have neighbors with higher shares of regional enrollment, and therefore tend to have enrollment-proximity measures above their region average.

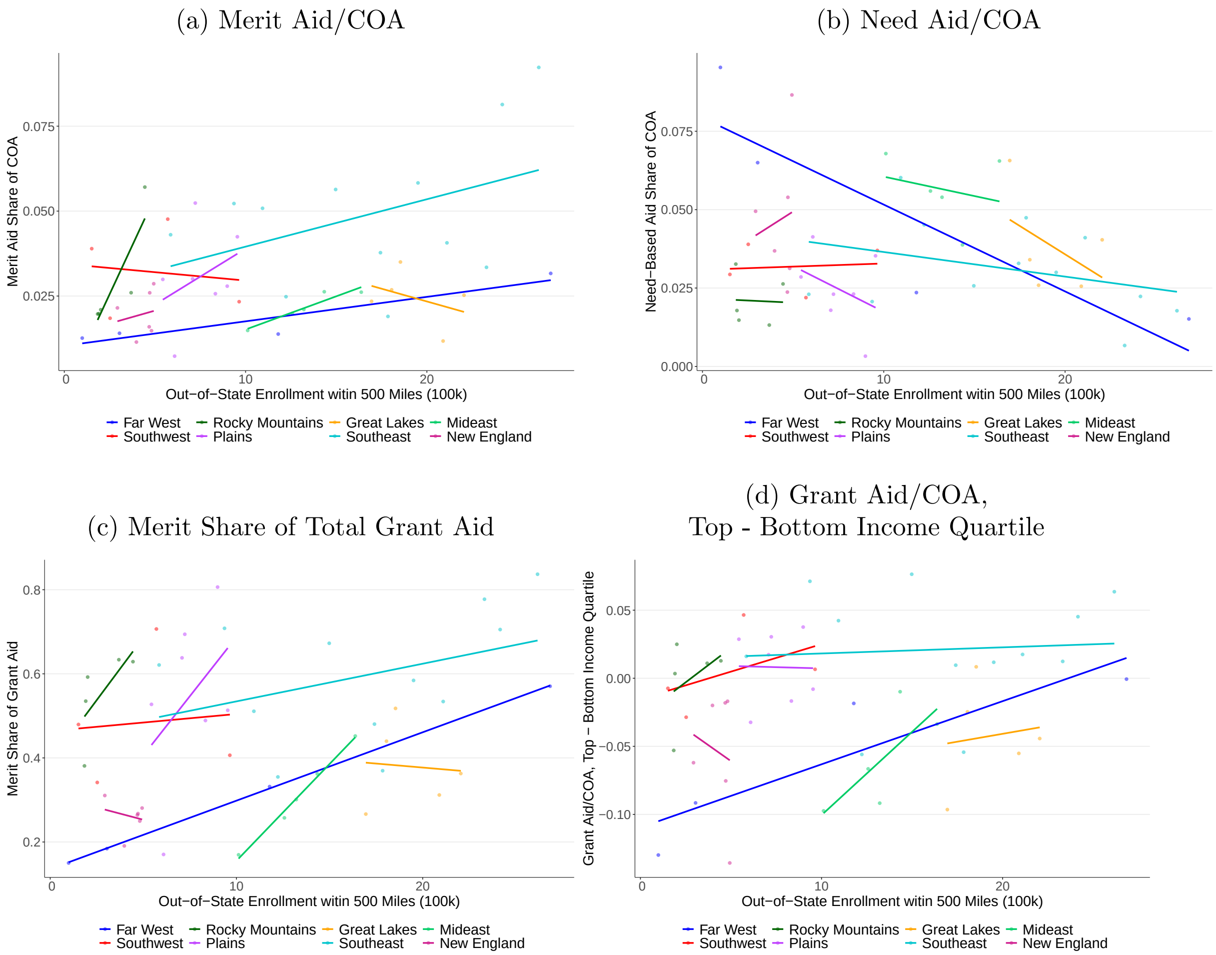
3.4 Results

3.4.1 Main Results

Figure 2 gives a graphical depiction of the identification strategy and foreshadows the regression results. Each point in the scatter plots represents a state-level average taken over all resident students in all NPSAS survey years. The x-axis shows the enrollment-within-500-miles measure, and the y-axes show financial aid outcomes of interest. Separate linear

[19] Here in particular it is worth noting that any endogeneity of the enrollment weights (despite their being fixed at the beginning of the sample period) would work against my hypotheses. Suppose a state chooses an aid allocation that is tilted less toward merit-based grants and more toward need-based grants, thereby inducing more high-income and high-achieving students to leave the state and increasing the out-of-state enrollment weights in (19). This would tend to establish a negative relationship between the enrollment-proximity measure and the merit share of financial aid, while I hypothesize a positive relationship.

Figure 2: Proximity to Out-of-State Institutions and Financial Aid Allocation



Note: Each point in these scatter plots represents a state-level average, taken over all resident students in all NPSAS survey years. The x-axis shows the enrollment-proximity measure defined in Section 3.3. The y-axes show the financial aid measures defined in Section 3.2. Separate linear best-fit lines are shown for each BEA region, extending only as far as the corresponding region's range of x-axis values.

best-fit lines are drawn for each BEA region (with each line extending only as far as the corresponding region's range of x-axis values). There is substantial intra-region variation in measured interstate competition, and the model's theoretical predictions generally appear to hold. States with enrollment proximity above their region average tend to award more merit-based aid as a share of COA, less need-based aid as a share of COA, more merit-based aid as a share of total grant aid, and more total grant aid to high-income students relative to low-income students. Some lines are flat or wrongly sloped, but they tend to be for regions with relatively small amounts of variation in the enrollment-proximity measure (and therefore receive relatively less weight in the regressions).

Tables 1 and 2 give the full set of formal regression results. The specifications based on (14), which relate the geographic distance measures to the allocation of aid between

Table 1: Proximity to Out-of-State Institutions and the Merit-Need Allocation of Financial Aid

	Nonzero Merit	Merit/ COA	Nonzero Need	Need/ COA	Merit Share of Grant Aid
	(1)	(2)	(3)	(4)	(5)
Panel A:					
Enrollment within 500 Miles	0.035***	0.010***	-0.031***	-0.008***	0.076***
(S.D.: 775,952)	(0.013)	(0.004)	(0.007)	(0.002)	(0.017)
Panel B:					
Avg. Distance	-0.051***	-0.014***	0.027**	0.008**	-0.099***
(S.D.: 196.88)	(0.019)	(0.005)	(0.012)	(0.003)	(0.027)
Panel C:					
Avg. Flagship Distance	-0.031**	-0.009**	0.024**	0.007**	-0.061***
(S.D.: 185.26)	(0.015)	(0.004)	(0.010)	(0.003)	(0.021)
Mean Dep. Var.	0.145	0.030	0.238	0.042	0.361
Observations	171,980	153,220	171,980	153,220	58,390

Note: Each panel shows a separate set of regressions for the corresponding distance measure. Only resident students at public institutions are included, and institutions in Alaska and Hawaii are omitted. All specifications include region and survey-year fixed effects, as well as controls for household income quartiles. Standard errors are clustered by institution and are shown in parentheses; asterisks indicate statistical significance at p-values of 0.1, 0.05, and 0.01. For readability and ease of interpretation, all coefficient estimates and standard errors are multiplied by the standard deviation of the corresponding distance measure, so that they represent the effect of a one-standard-deviation increase in that measure. These standard deviations are reported on the left-hand side of each panel. See Sections 3.2 and 3.3 for variable definitions.

merit- and need-based grants, are shown in Table 1. Each panel represents a separate set of regressions for one of the three geographic distance measures. For readability and ease of interpretation, I scale the reported coefficients and standard errors so that they represent the effect of a one-standard-deviation increase in the relevant geographic distance measure.

The coefficient estimates in Table 1 provide strong evidence in support of the model's predictions. All coefficient estimates have the predicted sign, and all are statistically significant at the 5% level. Because the enrollment-within-500-miles measure is larger when the degree of proximate interstate competition is higher, it displays positive relationships with the nonzero-merit, merit/COA, and merit-share-of-grant-aid outcomes, and negative relationships with the nonzero-need and need/COA outcomes. Conversely, because the average-distance and average-flagship-distance measures are larger when competing out-of-state institutions are *futher away* from the relevant state's population center, they display negative relationships with the merit outcomes and positive relationships with the need outcomes.

The estimated relationships in Table 1 are economically meaningful as well as statistically significant. A one-standard-deviation increase in the enrollment-proximity measure increases the probability of merit-based aid receipt by 3.5 percentage points and decreases the probability of need-based aid receipt by 3.1 percentage points. These magnitudes are large both in isolation and when considered relative to the sample means of the dependent variables (with the merit effect representing 24% of the baseline rate of merit-based aid receipt, and the need effect representing 13% of the baseline rate of need-based aid receipt). The same one-standard-deviation increase in the enrollment-proximity measure also corresponds to a 1.0 percentage point increase in merit-based aid as a share of COA and a 0.8 percentage point decrease in need-based aid as a share of COA (representing proportional effects of 33% and 19% relative to baseline averages, respectively). Given that increases in enrollment proximity predict greater use of merit-based aid and less use of need-based aid, the relationship with the merit share of total grant aid is also strong: a one-standard-deviation increase raises this share by 7.6 percentage points (a proportional effect of 21% relative to the baseline average). The average-distance measure produces estimated coefficients with magnitudes similar to those produced by the enrollment-proximity measure, though its effects on merit outcomes are slightly larger and its effects on need outcomes are slightly smaller. Finally, the average-flagship-distance measure produces coefficients that, though slightly smaller in magnitude, are generally comparable with the the rest of Table 1.

The specifications based on (15), which relate geographic distance measures to the overall income progressivity of financial aid, are shown in Table 2. Again, each panel represents a separate set of regressions for one of the three distance measures, and all coefficients and standard errors are scaled by the standard deviation of the corresponding measure. The interaction coefficients can thus be interpreted as the effect of a one-standard-deviation increase in the independent variable on the difference in outcomes between the relevant income quartile and the lowest income quartile.

The estimates in Table 2 are again largely consistent with the model's predictions. When heightened proximity of competing out-of-state institutions increases the use of merit-based aid and decreases the use of need-based aid, the overall distribution of grant aid becomes less progressive with respect to income. This result can be seen most clearly for the enrollment-within-500-miles measure. Nearly all interaction coefficients in the top panel are positive and statistically significant, indicating that when out-of-state institutions are more proximate, each of the top three income quartiles receives more grant aid relative to the bottom quartile. The magnitudes of the interaction coefficients also increase from the second quartile to the fourth, meaning that the increase in grant aid is largest for the highest-income students. Concretely, a one-standard-deviation increase in the enrollment-proximity measure raises total grant aid for the top income quartile by $419 relative to the bottom quartile (a proportional effect of 31% relative to the sample's average grant aid award). When adjusting

Table 2: Proximity to Out-of-State Institutions and the Income Progressivity of Financial Aid

	Grant Aid	Grant Aid Net of Demonstrated Need	Grant Aid/COA
	(1)	(2)	(3)
Panel A:			
Enrollment within 500 Miles	-72.43	-583.51***	-0.006
(S.D.: 775,952)	(80.02)	(200.80)	(0.004)
* Income Quartile 2	16.80	291.89***	0.001
	(37.16)	(107.35)	(0.002)
* Income Quartile 3	178.00***	669.79***	0.009***
	(45.77)	(129.12)	(0.002)
* Income Quartile 4	418.71***	619.92***	0.020***
(highest)	(71.09)	(167.47)	(0.004)
Panel B:			
Avg. Distance	-160.37	233.97	-0.009
(S.D.: 196.88)	(129.49)	(273.52)	(0.006)
* Income Quartile 2	83.27**	-391.59***	0.003**
	(35.06)	(100.54)	(0.002)
* Income Quartile 3	110.73**	-425.55***	0.007***
	(44.39)	(140.35)	(0.002)
* Income Quartile 4	-47.99	-66.95	0.000
(highest)	(77.14)	(177.70)	(0.004)
Panel C:			
Avg. Flagship Distance	-101.74	573.69**	-0.005
(S.D.: 185.26)	(120.88)	(239.44)	(0.006)
* Income Quartile 2	76.25**	-387.76***	0.003*
	(35.94)	(101.25)	(0.002)
* Income Quartile 3	123.37***	-443.34***	0.008***
	(42.62)	(143.23)	(0.002)
* Income Quartile 4	-10.99	-134.62	0.002
(highest)	(77.19)	(182.15)	(0.004)
Mean Dep. Var.	1,370	-8,108	0.072
Observations	171,980	152,300	153,220

Note: Each panel shows a separate set of regressions for the corresponding distance measure. Only resident students at public institutions are included, and institutions in Alaska and Hawaii are omitted. Grant aid values are in 2016 dollars. All specifications include region and survey-year fixed effects. Standard errors are clustered by institution and are shown in parentheses; asterisks indicate statistical significance at p-values of 0.1, 0.05, and 0.01. For readability and ease of interpretation, all coefficient estimates and standard errors are multiplied by the standard deviation of the corresponding distance measure, so that they represent the effect of a one-standard-deviation increase in that measure. These standard deviations are reported on the left-hand side of each panel. See Sections 3.2 and 3.3 for variable definitions.

grant aid for demonstrated need, the same one-standard-deviation increase raises aid for the top quartile by $620 relative to the bottom quartile; when measuring aid as a share of COA, the effect is equal to 2 percentage points (a proportional effect of 28% relative to the average).

The coefficient magnitudes in the top panel of Table 2 are also meaningful when considered relative to prior research estimating the effect of tuition subsidies on four-year college enrollment. This literature (including Dynarski 2000; Dynarski 2003; Kane 2003; Cornwell, Mustard, and Sridhar 2006; Castleman and Long 2016; and Angrist, Autor, and Pallais 2020) generally finds that quasi-experimental increases in grant aid at public universities produce substantial changes in enrollment rates, particularly for low-income students and other populations with low baseline rates of college attendance. Deming and Dynarski (2009) summarize these studies by stating, "the best estimates suggest that eligibility for $1,000 of subsidy increases college attendance rates by roughly 4 percentage points." Given that a one-standard-deviation increase in the enrollment-proximity measure raises grant aid for the top relative to the bottom quartile by $419 in raw terms or $620 in need-adjusted terms, empirically observed variation in interstate competition appears capable of widening enrollment gaps between high- and low-income students by roughly 2 percentage points.

The results for the average-distance measures in the bottom two panels of Table 2 are more mixed. With need-adjusted grant aid as the dependent variable, the interaction coefficients have the expected negative sign (out-of-state institutions being further away causes high-income students to receive relatively less aid and makes the distribution *more* progressive) and are mostly significant. However, with raw grant aid and grant aid as a share of COA as the dependent variables, the interaction coefficients move toward zero, and some even flip sign and become positive (though they remain relatively small in magnitude).

Taken together, the regression results in Tables 1 and 2 tell a coherent story that confirms the model's theoretical predictions. When competing out-of-state institutions are closer to state population centers, resident students receive less need-based aid and more merit-based aid. Notwithstanding a few mixed results in Table 2, most of the evidence shows that the shift from need-based to merit-based funding causes the overall distribution of grant aid from state and institutional sources to become less progressive with respect to income.

3.4.2 Falsification

To strengthen the conclusions of the main regression analysis above, I conduct two falsification tests. First, I rerun the specifications shown in Tables 1-2, but after redefining the geographic distance measures to include in-state institutions (i.e, with the summations in (17)-(19) taken over *all* public institutions in state s's region, including those in state s itself). Because states' enrollment objective functions suffer a loss only when resident students decide to migrate across state lines, the distance between a representative student and in-state universities should not (conditional on the spatial distribution of out-of-state schools) affect aid policy. Accounting for in-state schools when constructing the geographic distance measures should therefore weaken their relationship with the allocation of resident financial aid. Such a falsification result would also provide evidence that time-invariant unobservables are not driving the baseline estimates: if financial aid policy were simply correlated with unobserved factors that covary with the local density of four-year colleges, it is not clear why the spatial distribution of nearby *out*-of-state institutions should be much better at predicting aid outcomes than that of *in*-state institutions. Tables B2-B3 demonstrate that accounting for in-state institutions does indeed nullify the results; even the average-flagship-distance coefficients (which cannot change too much from the baseline analysis, since there is only one in-state flagship campus to account for) are noticeably attenuated.

As a second falsification test, I repeat the analysis in Tables 1-2, but with an alternative sample of resident students at private four-year institutions (recall that the main specifications limit to resident students at public universities). The relevant competitors for a private institution likely differ from the set of regional public universities that the summations in (17)-(19) consider. Private schools tend to draw students from wider geographic ranges and compete at a national level against other private schools with similar characteristics (e.g., Stanford competes more heavily with the University of Chicago than does the University of Wisconsin-Madison). The tradeoff between merit- and need-based aid may also be less relevant for selective private institutions who do not need to rely as heavily on merit scholarships to attract high-achieving students. Tables B4-B5 show that the model predictions indeed fail to hold for students at private schools (in Table B4, there is some evidence that private institutions award more aid of *all* types when regional public competitors are more proximate, but there is no discernible relationship with the merit-need allocation of aid).

3.4.3 Robustness

I also consider the robustness of the baseline results to reasonable changes in empirical methodology. First, as discussed above, I sum grants from state and institutional sources when defining my financial aid outcomes. Tables B6-B9 show that the baseline results generally hold when considering state and institutional aid separately, and in fact that institutional grants are slightly more responsive to the geographic distance measures than state grants.

Next, recall that I control for time-invariant regional characteristics by including region fixed effects in the regression specifications. To mirror the regional market definitions that are embedded in these fixed effects, I define the geographic distance measures with respect to the same BEA region boundaries (i.e., with the summations in (17)-(19) taken over out-of-state public institutions in the same BEA region as state s). Aside from the symmetry with the fixed-effect definitions, there are institutional reasons – overlapping boundaries of tuition reciprocity agreements and collegiate athletic conferences, cultural and political similarities – that the BEA region boundaries capture the most relevant set of competing institutions for a given state university system.[20] However, another reasonable definition for a given state's relevant geographic market would simply be the set of contiguous bordering states, regardless of whether they fall within the same BEA region. Tables B11-B12 show that the results generally continue to hold when redefining the geographic distance measures to sum over institutions in neighboring states. A final approach to the market-definition problem would be to use observed migration flows, i.e., labeling state s's competitors as those who enroll the largest numbers of nonresident students from state s. Empirical migration patterns are themselves equilibrium objects, but it is nonetheless reassuring that most of the results persist in Tables B13-B14, which define state s's market as the five states that draw the most migrating students from state s.[21]

Lastly, I consider other methodological adjustments to the geographic distance measures. The measures in the baseline analysis are defined relative to states' population centroids, since this treatment gives the best representation of resident students' average travel costs. However, it is reasonable to expect that the locations of individual institutions also matter, and defining institution-level measures introduces more granular variation. Tables B15-B16 show that the results generally persist when using institution-specific distance measures. Tables B17-B22 show that the results continue to hold when redefining the distance measures to include private institutions in the relevant regional market, to use simple rather than enrollment-weighted averages, and to use alternative proximity cutoffs of 300 and 700 miles.

4 Aid Allocation and Time-Varying Competition

Geography is a natural starting point for the empirical measurement of travel costs but is also limiting, since its mostly static nature prevents me from analyzing changes in aid policy over time. An alternative approach is to study a time-varying factor that makes migrating more or less costly for students. I can then control for state (rather than region) fixed effects and determine whether the predictions in Proposition 3 and Corollary 2 correctly describe how a given university system behaves over time as the degree of competition fluctuates. To complement the geographic analysis and provide more robust evidence in support of the model, I now consider annual university rankings as a time-varying source of competition.

[20] Furthermore, if the BEA regions were arbitrary and did not capture relevant competing institutions, accounting for region boundaries would simply introduce attenuation bias.

[21] Based on IPEDS enrollment data for public four-year institutions between 1992 and 2016.

4.1 USNWR Rankings

U.S. News and World Report (USNWR) rankings generate variation in interstate competition by changing (or reflecting changes in) the institutional quality of students' out-of-state options. When out-of-state competitors receive higher rankings, students have a greater incentive to migrate and attend college away from home. Constructing statistics that aggregate the rankings of regional competitors thus permits a final set of empirical tests: higher USNWR rankings of institutions in state s's region should correlate with more merit-based aid, less need-based aid, and less progressive overall grant aid for resident students in state s.

Researchers and higher-education officials have often questioned the accuracy of the USNWR rankings. However, despite their imperfections, the rankings clearly influence students' application and enrollment decisions: empirical work has explicitly shown that improved rankings cause increases in applications, yield, and enrolled students' standardized test scores (Griffith and Rask 2007, Bowman and Bastedo 2009, Luca and Smith 2013). Because I am interested in time-varying factors that change students' willingness to travel out of state for college, the perceived authority of the USNWR rankings and their influence on student choices are actually more important for my purposes than their accuracy.

I define two measures of regional USNWR rankings for use in the regression analysis. The first measure captures the quantity of top-tier regional competitors by simply counting the public institutions ranked among the top 100 in USNWR's national universities category:

$$\text{Top-100 USNWR Institutions}_{st} \equiv \sum_{u \in U_t(s)} \mathbf{1}\{\text{rank}_{ut} \leq 100\}, \tag{20}$$

where s again indexes states, $U_t(s)$ is again the set of public four-year universities in state s's region in year t (excluding institutions in state s itself), and rank_{ut} is the USNWR ranking for university u in year t. The second measure gives a more precise accounting of regional competitors' place within the USNWR rankings. To construct this measure, define a linear scale (referred to as ranking "points") with larger values corresponding to better rankings: $\text{points}_{ut} \equiv 271 - \text{rank}_{ut}$. The 271 term appears because 270 is the lowest observed ranking for a public four-year university during the sample period; a university ranked at the very bottom of the list is thus assigned 1 ranking point and the top-ranked university receives 270 ranking points. Unranked universities receive 0 ranking points. The second USNWR measure then sums the ranking points of state s's regional competitors:

$$\text{USNWR Ranking Points}_{st} \equiv \sum_{u \in U_t(s)} \text{points}_{ut}. \tag{21}$$

I now use the t subscript in (20)-(21) to index the full set of academic years during the sample period (1993-2016).[22] This is a change from the discussion in Section 3.2, where t indexes the seven NPSAS survey years comprising the sample. I make this change because I aim to capture the university rankings facing students in the year they applied to college, rather than the year in which they were surveyed by the NPSAS. I therefore define the measures in (20)-(21) for each unique academic year, and match them to students based on their year of college entry (i.e., for a sophomore observed in the 2004 NPSAS survey, I use the USNWR measures for his or her state in the 2003 academic year).[23]

4.2 Regression Specifications and Identification

To implement the USNWR analysis, I make three changes to the regression specifications in (14)-(15). First, I replace the geographic distance measures $g_{s(i)t}$ with the time-varying USNWR measures defined in (20)-(21). Second, as discussed above, I now let the t subscript refer to students' college-entry year, rather than the year in which they were surveyed by the NPSAS.[24] Finally and most importantly, I adjust the fixed effects included in the specifications. Because the USNWR measures exhibit within-state variation over the course of the sample period, I can replace the region effects η_r with a finer set of state fixed effects.

For the estimated USNWR coefficients to represent the causal effect of heightened quality among competing institutions, unobserved factors affecting financial aid policy must be uncorrelated with regional competitors' USNWR rankings. Because the score that determines an institution's USNWR ranking is based solely on its *own* characteristics (students' standardized test scores, faculty salaries, etc.), it is difficult to draw a direct link between institutions' financial aid policies and the USNWR rankings of *other* competing institutions. The most plausible threat to identification is a scenario where institution i shifts money from need-based to merit-based aid, draws high-achieving students away from regional competitor j, and causes j's ranking to fall. But the resulting bias would make it harder to establish the hypothesized results, since it would tend to imply that merit-based aid is decreasing and need-based aid is increasing in regional competitors' USNWR rankings.

[22] USNWR has gradually expanded the length of its national universities rankings list, which causes the meaning of the rankings to change over time. To ensure that the rankings measures I construct are comparable across years, I restrict the analysis to consider data only for the 2005-2016 period, when USNWR maintained a stable practice of ranking between 250 and 270 institutions each year.

[23] This treatment reflects an assumption that students observed in their xth year of college applied to and entered college x years ago. The possibility of students pausing and then resuming their studies means this is not true in all cases, but it is true in most cases and is the only reasonable assumption to be made. It also reflects the reality that most financial aid awards are recurring (i.e., a grant awarded to a student in his or her freshman year will be for the duration of the student's four-year tenure and will appear in the NPSAS when he or she is surveyed as an upperclassman.)

[24] This also means that the τ_t now become a full set of college-entry-year fixed effects, rather than a set of fixed effects for the seven NPSAS survey years.

Table 3: Out-of-State USNWR Rankings and the
Merit-Need Allocation of Financial Aid

	Nonzero Merit	Merit/ COA	Nonzero Need	Need/ COA	Merit Share of Grant Aid
	(1)	(2)	(3)	(4)	(5)
Panel A:					
Top-100 USNWR Insts.	0.013***	0.004***	-0.009*	-0.001	0.033***
(S.D.: 0.81)	(0.004)	(0.001)	(0.005)	(0.001)	(0.007)
Panel B:					
USNWR Ranking Points	0.010**	0.003	-0.016***	-0.003*	0.035***
(S.D.: 128.69)	(0.004)	(0.002)	(0.005)	(0.001)	(0.008)
Mean Dep. Var.	0.212	0.044	0.300	0.056	0.398
Observations	77,400	64,320	77,400	64,320	34,110

Note: Each panel shows a separate set of regressions for the corresponding rankings measure. Only resident students at public institutions are included. All specifications include state and year fixed effects, as well as controls for household income quartiles. Standard errors are clustered by institution and are shown in parentheses; asterisks indicate statistical significance at p-values of 0.1, 0.05, and 0.01. For readability and ease of interpretation, all coefficient estimates and standard errors are multiplied by the standard deviation of the corresponding distance measure, so that they represent the effect of a one-standard-deviation increase in that measure. Only data since the 2004-2005 academic year (when the USNWR rankings list expanded to its current length) are considered. See Sections 3.2 and 4.1 for variable definitions.

4.3 Results

Table 3 shows the regression specifications relating regional USNWR rankings to the allocation of aid between merit- and need-based grants. The USNWR coefficients and standard errors are again scaled so that they represent the effect of a one-standard-deviation increase in the relevant measure. Because the within-state variation in regional USNWR rankings is substantially smaller than the full amount of cross-state variation, I scale the coefficients by the average state-level (rather than the unconditional) standard deviation.

The results in Table 3 are again broadly supportive of the model predictions. One-standard-deviation increases in the top-100-institutions and ranking-points measures raise the probability of merit-based aid receipt by 1.3 and 1.0 percentage points; the corresponding effects on merit-based aid as a share of COA are 0.4 and 0.3 percentage points, respectively. The estimated effects on the probability of need-based aid receipt are also significant: one-standard-deviation changes in the USNWR measures reduce it by 0.9 and 1.6 percentage points. The relationships with need-based aid as a share of COA have the predicted negative sign but are smaller in magnitude and insignificant. The net result is that the merit share of total aid is strongly increasing in both measures: one-standard-deviation increases in the top-100-institutions and ranking-points variables raise it by 3.3 and 3.5 percentage points.

Table 4: Out-of-State USNWR Rankings and the Income Progressivity of Financial Aid

	Grant Aid	Grant Aid Net of Demonstrated Need	Grant Aid/COA
	(1)	(2)	(3)
Panel A:			
Top-100 USNWR Insts.	-45.71	6.50	0.000
(S.D.: 0.81)	(38.12)	(73.24)	(0.002)
* Income Quartile 2	19.60*	28.85*	0.001**
	(10.24)	(17.08)	(0.000)
* Income Quartile 3	72.94***	141.99***	0.004***
	(12.00)	(23.35)	(0.001)
* Income Quartile 4	157.77***	103.71***	0.008***
(highest)	(18.71)	(28.14)	(0.001)
Panel B:			
USNWR Ranking Points	-80.03**	119.37*	-0.002
(S.D.: 128.69)	(36.49)	(72.44)	(0.002)
* Income Quartile 2	10.95***	7.73	0.001***
	(3.83)	(6.47)	(0.000)
* Income Quartile 3	37.10***	46.15***	0.002***
	(4.25)	(9.02)	(0.000)
* Income Quartile 4	65.93***	45.31***	0.003***
(highest)	(6.76)	(11.52)	(0.000)
Mean Dep. Var.	2,114	-9,632	0.100
Observations	77,400	64,320	64,320

Note: Each panel shows a separate set of regressions for the corresponding rankings measure. Only resident students at public institutions are included. Grant aid values are in 2016 dollars. All specifications include state and year fixed effects. Standard errors are clustered by institution and are shown in parentheses; asterisks indicate statistical significance at p-values of 0.1, 0.05, and 0.01. For readability and ease of interpretation, all coefficient estimates and standard errors are multiplied by the standard deviation of the corresponding distance measure, so that they represent the effect of a one-standard-deviation increase in that measure. These standard deviations are reported in the upper-left corner of each panel. Only data since the 2004-2005 academic year (when the USNWR rankings list expanded to its current length) are considered. See Sections 3.2 and 4.1 for variable definitions.

Table 4 displays the regression specifications testing the effects of USNWR rankings on the overall income progressivity of financial aid. The results again confirm the theoretical prediction that financial aid becomes less progressive when interstate competition is more intense. Again, the interaction coefficients are nearly all positive and statistically significant (and are largest in magnitude for the third and fourth quartiles), confirming that high-income students receive relatively more grant aid when competing regional institutions earn higher

USNWR rankings. A one-standard-deviation increase in the top-100-institutions measure raises total grant aid for the top quartile by \$158 relative to the bottom quartile; this effect becomes \$104 when adjusting for demonstrated need and 0.8 percentage points when measuring grant aid as a share of COA. The ranking-points measure produces interaction coefficients that are similarly positive but about half as large in magnitude: a one-standard-deviation increase raises top-quartile grant aid by \$66 in raw terms, \$45 in need-adjusted terms, and 0.3 percentage points as a share of COA.

5 Quantifying the Effects of Interstate Competition

The preceding reduced-form analysis verifies the model's empirically testable implications and confirms that the business-stealing incentive that distorts equilibrium financial aid policy is operating empirically. But how large is this distortion? What would be the real effects on financial aid outcomes and college-attendance rates if a national planner were instead responsible for aid allocation decisions? I now conduct calibrated simulations of the model in order to provide quantitative answers to these questions.

5.1 Calibration

5.1.1 Directly Observed Parameters

I begin by restricting the NPSAS data to the most recent 2016 survey wave: to the extent that the model parameters or financial aid policy environment have changed over time, I would like the simulation results to reflect current conditions. Several model parameters can be observed directly from this calibration data.

First, the budget constraint facing the states and planner requires that the average net tuition receipt across all enrolled students equal c. To implement this constraint empirically and accurately capture the scale of financial costs facing a typical student, I set c equal to the average total cost of attendance, net of all state and institutional grant aid.

Second, the model requires information about the relative sizes of the different student populations. For simplicity in the theoretical analysis of Section 2, I assume that the masses of the high- and low-income student populations are equal. The empirical rate of need-based aid receipt, however, is less than 50%. I therefore introduce a new parameter m_L to specify the mass of low-income students, and set it equal to the share of students in the calibration data who receive nonzero need-based aid from state or institutional sources (the mass of high-income students is $m_H = 1 - m_L$). Finally, the ϕ_i parameters specify the high-achieving shares of each income population. I set ϕ_H and ϕ_L equal to the rate of merit-based aid receipt among the high- and low-income student populations, respectively.

5.1.2 Target Moments

The remaining parameters to calibrate are the enrollment-preference weights that appear in the states' objective function, as well as the parameters appearing in students' utility expressions. As with any logit model, the utility parameters are not separately identifiable from the dispersion parameter ψ (Train, 2009), so I use tildes to denote parameters that are inclusive of ψ (i.e., $\tilde{x} \equiv \psi x$). The six parameters to calibrate are thus $(\alpha_r, \alpha_A, \tilde{\gamma}, \tilde{\beta}_L, \tilde{\beta}_H, \tilde{\delta})$, and I use six target moments to determine them.

First, I choose the resident-preference parameter α_r to match the empirical nonresident tuition gap. Fixing the student utility parameters, higher values of α_r lead states to treat resident students more favorably and widen the gap between average resident and nonresident tuition in the model. The relevant model outcome (using hats to denote model quantities) is the average nonresident tuition gap across the four student categories:

$$\hat{G} \equiv \sum_{i \in \{H,L\}} m_i \Big(\phi_i (n_{i,A} - r_{i,A}) + (1 - \phi_i)(n_{i,B} - r_{i,B}) \Big). \tag{22}$$

The target empirical value G is the average within-institution difference between resident and nonresident tuition in the calibration sample (obtained by regressing students' net tuition costs on an indicator for nonresident status and a full set of institution fixed effects).

Second, I choose the preference for high achievers α_A to match the size of empirical merit aid awards. Fixing the utility parameters, higher values of α_A lead states to treat high-achieving students more favorably and increase the amount of merit aid provided in the model. I define the relevant model outcome (denoted with $\hat{a}_m$) as the amount of merit aid awarded to resident students, averaged across the high achievers in each income group:

$$\hat{a}_m \equiv \frac{m_H \phi_H (r_{H,B} - r_{H,A}) + m_L \phi_L (r_{L,B} - r_{L,A})}{m_H \phi_H + m_L \phi_L}. \tag{23}$$

The target value a_m is the average merit aid award (combining state and institutional grants) to resident students in the calibration sample, conditional on merit aid receipt.

Third, the travel-cost parameter δ controls students' migration propensity and thus determines nonresident enrollment rates. Fixing α_r and the nonresident tuition gap, higher values of δ make migration more costly and reduce the share of students who attend college as nonresidents. I define the relevant model outcome (denoted with $\hat{p}^n_{cond}$) as the conditional nonresident attendance rate, i.e., the share of college attendees who are nonresidents, averaged across the four student categories:

$$\hat{p}^n_{cond} \equiv \sum_{i\in\{H,L\}} m_i \left(\phi_i \frac{p^n_{i,A}}{p^r_{i,A} + p^n_{i,A}} + (1-\phi_i) \frac{p^n_{i,B}}{p^r_{i,B} + p^n_{i,B}} \right). \tag{24}$$

The target empirical value p^n_{cond} is the average nonresident student share among public four-year institutions reporting to the IPEDS database in 2016.

Finally, I use three target moments to jointly determine the college-attendance benefit $\tilde{\gamma}$ and the tuition sensitivities $\tilde{\beta}_L$ and $\tilde{\beta}_H$. The attendance benefit $\tilde{\gamma}$ applies to all students and therefore determines the overall college-attendance rate, fixing states' tuition profiles and the other utility parameters. The $\tilde{\beta}_i$ parameters, by setting the difference in tuition sensitivity between the income groups, determine the extent to which high- and low-income attendance rates vary (at any given tuition profile) around the overall attendance rate. Additionally, since the gap in tuition sensitivities controls states' incentive to subsidize low-income tuition, the $\tilde{\beta}_i$ parameters also determine the amount of need-based aid that is provided in equilibrium. The vector $(\tilde{\gamma}, \tilde{\beta}_H, \tilde{\beta}_L)$ can thus be chosen to match three empirical moments: high- and low-income attendance rates (which together with the fixed population masses also imply the overall attendance rate) and the average size of need-based aid awards.

I define college-attendance rates in the model (denoted with $\hat{R}_i$) as the share of students choosing either resident or nonresident attendance:

$$\hat{R}_i \equiv \phi_i(p^r_{i,A} + p^n_{i,A}) + (1-\phi_i)(p^r_{i,B} + p^n_{i,B}). \tag{25}$$

According to the 2016 Digest of Education Statistics, 46% of recent high-school completers were enrolled in four-year colleges or universities in 2016.[25] Additionally, Belley and Lochner (2007) report that the gap in college-attendance rates between the bottom income quartile and top three income quartiles is 10 percentage points;[26] since the calibrated mass of low-income students is $m_L = 0.31$, this bottom-versus-top-three-quartile comparison is roughly applicable for my model setup. I therefore set the target attendance rates R_H and R_L so that their difference is 10 percentage points ($R_H - R_L = 0.1$) and their average is 46 percentage points ($m_H R_H + m_L R_L = 0.46$); this gives target values of $R_H = 0.49$ and $R_L = 0.39$.

As the model's need-based aid outcome (denoted with $\hat{a}_n$), I take the amount of need-based aid provided to resident students, averaged across the high- and low-achieving students within the low-income group:

$$\hat{a}_n \equiv \phi_L(r_{H,A} - r_{L,A}) + (1-\phi_L)(r_{H,B} - r_{L,B}). \tag{26}$$

[25] The NCES defines recent high-school completers as "individuals ages 16 to 24 who graduated from high school or completed a GED or other high school equivalency credential." The data table is accessible here.

[26] I obtain this 10 percentage point gap by averaging the bottom three coefficients in column 4 of Table 3 in Belley and Lochner (2007).

The target value a_n is the average need-based aid award (combining state and institutional grants) to resident students in the calibration sample, conditional on need-based aid receipt.

5.1.3 Accounting for Federal Aid

In the model discussed in Section 2, the equilibrium is defined as the set of outcomes that result when competing states are fully responsible for setting net tuition prices, and the social optimum is defined as the set of outcomes that result when a national planner (i.e., the federal government) instead has complete policy responsibility. However, in the equilibrium captured by the NPSAS data, policy responsibility is shared: state university systems set gross tuition prices and award need- and merit-based scholarships, but students also receive aid from the federal government, mostly in the form of need-based Pell Grants. Rather than showing how outcomes differ between the polar cases of zero and full federal involvement, the model simulations here should instead project how outcomes would change if the federal government moved from its current partial role to having full responsibility for aid policy.

To account for federal aid in the equilibrium game played by the competing states, I make a slight adjustment to the low-income utility expressions in (4)-(5):

$$u^r_{L,g,k} = \gamma - \beta_L(r^{s(k)}_{L,g} - f_L) + \frac{\epsilon^r_k}{\psi}, \tag{27}$$

$$u^n_{L,g,k} = \gamma - \beta_L(n^{-s(k)}_{L,g} - f_L) - \delta + \frac{\epsilon^n_k}{\psi}. \tag{28}$$

In (27)-(28), f_L is the average amount of Pell Grant aid received by low-income students in the NPSAS calibration sample.[27] States are still free to choose their tuition profiles $\{\{r_{i,g}\},\{n_{i,g}\}\}$, but for any chosen state policy, low-income students' net prices are always reduced by the fixed amount f_L.[28]

I award low-income students the fixed Pell Grant amount f_L both when solving for the equilibrium and when computing the social optimum. The difference in outcomes between the equilibrium and optimum can then be interpreted as the changes that would occur if the federal government held its Pell Grant policy constant, but assumed control over the aid decisions previously made by states and institutions. I hold Pell Grant aid constant in order to isolate the policy distortions that arise from states' business-stealing incentives, and because the resulting counterfactual claims are conservative (the welfare gains achieved at

[27] I implicitly assume that the students who receive need-based aid from state or institutional sources are the same as those who receive Pell Grant aid; Cai and Heathcote (2022) make a similar assumption in specifying their model. In the 2016 NPSAS sample that I use for calibration, $f_L = \$2,930$.

[28] Pell Grants are "first-dollar" scholarships, i.e., students' eligibility and award amounts are determined solely by their gross cost of attendance and expected family contribution and do not depend on the aid they receive from state or institutional sources. See these Pell eligibility rules and this definition of eligible costs. It is therefore accurate to model federal aid f_L as being fixed before states make their own aid choices.

the optimum would be weakly higher if I allowed the planner to adjust f_L as well).

5.1.4 Calibration Results

Table 5 shows the parameter values that result from the calibration process. To rationalize a 10-percentage-point income gap in college-attendance rates and the substantial amount of need-based aid provided by states and institutions (the average award among need-based aid recipients is a_n = \$3,771), the difference in tuition sensitivities must also be considerable, with $\tilde{\beta}_L$ about 1.7 times larger than $\tilde{\beta}_H$. With a target nonresident attendance share of p^n_{cond} = 0.19, the nonresident tuition gap of G = \$6,691 is not, by itself, large enough to keep 81% of enrolled students in their home states. The travel cost $\tilde{\delta}$ must therefore be positive and of moderate magnitude, constituting about 9% of the utility benefit of college attendance.

Given the sizable gap in tuition sensitivities, the incentive to provide need-based aid is strong. But even with this tendency toward need-based aid, the model must still match large empirical merit aid awards (the average grant among merit recipients is a_m = \$3,966). As a result, the calibrated value for α_A is 1.93, implying that states value high-achieving students nearly twice as much as low-achieving students. Similarly, in order to match the nonresident tuition gap, the preference for resident students must be large, with a calibrated value for α_r of 14.80. The magnitude of α_r implies that nonresident students do not make a large contribution to states' enrollment objective functions (with resident enrollment nearly 15 times more valuable). Nonresidents' most important role is instead in the budget constraint: states charge high nonresident tuition, capture the inframarginal out-of-state students whose idiosyncratic preference draws make them likely to migrate, and use the resulting revenue to lower prices for the resident students whose enrollment is inherently valuable.

5.2 Counterfactual Results

5.2.1 Outcome Definitions

I analyze three financial aid outcomes. The first two, defined above as $\hat{a}_m$ in (23) and $\hat{a}_n$ in (26), are merit-based aid for resident students (averaged across the income groups) and need-based aid for resident students (averaged across the achievement groups). As an additional outcome measuring the relative sizes of the total dollar amounts devoted to merit- versus need-based aid, I also report the merit share of total resident financial aid:

$$\text{Merit Share of Total Aid} \equiv \frac{(m_H\phi_H + m_L\phi_L)\hat{a}_m}{(m_H\phi_H + m_L\phi_L)\hat{a}_m + m_L\hat{a}_n}. \tag{29}$$

The right-hand side of (29) gives the ratio of merit-based to total (merit-based plus need-based) aid, with merit-based aid multiplied by the mass of high-achieving recipients and

Table 5: Parameter Calibrations

Parameter	Description	Value
$\tilde{\gamma}$	utility benefit of college attendance	2.86
$\tilde{\beta}_L$	low-income tuition sensitivity (/$10,000)	2.96
$\tilde{\beta}_H$	high-income tuition sensitivity (/$10,000)	1.75
$\tilde{\delta}$	travel cost	0.25
m_L	mass of low-income students	0.31
ϕ_L	low-income rate of merit aid receipt	0.20
ϕ_H	high-income rate of merit aid receipt	0.28
α_r	states' resident enrollment preference	14.80
α_A	states' high-achieving enrollment preference	1.93
c	resource cost	$17,868

Note: This table shows the parameter values that result from the calibration process described in Section 5.1. Tildes denote values that are inclusive of the dispersion parameter ψ, i.e., $\tilde{x} \equiv \psi x$.

need-based aid multiplied by the mass of low-income recipients.

Next, I analyze college-attendance rates, which as defined above in (25) are the share of students choosing either resident or nonresident attendance. I report the high- and low-income attendance rates $\hat{R}_H$ and $\hat{R}_L$, as well as the overall rate, $\hat{R} = m_L\hat{R}_L + m_H\hat{R}_H$.

Finally, I consider changes in the social planner's objective function $E_{planner}$, which as defined above in (10) is the achievement-weighted overall attendance rate:

$$E_{planner} \equiv \sum_{i\in\{H,L\}} m_i\Big(\phi_i\alpha_A(p^r_{i,A} + p^n_{i,A}) + (1-\phi_i)(p^r_{i,B} + p^n_{i,B})\Big). \tag{30}$$

Since the social optimum is defined as the tuition profile that maximizes this objective, $E_{planner}$ is the model object that is guaranteed to increase at the optimum. However, because it contains the achievement weight α_A, the planner's objective is not a readily interpretable probability; to quantify the equilibrium welfare loss, I instead define a money-metric measure.

Let $t^{eq} = \{\{r^{eq}_{i,g}\}, \{n^{eq}_{i,g}\}\}$ be the equilibrium tuition profile at the calibrated parameter values, and similarly let $t^* = \{\{r^*_{i,g}\}, \{n^*_{i,g}\}\}$ be the socially optimal tuition profile at the calibrated parameter values. More generally, let $t^{eq}(\cdot)$ and $t^*(\cdot)$ be the equilibrium and socially optimal tuition profiles for an arbitrary resource cost, keeping all other parameters fixed at their calibrated values. Finally, write the planner's objective as an explicit function of the employed tuition profile, $E_{planner}(t)$. I solve for the resource cost $\bar{c}$ that satisfies

$$E_{planner}(t^{eq}(c)) = E_{planner}(t^*(\bar{c})), \tag{31}$$

where c is the originally calibrated resource cost reported in Table 5. Since $E_{planner}(t^{eq}(c)) < E_{planner}(t^*(c))$ for any given c value (as established in Corollary 1) and $E_{planner}(t^*(\bar{c}))$ is strictly decreasing in $\bar{c}$ (imposing a tighter budget constraint on the planner and requiring more revenue to be raised per enrolled student lowers the optimized objective value), we must have $\bar{c} > c$. I can thus report the difference

$$\Delta_c \equiv \bar{c} - c \tag{32}$$

as an interpretable quantification of the equilibrium welfare loss: by correcting the inefficiencies in states' distorted tuition choices, the planner can attain the same achievement-weighted aggregate college enrollment that occurs in equilibrium, while raising Δ_c more dollars in net tuition revenue per enrolled student. We could imagine the excess tuition revenue being spent on another non-education-related public program or simply passed back in lump-sum form to some subset of students; either way, replicating the equilibrium outcome with fewer public subsidies constitutes a welfare improvement.

5.2.2 Baseline Results

Table 6 gives the counterfactual results. The first column reports the equilibrium values of each model outcome, while the second column shows how the outcomes change in the social optimum. The signs of the financial aid changes reflect the theoretical results discussed in Section 2: with the business-stealing incentive eliminated, need-based aid increases and merit-based aid decreases under socially optimal policy. Even though the overall attendance rate differs slightly in definition from the planner's objective (since it does not include the α_A achievement weight), it is also higher at the optimum. Because the shift from merit- to need-based aid involves a reallocation of tuition subsidies from high- to low-income students, the increase in overall attendance is driven primarily by the low-income group (though the change in high-income attendance is positive as well).

The magnitudes of the results in Table 6 establish that the shift from equilibrium to socially optimal policy is consequential, producing quantitatively important changes in the aid and attendance outcomes. The increase in the average need-based aid award for low-income residents is \$1,018, or 27% of the equilibrium value. The decrease in average merit-based aid for high-achieving residents is about half as large in magnitude, but at \$539 is still a substantial change in both absolute and relative terms (representing 14% of the equilibrium value). Together, these two changes cause the merit share of total resident financial aid to fall from 47% to 37.6%. Perhaps the most notable result is the large increase in low-income attendance, which rises by 8 percentage points from its equilibrium value of 39%. After accounting for a smaller 1.6 percentage point increase in high-income attendance, the gain

Table 6: Counterfactual Results

	Equilibrium Value	Change in Social Optimum
Resident Financial Aid		
Need-Based Aid	\$3,771	\$1,018
Merit-Based Aid	\$3,966	-\$539
Merit Share of Total Aid	47.0	-9.4
College-Attendance Rates		
Low-Income Students	39.0	8.0
High-Income Students	49.0	1.6
Overall	46.0	3.6
Money-Metric Welfare Loss	\$711	–

Note: This table shows the simulated changes in outcomes between the model's equilibrium and social optimum. College-attendance rates and the merit share of total aid are reported in percentage points. See Section 5.2.1 for definitions of the outcomes.

in the overall attendance rate is 3.6 percentage points. Finally, the money-metric welfare loss summarizes the overall cost-inefficiency of states' policy choices, implying that the planner can obtain the same achievement-weighted aggregate enrollment that occurs in equilibrium while raising an additional \$711 in net tuition revenue per college attendee. Scaling this figure by the total amount of state and institutional grant aid in the calibration data (\$2,289 per student), the model suggests that as much as 31% of empirical aid awards serve distortionary purposes that are not socially valuable from the perspective of a national planner.

5.2.3 Parameter Sensitivity

As a final quantification exercise, I probe the mechanisms underlying the counterfactual results by considering their sensitivity to instructive parameter changes. To highlight the role of travel costs in governing the size of equilibrium policy distortions, the first four columns of Table 7 give results for model simulations with low ($\tilde{\delta}_{low} = 0.13$) and high ($\tilde{\delta}_{high} = 0.38$) values of the travel-cost parameter. I obtain these alternative values by scaling the baseline value by a constant d, with $\tilde{\delta}_{low} = (1-d)\tilde{\delta}$ and $\tilde{\delta}_{high} = (1+d)\tilde{\delta}$. I let d be the coefficient of variation (i.e., standard deviation divided by mean) of the average-distance measure defined in (17) and used in the reduced-form analysis of Section 3, so that the range of $\tilde{\delta}$ values in Table 7 roughly approximates empirically observed variation in travel costs.

Consistent with the theoretical discussion in Section 2, equilibrium distortions are larger when migration is easier and states' business-stealing incentives are stronger. The changes in outcomes between the equilibrium and optimum are therefore moderately larger than the baseline for $\tilde{\delta}_{low}$ (with the merit share of total aid falling by 10.3 percentage points and low-

Table 7: Counterfactual Results:
Alternative Travel-Cost and Resident-Preference Parameters

	Low Travel Cost ($\tilde{\delta} = 0.13$)		High Travel Cost ($\tilde{\delta} = 0.38$)		No Resident Preference ($\alpha_r = 1$)	
	Eq. Value	Change	Eq. Value	Change	Eq. Value	Change
Resident Financial Aid						
Need-Based Aid	\$3,738	\$1,121	\$3,801	\$922	\$3,488	\$1,300
Merit-Based Aid	\$4,015	-\$594	\$3,920	-\$488	\$3,909	-\$482
Merit Share of Total Aid	47.5	-10.3	46.5	-8.5	48.6	-11.0
College-Attendance Rates						
Low-Income Students	40.0	8.9	38.3	7.3	40.4	6.7
High-Income Students	50.1	1.8	48.1	1.4	52.5	-1.8
Overall	47.0	3.9	45.1	3.2	48.8	0.8
Money-Metric Welfare Loss	\$785	–	\$251	–	\$58	–

Note: This table has the same setup as Table 6, but presents counterfactual results for model simulations with alternative travel-cost and resident-preference parameters.

income attendance rising by 8.9 percentage points) and moderately smaller than the baseline for $\tilde{\delta}_{high}$ (with those figures shrinking to 8.5 percentage points and 7.3 percentage points, respectively). The money-metric welfare loss is more sensitive to the parameter specification, rising to \$785 in the low-travel-cost simulation and falling to \$251 in the high-travel-cost simulation. Migration costs are thus an important determinant of equilibrium financial aid policy, and the model indicates that distortions to aid allocation are appreciably larger in regional markets where geographic competition is more intense.

The last two columns in Table 7 consider a model simulation where states do not have a preference for resident enrollment (i.e., with $\alpha_r = 1$). I present these results in order to distinguish between two separate distortions that shape the model's equilibrium. First, because α_r has a calibrated value strictly larger than 1, states charge lower tuition to residents than to nonresidents. This deviates from the socially optimal policy employed by the planner, who does not discriminate on the basis of residence status and sets $r_{i,g} = n_{i,g}\ \forall(i, g)$.[29] The nonresident tuition gap artificially incentivizes resident enrollment and reduces equilibrium welfare, a point already established in prior work like Knight and Schiff (2019). Second, conditional on α_r and the preference for residents within a given state university system, states also engage in inefficient business-stealing because they do not place *any* value on enrollment that occurs outside their borders. This business-stealing distortion is the focus of the theoretical discussion in Section 2 and introduces the possibility of aid distortions *within* a given resident student population.

The simulation with $\alpha_r = 1$ allows us to assess these two factors (resident-preference

[29] I prove this formally in Appendix Section A.2.5.

versus business-stealing) independently. After eliminating the preference for resident enrollment, the distortions to resident financial aid persist and low-income attendance still increases sharply (by 6.7 percentage points) in the social optimum. In fact, two of the three aid outcomes change by larger magnitudes than in the baseline simulation. This result is intuitive: with the nonresident tuition gap eliminated, nonresident attendance is less costly, the threat of outmigration is higher, and the distortion to resident financial aid is more pronounced (setting $\alpha_r = 1$ is similar in this respect to lowering the travel cost $\tilde{\delta}$). However, with $\alpha_r = 1$, the equilibrium-optimum gap in high-income attendance is eliminated (now becoming slightly negative, with the shift in tuition subsidies toward low-income students no longer offset by the gain from eliminating the nonresident tuition gap). The business-stealing incentive thus distorts aid allocation within resident student populations and depresses low-income attendance rates, while the nonresident tuition gap is primarily responsible for the increase in the high-income and overall attendance rates at the optimum.

6 Conclusion

In a model that formalizes the competitive interactions between state university systems, I show that business-stealing incentives cause states to provide less need-based and more merit-based aid than a national planner. Comparative statics in the model's travel-cost parameter are a continuous, testable version of the equilibrium-optimum comparison, and hold when using geographic distance and time-varying university rankings as empirical competition proxies. Calibrated model simulations show that the business-stealing wedge is quantitatively important, with socially optimal policy raising need-based aid by 27%, lowering merit-based aid by 14%, and increasing low-income college-attendance rates by 8 percentage points.

This paper focuses on the distortionary consequences of competition between state university systems. Of course, in most markets, competition between supply-side actors also produces social benefits by expanding consumer choice and incentivizing innovation. Future research should take a broader view of interstate university competition, comparing the benefits it provides and the costs it imposes on American students.

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Appendix A Proofs of Theoretical Results (For Online Publication)

A.1 Proof of Proposition 1

Choosing some $g \in \{A, B\}$ and taking first-order conditions with respect to $r_{H,g}$ and $r_{L,g}$ for the state's optimization problem in (9), we obtain:

$$\alpha_r \cdot (\mathbf{1}_{\{g=A\}}\alpha_A) \cdot \frac{\partial p^r_{H,g}}{\partial r_{H,g}} + \lambda \left(\frac{\partial p^r_{H,g}}{\partial r_{H,g}}(r_{H,g} - c) + p^r_{H,g} \right) = 0, \tag{33}$$

$$\alpha_r \cdot (\mathbf{1}_{\{g=A\}}\alpha_A) \cdot \frac{\partial p^r_{L,g}}{\partial r_{L,g}} + \lambda \left(\frac{\partial p^r_{L,g}}{\partial r_{L,g}}(r_{L,g} - c) + p^r_{L,g} \right) = 0, \tag{34}$$

where λ is the Lagrange multiplier on the budget constraint. These optimality conditions must hold for the states in symmetric equilibrium. Combining (33) and (34), and using the fact that $\frac{\partial p^r_{i,g}}{\partial r_{i,g}} = -\psi \beta_i p^r_{i,g}(1 - p^r_{i,g})$, gives

$$\frac{\beta_H(1 - p^r_{H,g})}{1 - \psi\beta_H(1 - p^r_{H,g})(r_{H,g} - c)} = \frac{\beta_L(1 - p^r_{L,g})}{1 - \psi\beta_L(1 - p^r_{L,g})(r_{L,g} - c)}. \tag{35}$$

Consider the limiting case where $\psi \to 0$. The denominators on both sides of (35) go to 1, giving

$$\begin{aligned} \frac{1 - p^r_{L,g}}{1 - p^r_{H,g}} &= \frac{\beta_H}{\beta_L} \\ \implies 1 - p^r_{H,g} &> 1 - p^r_{L,g} \\ \implies p^r_{L,g} &> p^r_{H,g} \end{aligned}$$

Now rearrange (35) to read as

$$r_{H,g} - r_{L,g} = \frac{\beta_L(1 - p^r_{L,g}) - \beta_H(1 - p^r_{H,g})}{\psi\beta_H\beta_L(1 - p^r_{H,g})(1 - p^r_{L,g})} \tag{36}$$

and consider the limiting case where $\psi \to \infty$. The right-hand side of (36) goes to 0, giving

$$r_{H,g} = r_{L,g}.$$

This in turn implies that $p^r_{H,g} > p^r_{L,g}$, since $\beta_L > \beta_H$. This establishes that

$$\begin{aligned} \lim_{\psi \to 0} p^r_{H,g} - p^r_{L,g} &< 0, \\ \lim_{\psi \to \infty} p^r_{H,g} - p^r_{L,g} &> 0. \end{aligned}$$

Therefore, by the intermediate value theorem, there exists some $\bar{\psi}^r$ such that in the equilibrium arising from $\bar{\psi}^r$, we have $p^r_{H,g} - p^r_{L,g} = 0$.

Finally, rearrange (35) to read as

$$r_{H,g} - r_{L,g} = \frac{1}{\psi}\left(\frac{1}{\beta_H(1-p^r_{H,g})} - \frac{1}{\beta_L(1-p^r_{L,g})}\right). \tag{37}$$

Let (37) hold for some ψ_0, and consider a small increase to $\psi_1 > \psi_0$. Fixing the tuition values that arise in the ψ_0 equilibrium, the left-hand side of (37) is larger than the right-hand side after the increase to ψ_1. To reestablish equality in the ψ_1 equilibrium, $r_{H,g}$ must decrease relative to $r_{L,g}$, which decreases the left-hand side and increases the right-hand side (since $\frac{\partial p^r_{i,g}}{\partial r_{i,g}} < 0$, and the right-hand side is increasing in $p^r_{H,g}$ and decreasing in $p^r_{L,g}$). This establishes that

$$\frac{\partial}{\partial \psi}\left[p^r_{H,g} - p^r_{L,g}\right] > 0.$$

Therefore, for all $\psi > \bar{\psi}^r$, we have $p^r_{H,g} - p^r_{L,g} > 0$ in equilibrium, and for all $\psi \leq \bar{\psi}^r$, we have $p^r_{H,g} - p^r_{L,g} \leq 0$ in equilibrium. To the extent that the above logic produces different $\bar{\psi}^r$ values for $g = A$ versus $g = B$, simply take the larger value.

An identical argument using the first-order conditions for $n_{H,g}$ and $n_{L,g}$ produces a $\bar{\psi}^n$ that establishes the same result for the nonresident enrollment values $p^n_{H,g}$ and $p^n_{L,g}$. Letting $\bar{\psi} = \max\{\bar{\psi}^r, \bar{\psi}^n\}$, the statement of the proposition holds. ■

A.2 Proof of Proposition 2 - Existence and Uniqueness of Equilibrium and Social Optimum

A.2.1 Break Game into (i, g) Subgames

To establish the existence and uniqueness of the symmetric equilibrium, it is helpful to break the game into four "subgames," for each combination of the income type $i \in \{H, L\}$ and achievement type $g \in \{A, B\}$. Fixing a value for i and a value for g, taking first-order conditions with respect to $r_{i,g}$ and $n_{i,g}$ for the state's optimization problem in (9) gives

$$\alpha_r \cdot (\mathbf{1}_{\{g=A\}}\alpha_A) \cdot \frac{\partial p^r_{i,g}}{\partial r_{i,g}} + \lambda\left(\frac{\partial p^r_{i,g}}{\partial r_{i,g}}(r_{i,g} - c) + p^r_{H,g}\right) = 0, \tag{38}$$

$$(\mathbf{1}_{\{g=A\}}\alpha_A) \cdot \frac{\partial p^n_{i,g}}{\partial n_{i,g}} + \lambda\left(\frac{\partial p^n_{i,g}}{\partial n_{i,g}}(n_{i,g} - c) + p^n_{i,g}\right) = 0, \tag{39}$$

where λ is the Lagrange multiplier on the budget constraint. Combining (38) and (39), and using $\frac{\partial p^r_{i,g}}{\partial r_{i,g}} = -\psi\beta_i p^r_{i,g}(1-p^r_{i,g})$, $\frac{\partial p^n_{i,g}}{\partial n_{i,g}} = -\psi\beta_i p^n_{i,g}(1-p^n_{i,g})$ gives

$$\frac{\alpha_r(1-p^r_{i,g})}{1-\psi\beta_i(1-p^r_{i,g})(r_{i,g}-c)} = \frac{1-p^n_{i,g}}{1-\psi\beta_i(1-p^n_{i,g})(n_{i,g}-c)}. \tag{40}$$

Additionally, since the states act symmetrically, student choice probabilities are given by

$$p^r_{i,g} = \frac{\exp(\psi(\gamma - \beta_i r_{i,g}))}{1 + \exp(\psi(\gamma - \beta_i r_{i,g})) + \exp(\psi(\gamma - \beta_i n_{i,g} - \delta))}, \tag{41}$$

$$p^n_{i,g} = \frac{\exp(\psi(\gamma - \beta_i n_{i,g} - \delta))}{1 + \exp(\psi(\gamma - \beta_i r_{i,g})) + \exp(\psi(\gamma - \beta_i n_{i,g} - \delta))}. \tag{42}$$

Finally, though each state has only a single budget constraint, we can imagine imposing one on each of the four subgames. In other words, we can require that the net revenue collected in the (i,g) subgame equal some arbitrary value $R_{i,g}$:

$$\phi_{i,g}\left[p^r_{i,g}(r_{i,g}-c)+p^n_{i,g}(n_{i,g}-c)\right]=R_{i,g}, \tag{43}$$

where $\phi_{i,g}\equiv\phi_i$ if $g=A$ and $\phi_{i,g}\equiv(1-\phi_i)$ if $g=B$. The (i,g) subgame has four unknowns $(r_{i,g},n_{i,g},p^r_{i,g},p^n_{i,g})$ and four equilibrium conditions: (40), (41), (42), and (43).

A.2.2 Unique Equilibrium to (i,g) Subgame

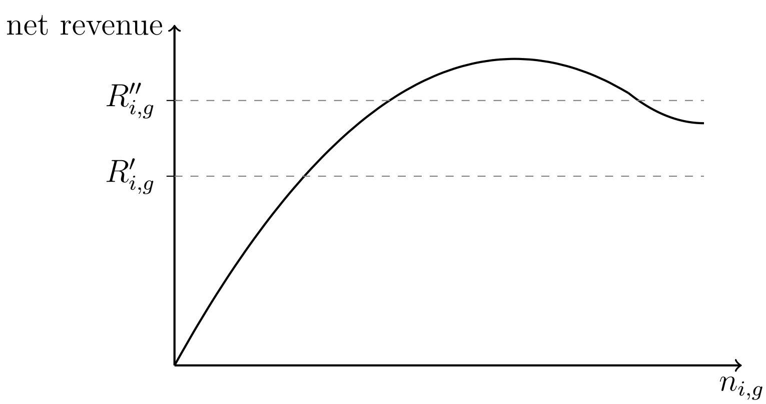
First, establish that for any given $R_{i,g}$, there is a unique $(r_{i,g},n_{i,g})$ pair that satisfies all four equilibrium conditions for the (i,g) subgame. To do so, begin by fixing $r_{i,g}$ and differentiating the left-hand side of the budget constraint in (43) with respect to $n_{i,g}$. This derivative is:

$$\phi_{i,g}\left[\frac{\partial p^r_{i,g}}{\partial n_{i,g}}(r_{i,g}-c)+\frac{\partial p^n_{i,g}}{\partial n_{i,g}}(n_{i,g}-c)+p^n_{i,g}\right]. \tag{44}$$

Setting (44) equal to 0, and using the choice probability expressions in (41)-(42) to evaluate $\frac{\partial p^r_{i,g}}{\partial n_{i,g}}$ and $\frac{\partial p^n_{i,g}}{\partial n_{i,g}}$, we obtain:

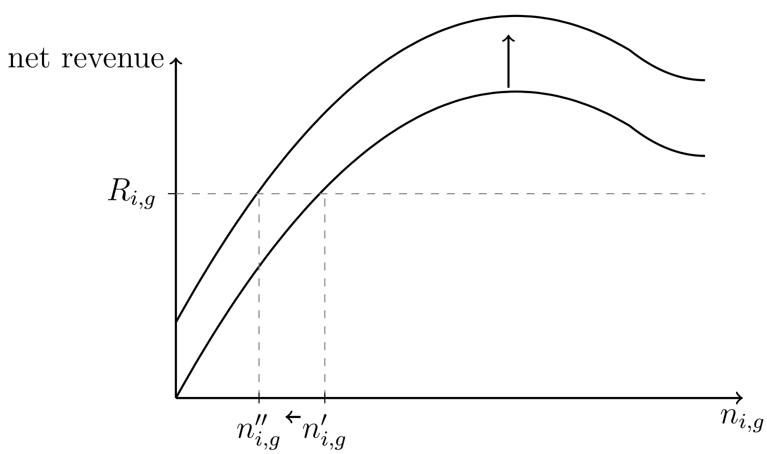
$$n_{i,g}-\frac{1}{\psi\beta_i}\cdot\frac{\exp(\psi(\gamma-\beta_i n_{i,g}-\delta))}{1+\exp(\psi(\gamma-\beta_i r_{i,g}))}=\frac{\exp(\psi(\gamma-\beta_i r_{i,g}))}{1+\exp(\psi(\gamma-\beta_i r_{i,g}))}\cdot(r_{i,g}-c)+\frac{1}{\psi\beta_i}+c. \tag{45}$$

In (45), $n_{i,g}$ only appears on the left-hand side, and the left-hand side is strictly increasing in $n_{i,g}$. Thus, for any fixed $r_{i,g}$, there is a unique $n_{i,g}$ such that the derivative of the budget constraint with respect to $n_{i,g}$ equals 0. Observe also that for any fixed $r_{i,g}$, as $n_{i,g}\to-\infty$, we have $p^n_{i,g}\to 1$ and $p^r_{i,g}\to 0$, so net revenue goes to $-\infty$. Similarly, for any fixed $r_{i,g}$, as $n_{i,g}\to\infty$, we have $p^n_{i,g}\to 0$ and $p^r_{i,g}$ approaches some value between 0 and 1, so net revenue approaches some finite value. Taken together, this implies that fixing $r_{i,g}$, net revenue is a single-peaked function of $n_{i,g}$ with a horizontal asymptote:



Thus, for smaller values of $R_{i,g}$ (like $R'_{i,g}$ in the above figure), for a fixed value of $r_{i,g}$, there is a single value of $n_{i,g}$ that ensures net revenue in the (i,g) subgame equals $R_{i,g}$. For larger values of $R_{i,g}$ (like $R''_{i,g}$ in the above figure), there are two such values of $n_{i,g}$. But in the latter case, observe that optimizing states cannot choose the larger $n_{i,g}$ value: since net revenue is decreasing in $n_{i,g}$ at this point, the states could lower $n_{i,g}$ and increase nonresident enrollment while simultaneously relaxing the overall budget constraint, since net revenue would also increase. Thus, fixing $r_{i,g}$, there is a unique plausible $n_{i,g}$ value that satisfies the budget constraint for the (i,g) subgame in (43).

The logic about plausible tuition values also applies in reverse: for any fixed $n_{i,g}$, net revenue must be increasing in $r_{i,g}$ at any plausible value of $r_{i,g}$. Thus, increasing $r_{i,g}$ shifts the net revenue curve upward at every point, and decreases the value of $n_{i,g}$ that satisfies the budget constraint (in the figure below, from $n'_{i,g}$ to $n''_{i,g}$):



The budget constraint thus creates a strictly decreasing relationship between $r_{i,g}$ and $n_{i,g}$: an increase in $r_{i,g}$ strictly decreases the budget-balancing value of $n_{i,g}$.

Now analyze the optimality condition in (40), which can be rewritten as

$$\frac{(\mathbf{1}_{\{g=A\}}\alpha_A)\alpha_r(1-p^r_{i,g})}{1-\psi\beta_i(1-p^r_{i,g})(r_{i,g}-c)} - \frac{(\mathbf{1}_{\{g=A\}}\alpha_A)(1-p^n_{i,g})}{1-\psi\beta_i(1-p^n_{i,g})(n_{i,g}-c)} = 0. \tag{46}$$

Again, fix $r_{i,g}$. The derivative of the first term in (46) with respect to $n_{i,g}$ is

$$(\mathbf{1}_{\{g=A\}}\alpha_A)\cdot\frac{-\alpha_r}{(1-\psi\beta_i(1-p^r_{i,g})(r_{i,g}-c))^2}\cdot\psi\beta_i p^r_{i,g}p^n_{i,g} < 0.$$

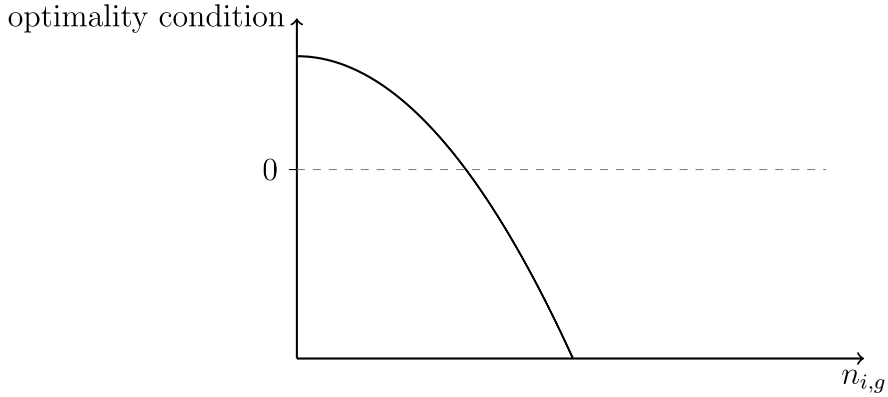
The derivative of the second term in (46) (including the minus sign in front) with respect to $n_{i,g}$ is

$$(\mathbf{1}_{\{g=A\}}\alpha_A)\cdot\frac{-\psi\beta_i(1-p^n_{i,g})}{(1-\psi\beta_i(1-p^n_{i,g})(n_{i,g}-c))^2} < 0.$$

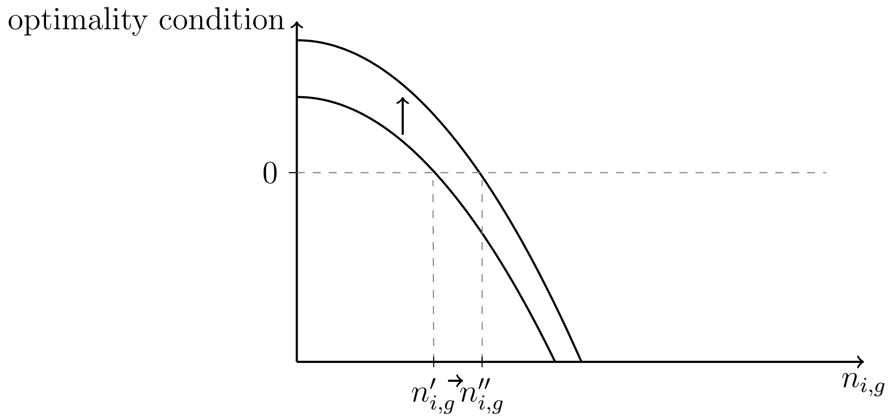
Thus for fixed $r_{i,g}$, the optimality condition in (46) is strictly decreasing in $n_{i,g}$. Now consider the limiting cases: as $n_{i,g} \to -\infty$, we have $p^n_{i,g} \to 1$, $p^r_{i,g} \to 0$, so (46) approaches

$$(\mathbf{1}_{\{g=A\}}\alpha_A) \cdot \frac{\alpha_r}{1 - \psi\beta_i(r_{i,g} - c)} > 0,$$

since the denominators of both terms in (46) must be positive at any plausible solution (they are the derivatives of net revenue with respect to $r_{i,g}$ and $n_{i,g}$, respectively, which as discussed above must be positive). In the other limit, as $n_{i,g}$ increases to ∞, $\psi\beta_i(1-p^n_{i,g})(n_{i,g}-c) \to 1$, the denominator of the second term in (46) approaches its plausible limit of 0, and the left-hand side of (46) approaches $-\infty$. Taken together, this implies that fixing $r_{i,g}$, the left-hand side of (46) is a strictly decreasing function of $n_{i,g}$ that crosses the target value of 0:

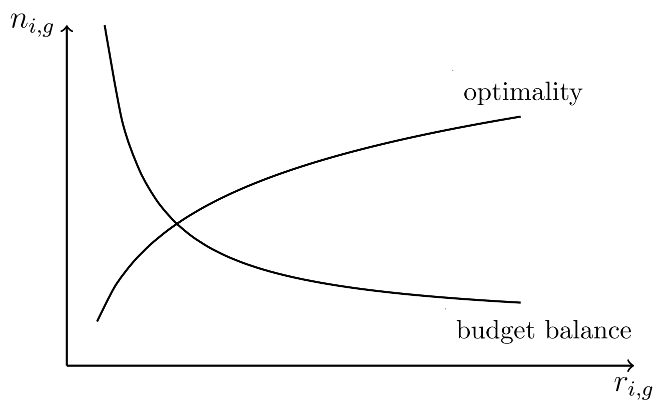


Now mirroring the logic used above, one can show that, fixing $n_{i,g}$, both terms on the left-hand side of (46) are strictly increasing in $r_{i,g}$. This implies that increasing $r_{i,g}$ shifts the optimality curve upward at every point, and increases the value of $n_{i,g}$ that satisfies the optimality condition (in the figure below, from $n'_{i,g}$ to $n''_{i,g}$):



The optimality condition thus creates a strictly increasing relationship between $r_{i,g}$ and $n_{i,g}$: an increase in $r_{i,g}$ strictly increases the value of $n_{i,g}$ that satisfies the optimality condition.

Equilibrium in the (i, g) subgame (for arbitrary net revenue requirement $R_{i,g}$) thus occurs at the intersection of a strictly increasing relationship and a strictly decreasing relationship between $r_{i,g}$ and $n_{i,g}$:



Note also that the budget-balance relationship satisfies an Inada condition: For any finite net revenue requirement $R_{i,g}$, sending $r_{i,g}$ to $-\infty$ must cause the budget-balancing $n_{i,g}$ to go to ∞ (since (43) must hold and $p^r_{i,g}$ and $p^n_{i,g}$ are bounded between 0 and 1). Therefore, for any given net revenue requirement $R_{i,g}$, there exists a unique equilibrium to the (i, g) subgame.

A.2.3 Unique Equilibrium to Combined i Subgame

Now fix a value for i and "combine" the (i, A) and (i, B) subgames into an i subgame. We showed above that any net revenue requirement $R_{i,g}$ maps to a unique equilibrium in the (i, g) subgame, where net revenue of $R_{i,g}$ is collected and the optimality condition in (40) is satisfied. Let $\lambda_{i,g}(R_{i,g})$ be the Lagrange multiplier value – as a function of $R_{i,g}$ – that is equal to both sides of (40) in the (i, g)-subgame equilibrium. Equilibrium in the i subgame occurs when the Lagrange multipliers are equated across the (i, A) and (i, B) subgames,

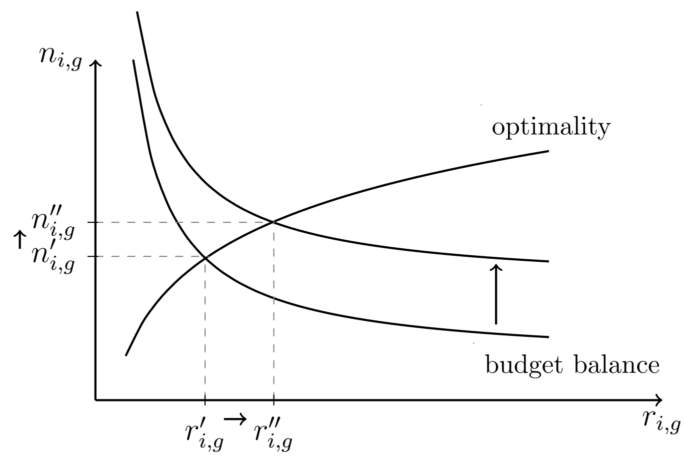
$$\lambda_{i,A}(R_{i,A}) = \lambda_{i,B}(R_{i,B}), \tag{47}$$

and the net revenue requirements for the (i, A) and (i, B) subgames sum to the net revenue requirement for the i subgame,

$$R_{i,A} + R_{i,B} = R_i. \tag{48}$$

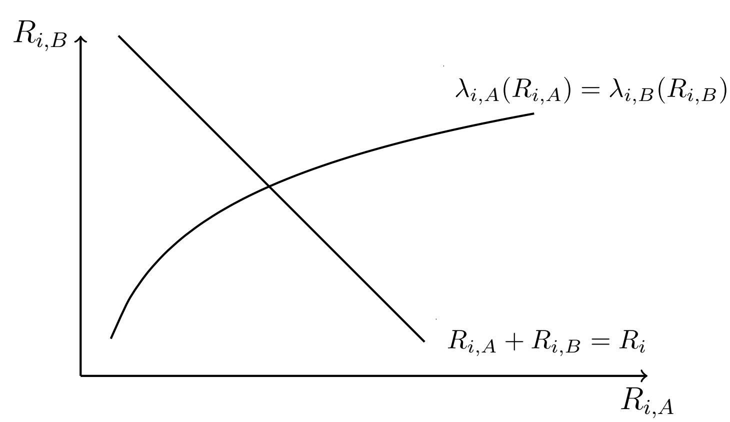
We now wish to show that for any given net revenue requirement R_i, there exists a unique $(R_{i,A}, R_{i,B})$ pair that establishes equilibrium in the i subgame by simultaneously satisfying (47) and (48).

The condition in (48) obviously establishes a strictly decreasing relationship between $R_{i,A}$ and $R_{i,B}$ (i.e., a line with a slope of -1). Now consider what happens in the (i,g) subgame when the net revenue requirement $R_{i,g}$ increases. Since more net revenue must be collected, for any value of $r_{i,g}$, the budget-balancing value of $n_{i,g}$ increases. This causes the budget-balance curve to shift upward, and therefore causes both $r_{i,g}$ and $n_{i,g}$ to increase:



As $r_{i,g}$ and $n_{i,g}$ increase and we move to the right along the optimality curve, both sides of (40) increase and therefore the Lagrange multiplier $\lambda_{i,g}$ increases (intuitively, increasing $R_{i,g}$ tightens the budget constraint and raises the shadow value of funds in the (i,g) subgame). The function $\lambda_{i,g}(R_{i,g})$ is thus strictly increasing, and (47) therefore gives a strictly increasing relationship between $R_{i,A}$ and $R_{i,B}$.

Equilibrium in the i subgame (for arbitrary net revenue requirement R_i) thus occurs at the intersection of a strictly increasing relationship and a strictly decreasing relationship between $R_{i,A}$ and $R_{i,B}$:



Since the $R_{i,A} + R_{i,B} = R_i$ relationship is simply a line with a slope of -1, it satisfies Inada conditions. Therefore, for any given net revenue requirement R_i, there exists a unique equilibrium to the i subgame.

A.2.4 Unique Equilibrium to the Overall Game

Finally, combine the H and L subgames into the overall game. We showed above that any net revenue requirement R_i maps to a unique equilibrium in the i subgame where (47) and (48) are satisfied. Let $\lambda_i(R_i) = \lambda_{i,A}(R_{i,A}) = \lambda_{i,B}(R_{i,B})$ be the Lagrange multiplier value – as a function of R_i – that is equated across the (i, A) and (i, B) subgames in the i-subgame equilibrium. Equilibrium in the overall game occurs when the Lagrange multipliers are equated across the H and L subgames,

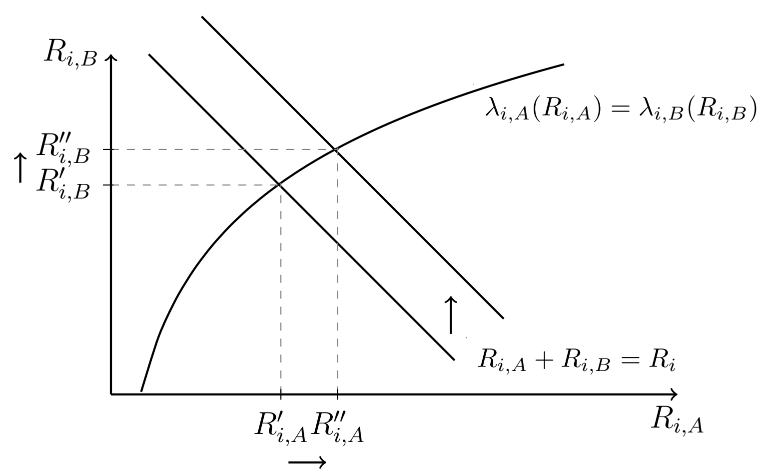
$$\lambda_H(R_H) = \lambda_L(R_L), \tag{49}$$

and the net revenue requirements for the H and L subgames sum to 0,

$$R_H + R_L = 0. \tag{50}$$

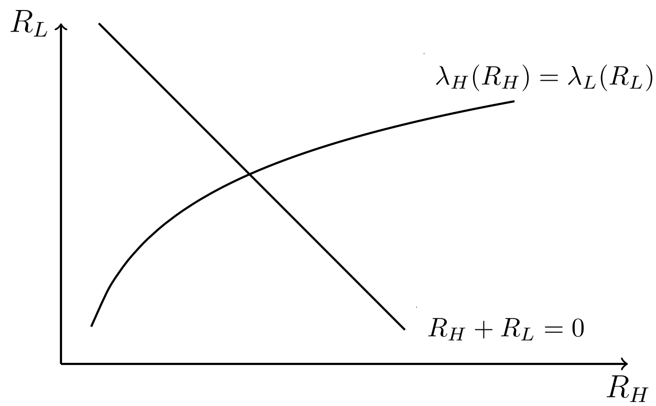
We now wish to show that there exists a unique (R_H, R_L) pair that establishes equilibrium in the overall game by simultaneously satisfying (49) and (50).

Again, (50) is simply a line with a slope of -1. Now consider what happens in the i subgame when the net revenue requirement R_i increases. This shifts the $R_{i,A} + R_{i,B} = R_i$ line upward, and therefore causes both $R_{i,A}$ and $R_{i,B}$ to increase:



Since $\lambda_{i,A}(R_{i,A})$ and $\lambda_{i,B}(R_{i,B})$ are strictly increasing functions, $\lambda_i = \lambda_{i,A} = \lambda_{i,B}$ increases. The function $\lambda_i(R_i)$ is thus strictly increasing, and (49) gives a strictly increasing relationship between R_H and R_L.

Equilibrium in the overall game thus occurs at the intersection of a strictly increasing relationship and a strictly decreasing relationship between R_H and R_L:



Since the $R_H + R_L = 0$ relationship is simply a line with a slope of -1, it satisfies Inada conditions. Therefore, there exists a unique symmetric equilibrium to the overall game.

A.2.5 Unique Social Optimum

The social optimum has the states acting symmetrically, and subjects the states to the same budget constraint as in the symmetric equilibrium. The only difference between the social optimum and equilibrium is the divergence between the social planner's and competing states' objective functions. Taking first-order conditions with respect to $r_{i,g}$ and $n_{i,g}$ for the social planner's problem in (11), we obtain:

$$\mathbf{1}_{g=A}(\alpha_A) \cdot \left(\frac{\partial p^r_{i,g}}{\partial r_{i,g}} + \frac{\partial p^n_{i,g}}{\partial r_{i,g}} \right) + \lambda \left(\frac{\partial p^r_{i,g}}{\partial r_{i,g}}(r_{i,g} - c) + p^r_{i,g} + \frac{\partial p^n_{i,g}}{r_{i,g}}(n_{i,g} - c) \right) = 0, \tag{51}$$

$$\mathbf{1}_{g=A}(\alpha_A) \cdot \left(\frac{\partial p^n_{i,g}}{\partial n_{i,g}} + \frac{\partial p^r_{i,g}}{\partial n_{i,g}} \right) + \lambda \left(\frac{\partial p^n_{i,g}}{\partial n_{i,g}}(n_{i,g} - c) + p^n_{i,g} + \frac{\partial p^r_{i,g}}{n_{i,g}}(r_{i,g} - c) \right) = 0, \tag{52}$$

where λ is again the Lagrange multiplier on the budget constraint. Note that relative to the equilibrium first-order conditions in (38)-(39), the social-planner first-order conditions in (51)-(52) contain extra derivative terms accounting for business-stealing externalities (i.e., lowering $r_{i,g}$ increases resident enrollment $p^r_{i,g}$ but decreases nonresident enrollment $p^n_{i,g}$, and vice versa). Combining (51) and (52) and again substituting for the choice probability derivatives, we obtain:

$$\frac{p^n_{i,g} - (1 - p^r_{i,g})}{1 + \psi\beta_i\big(p^n_{i,g}(n_{i,g} - c) - (1 - p^r_{i,g})(r_{i,g} - c)\big)} = \frac{p^r_{i,g} - (1 - p^n_{i,g})}{1 + \psi\beta_i\big(p^r_{i,g}(r_{i,g} - c) - (1 - p^n_{i,g})(n_{i,g} - c)\big)} \tag{53}$$

Since $p^n_{i,g} - (1 - p^r_{i,g}) = p^r_{i,g} - (1 - p^n_{i,g}) = -p^x_{i,g}$, the numerators on either side of (53) are equal. Thus the denominators must be equal, and we have:

$$\begin{aligned} p^n_{i,g}(n_{i,g} - c) - (1 - p^r_{i,g})(r_{i,g} - c) &= p^r_{i,g}(r_{i,g} - c) - (1 - p^n_{i,g})(n_{i,g} - c) \\ p^n_{i,g}(n_{i,g} - c) + (1 - p^n_{i,g})(n_{i,g} - c) &= p^r_{i,g}(r_{i,g} - c) + (1 - p^r_{i,g})(r_{i,g} - c) \\ n_{i,g} - c &= r_{i,g} - c \\ n_{i,g} &= r_{i,g} \end{aligned} \tag{54}$$

The social planner thus does not discriminate on the basis of residence status and sets $r_{i,g} = n_{i,g}, \forall i \in \{H, L\}, \forall g \in \{A, B\}$. This replicates the theoretical finding in Knight and Schiff (2019) that the social planner (in a model without income or achievement heterogeneity) sets resident tuition equal to nonresident tuition.

To see that there exists a unique social optimum, simply repeat the steps in Sections A.2.1-A.2.4, but in the (i, g) subgame, replace the optimality condition in (40) with the social planner's optimality condition in (54). Since both (40) and (54) give strictly increasing optimality relationships between $r_{i,g}$ and $n_{i,g}$, all logic used in Sections A.2.1-A.2.4 continues to hold. ■

A.3 Proof of Propositions 2-3: Need-Based Aid

A.3.1 Limits as $\delta \to \infty$

First, establish the final statement of Proposition 3: equilibrium and socially optimal resident financial aid converge in the limit as $\delta \to \infty$.

As $\delta \to \infty$, travel becomes prohibitively costly and no students choose to migrate, so $p^n_{i,g} = 0 \ \forall (i, g)$ no matter the states' tuition choices. Thus there is no strategic interaction between the two states (neither state faces the threat of outmigration or exerts any effort to attract the other's students), so the state optimization problem in (9) only concerns resident tuition choices and reduces to:

$$\begin{aligned} \max_{\{r^s_{i,g}\}} \ \alpha_r \sum_{i \in \{H,L\}} \phi_i \alpha_A p^{r,s}_{i,A} + (1 - \phi_i) p^{r,s}_{i,B} \\ \text{s.t.} \\ \sum_{i \in \{H,L\}} \phi_i p^{r,s}_{i,A}(r^s_{i,A} - c) + (1 - \phi_i) p^{r,s}_{i,B}(r^s_{i,B} - c) = 0. \end{aligned} \tag{55}$$

Similarly, since the $p^n_{i,g}$ values are fixed at 0 as $\delta \to \infty$, there are no business-stealing externalities between the states and the social planner simply chooses the tuition profile that maximizes achievement-weighted resident enrollment in each state independently. The cross-state summation in the planner's objective function can thus be replaced with a simple factor of 2, so the planner's problem in (11) becomes:

$$\max_{\{r_{i,g}\}} \; 2\sum_{i\in\{H,L\}} \phi_i \alpha_A p^r_{i,A} + (1-\phi_i)p^r_{i,B}$$

$$\text{s.t.}$$

$$\sum_{i\in\{H,L\}} \phi_i p^r_{i,A}(r_{i,A}-c) + (1-\phi_i)p^r_{i,B}(r_{i,B}-c) = 0 \;\; \forall s \in \{E, W\}. \tag{56}$$

Because the state and planner optimization problems in (55)-(56) have the same budget constraint and objective functions that differ only by a multiplicative constant, the states and planner make identical resident tuition choices. Thus, as $\delta \to \infty$, all functions of the resident tuition variables (including need- and merit-based aid) become equal in the equilibrium and the social optimum.

A.3.2 Monotonicity of Equilibrium Need-Based Aid

Next, establish the need-based comparative statics in Proposition 3, i.e., that equilibrium need-based aid for resident students (for both achievement types) is strictly increasing in δ.

Recall from Proposition 1 and the discussion in Section 2.1.4 that the assumption of a sufficiently large ψ guarantees that high-income attendance rates are higher – i.e., $p^r_{H,g} > p^r_{L,g}$, $p^n_{H,g} > p^n_{L,g}\,\forall g \in \{A, B\}$ – in equilibrium. Of course, since $p^r_{i,g} + p^n_{i,g} + p^x_{i,g} = 1$, the assumption on ψ also ensures that $p^x_{H,g} < p^x_{L,g}$ in equilibrium.

Start at the equilibrium that arises from some δ_0. Choosing some $g \in \{A, B\}$ and taking first-order conditions with respect to $r_{H,g}$ and $r_{L,g}$ for the state's optimization problem in (9), we obtain:

$$\alpha_r \cdot (\mathbf{1}_{\{g=A\}}\alpha_A) \cdot \frac{\partial p^r_{H,g}}{\partial r_{H,g}} + \lambda \left(\frac{\partial p^r_{H,g}}{\partial r_{H,g}}(r_{H,g}-c) + p^r_{H,g} \right) = 0, \tag{57}$$

$$\alpha_r \cdot (\mathbf{1}_{\{g=A\}}\alpha_A) \cdot \frac{\partial p^r_{L,g}}{\partial r_{L,g}} + \lambda \left(\frac{\partial p^r_{L,g}}{\partial r_{L,g}}(r_{L,g}-c) + p^r_{L,g} \right) = 0, \tag{58}$$

where λ is the Lagrange multiplier on the budget constraint. Combining (57) and (58), and using the fact that $\frac{\partial p^r_{i,g}}{\partial r_{i,g}} = -\psi\beta_i p^r_{i,g}(1-p^r_{i,g})$, we obtain:

$$\frac{\beta_H(1-p^r_{H,g})}{1-\psi\beta_H(1-p^r_{H,g})(r_{H,g}-c)} = \frac{\beta_L(1-p^r_{L,g})}{1-\psi\beta_L(1-p^r_{L,g})(r_{L,g}-c)}.$$

Rearranging, we obtain the equilibrium optimality condition for need-based aid:

$$r_{H,g} - r_{L,g} = \frac{1}{\psi}\left(\frac{1}{\beta_H(1-p^r_{H,g})} - \frac{1}{\beta_L(1-p^r_{L,g})} \right). \tag{59}$$

Now, fixing the tuition values from the δ_0 equilibrium (and thus the left-hand side of (59)), consider the effect of a small increase in travel costs from δ_0 to δ_1. Using the fact that

$\frac{\partial p^r_{i,g}}{\partial \delta} = \psi p^r_{i,g} p^n_{i,g}$, the change in the right-hand side of (59) is:

$$\begin{aligned}
&\frac{\partial}{\partial \delta}\left[\frac{1}{\psi \beta_H (1-p^r_{H,g})} - \frac{1}{\psi \beta_L (1-p^r_{L,g})}\right] \\
=&\frac{\partial}{\partial \delta}\left[\frac{1}{\psi \beta_H (1-p^r_{H,g})}\right] - \frac{\partial}{\partial \delta}\left[\frac{1}{\psi \beta_L (1-p^r_{L,g})}\right] \\
=&\frac{\frac{\partial p^r_{H,g}}{\partial \delta}}{\psi \beta_H (1-p^r_{H,g})^2} - \frac{\frac{\partial p^r_{L,g}}{\partial \delta}}{\psi \beta_L (1-p^r_{L,g})^2} \\
=&\frac{p^r_{H,g} p^n_{H,g}}{\beta_H (1-p^r_{H,g})^2} - \frac{p^r_{L,g} p^n_{L,g}}{\beta_L (1-p^r_{L,g})^2} \\
>&\,0,
\end{aligned}$$

since $\beta_H < \beta_L$, and in equilibrium, $p^r_{H,g} > p^r_{L,g}$, $p^n_{H,g} > p^n_{L,g}$. Thus, fixing the tuition values from the δ_0 equilibrium, the increase to δ_1 causes the right-hand side of (59) to increase. To reestablish equality in the δ_1 equilibrium, the tuition values must change so as to increase the left-hand side and decrease the right-hand side of (59). Since the left-hand side of (59) is simply the expression for need-based aid for (the arbitrarily chosen) achievement group g, it must be that need-based aid is strictly higher in the δ_1 equilibrium than in the δ_0 equilibrium, and more generally that equilibrium need-based aid is strictly increasing in δ.

A.3.3 Monotonicity of Socially Optimal Need-Based Aid

Now establish a helpful lemma: socially optimal need-based aid for resident students (for both achievement types) is strictly *decreasing* in δ.

Again start at some δ_0. Choosing some $g \in \{A, B\}$ and taking first-order conditions with respect to $r_{H,g}$ and $r_{L,g}$ for the social planner's problem in (11), we obtain:

$$\mathbf{1}_{g=A}(\alpha_A) \cdot \left(\frac{\partial p^r_{H,g}}{\partial r_{H,g}} + \frac{\partial p^n_{H,g}}{\partial r_{H,g}}\right) + \lambda \left(\frac{\partial p^r_{H,g}}{\partial r_{H,g}}(r_{H,g} - c) + p^r_{H,g} + \frac{\partial p^n_{H,g}}{r_{H,g}}(n_{H,g} - c)\right) = 0, \quad (60)$$

$$\mathbf{1}_{g=A}(\alpha_A) \cdot \left(\frac{\partial p^r_{L,g}}{\partial r_{L,g}} + \frac{\partial p^n_{L,g}}{\partial r_{L,g}}\right) + \lambda \left(\frac{\partial p^r_{L,g}}{\partial r_{L,g}}(r_{L,g} - c) + p^r_{L,g} + \frac{\partial p^n_{L,g}}{r_{L,g}}(n_{L,g} - c)\right) = 0. \quad (61)$$

Combining (60) and (61) and again substituting for the choice probability derivatives gives

$$\frac{\beta_H \big(p^n_{H,g} - (1-p^r_{H,g})\big)}{1 + \psi \beta_H \big(p^n_{H,g}(n_{H,g} - c) - (1-p^r_{H,g})(r_{H,g} - c)\big)} = \frac{\beta_L \big(p^n_{L,g} - (1-p^r_{L,g})\big)}{1 + \psi \beta_L \big(p^n_{L,g}(n_{L,g} - c) - (1-p^r_{L,g})(r_{L,g} - c)\big)}.$$

Rearranging, using the fact that $p^n_{i,g} - (1 - p^r_{i,g}) = -p^x_{i,g}$ to simplify the numerators, and using the fact that the planner sets $r_{i,g} = n_{i,g} \forall (i,g)$ (see again Section A.2.5) to simplify the denominators, we obtain the social planner's optimality condition for need-based aid:

$$r_{H,g} - r_{L,g} = \frac{1}{\psi}\left(\frac{1}{\beta_H p^x_{H,g}} - \frac{1}{\beta_L p^x_{L,g}}\right). \quad (62)$$

Now, fixing the socially optimal tuition values for δ_0 (and thus the left-hand side of (62)), consider the effect of a small increase in travel costs from δ_0 to δ_1. Using the fact that $\frac{\partial p^x_{i,g}}{\partial \delta} = \psi p^x_{i,g} p^n_{i,g}$, the change in the right-hand side of (62) is:

$$
\begin{aligned}
&\frac{\partial}{\partial \delta}\left[\frac{1}{\psi \beta_H p^x_{H,g}} - \frac{1}{\beta_L p^x_{L,g}}\right] \\
=&\frac{\partial}{\partial \delta}\left[\frac{1}{\psi \beta_H p^x_{H,g}}\right] - \frac{\partial}{\partial \delta}\left[\frac{1}{\beta_L p^x_{L,g}}\right] \\
=&\frac{\frac{-\partial p^x_{H,g}}{\partial \delta}}{\psi \beta_H p^{x^2}_{H,g}} - \frac{\frac{-\partial p^x_{L,g}}{\partial \delta}}{\psi \beta_L p^{x^2}_{L,g}} \\
=&\frac{p^n_{L,g}}{\beta_L p^x_{L,g}} - \frac{p^n_{H,g}}{\beta_H p^x_{H,g}}.
\end{aligned} \tag{63}
$$

The expression in (63) is negative if:

$$
\frac{p^n_{L,g}}{\beta_L p^x_{L,g}} < \frac{p^n_{H,g}}{\beta_H p^x_{H,g}}. \tag{64}
$$

There are two cases to consider. First, we could have $p^x_{H,g} \leq p^x_{L,g}$. If so, then we must have either $p^r_{H,g} \geq p^r_{L,g}$ or $p^n_{H,g} \geq p^n_{L,g}$ (since $p^r_{i,g} + p^n_{i,g} + p^x_{i,g} = 1$). But in fact, since the social planner does not discriminate on the basis of residence status and sets $r_{i,g} = n_{i,g}$ $\forall (i,g)$ (see again Section A.2.5), the H vs. L ranking of resident and nonresident enrollment rates must be the same, so we must have $p^r_{H,g} \geq p^r_{L,g}$ and $p^n_{H,g} \geq p^n_{L,g}$. So in the first case, $p^x_{H,g} \leq p^x_{L,g}$ and $p^n_{H,g} \geq p^n_{L,g}$. Since $\beta_H < \beta_L$, this implies that (64) is true, and thus (63) is negative.

In the second case, we could have $p^x_{H,g} > p^x_{L,g}$. Again using that $p^r_{i,g} + p^n_{i,g} + p^x_{i,g} = 1$, observe that:

$$
\begin{aligned}
\frac{p^x_{H,g}}{p^x_{L,g}} &= \frac{1 - p^r_{H,g} - p^n_{H,g}}{1 - p^r_{L,g} - p^n_{L,g}} \\
&= \frac{p^n_{H,g} + p^r_{H,g} - 1}{p^n_{L,g} + p^r_{L,g} - 1} \\
&< \frac{p^n_{H,g}}{p^n_{L,g}},
\end{aligned}
$$

where the last line follows from having $p^r_{H,g} < p^r_{L,g} < 1$ and $p^n_{H,g} < p^n_{L,g}$. We thus have:

$$
\begin{aligned}
&\frac{p^x_{H,g}}{p^x_{L,g}} < \frac{p^n_{H,g}}{p^n_{L,g}} \\
\implies &\frac{p^x_{H,g} p^n_{L,g}}{p^n_{H,g} p^x_{L,g}} < 1 < \frac{\beta_L}{\beta_H},
\end{aligned} \tag{65}
$$

since again $\beta_L > \beta_H$. Rearranging (65) gives (64), and so again in the second case we have that (63) is negative.

Since (63) is negative, when fixing the tuition values from the δ_0 social optimum, the increase to δ_1 causes the right-hand side of (62) to decrease. To reestablish equality in the δ_1 social optimum, the tuition values must change so as to decrease the left-hand side and increase the right-hand side of (62). Since the left-hand side of (62) is simply the expression for need-based aid for (the arbitrarily chosen) achievement group g, it must be that need-based aid is strictly lower in the δ_1 social optimum than in the δ_0 social optimum, and more generally that socially optimal need-based aid is strictly decreasing in δ.

A.3.4 Comparison of Equilibrium and Socially Optimal Need-Based Aid

Finally, establish the need-based comparison between equilibrium and socially optimal financial aid in Proposition 2, i.e., that resident need-based aid for both achievement types is strictly lower in the equilibrium than in the social optimum.

This follows directly from the results established above in Sections A.3.1-A.3.4. Proceed by contradiction. Emphasizing the dependence on travel costs by writing the resident tuition values as explicit functions of δ (and fixing all other model parameters at arbitrary values), suppose that for some δ_0 and some achievement type $g \in \{A, B\}$, equilibrium need-based aid were weakly higher than socially optimal need-based aid, with

$$r^{eq}_{H,g}(\delta_0) - r^{eq}_{L,g}(\delta_0) \geq r^*_{H,g}(\delta_0) - r^*_{L,g}(\delta_0). \tag{66}$$

Choose a small $\epsilon > 0$. Since equilibrium need-based aid is strictly increasing in δ and socially optimal need-based aid is strictly decreasing in δ, there must exist some sufficiently large $\delta_1 > \delta_0$ such that for all $\hat{\delta} \geq \delta_1$, the positive gap between equilibrium and socially optimal need-based aid is at least ϵ:

$$r^{eq}_{H,g}(\hat{\delta}) - r^{eq}_{L,g}(\hat{\delta}) - \left(r^*_{H,g}(\hat{\delta}) - r^*_{L,g}(\hat{\delta})\right) \geq \epsilon. \tag{67}$$

But (67) contradicts the limiting behavior established in Section A.3.1. Since equilibrium and socially optimal financial aid for resident students converge as $\delta \to \infty$, for any $\epsilon > 0$ (including the one we chose for (67)), there must exist some δ_2 such that for all $\hat{\delta} \geq \delta_2$, the absolute value of the difference between equilibrium and socially optimal need-based aid is strictly *less* than ϵ:

$$\left| r^{eq}_{H,g}(\hat{\delta}) - r^{eq}_{L,g}(\hat{\delta}) - \left(r^*_{H,g}(\hat{\delta}) - r^*_{L,g}(\hat{\delta})\right) \right| < \epsilon.$$

The supposition in (66) thus leads to a contradiction, and cannot be true: there cannot exist any δ value for which equilibrium need-based aid weakly exceeds socially optimal need-based aid for either achievement type. At any set of parameter values, equilibrium need-based aid must therefore be strictly lower than socially optimal need-based aid for both achievement types. ■

A.4 Proof of Propositions 2-3: Merit-Based Aid

A.4.1 Lower Tuition Prices and Higher Attendance Rates for High Achievers

First, note that since $\alpha_A > 1$, both the states and the social planner have a strict preference for high-achieving enrollment. The states and the planner must therefore treat high-achieving students more favorably than low-achieving students, and merit aid (for residents, nonresidents, and both income types) must be strictly positive in both the equilibrium and social optimum. Formally, we must have:

$$r_{i,A}^{eq} < r_{i,B}^{eq},\ n_{i,A}^{eq} < n_{i,B}^{eq}\ \ \forall i \in \{H, L\},$$
$$r_{i,A}^{*} < r_{i,B}^{*},\ n_{i,A}^{*} < n_{i,B}^{*}\ \ \forall i \in \{H, L\}.$$

Since high and low-achieving students in the same income group have the same tuition sensitivity, this in turn implies that high-achieving students must have strictly higher resident and nonresident enrollment in the equilibrium and the social optimum:

$$p_{i,A}^{r,eq} > p_{i,B}^{r,eq},\ p_{i,A}^{n,eq} > p_{i,B}^{n,eq}\ \ \forall i \in \{H, L\},$$
$$p_{i,A}^{r*} > p_{i,B}^{r*},\ p_{i,A}^{n*} > p_{i,B}^{n*}\ \ \forall i \in \{H, L\}.$$

Of course, since $p_{i,g}^{r} + p_{i,g}^{n} + p_{i,g}^{x} = 1$, high-achieving students must also have lower nonattendance rates in both the equilibrium and social optimum:

$$p_{i,A}^{x,eq} < p_{i,B}^{x,eq}\ \ \forall i \in \{H, L\},$$
$$p_{i,A}^{x*} < p_{i,B}^{x*}\ \ \forall i \in \{H, L\}.$$

A.4.2 Monotonicity of Equilibrium Tuition Prices

Now establish a helpful lemma: all equilibrium resident tuition prices $r_{i,g}$ are strictly increasing in δ, and all equilibrium nonresident tuition prices $n_{i,g}$ are strictly decreasing in δ.

Recall from Section A.2.1 the optimality condition in (40) governing resident and nonresident tuition for a given (i, g) type:

$$\frac{\alpha_r(1 - p_{i,g}^{r})}{1 - \psi\beta_i(1 - p_{i,g}^{r})(r_{i,g} - c)} = \frac{1 - p_{i,g}^{n}}{1 - \psi\beta_i(1 - p_{i,g}^{n})(n_{i,g} - c)}$$

The derivative of the left-hand side with respect to $p_{i,g}^{r}$ is

$$\alpha_r \frac{-1}{(1 - \psi\beta_i(1 - p_{i,g}^{r})(r_{i,g} - c))^2} < 0,$$

so the left-hand side is strictly decreasing in $p_{i,g}^{r}$. Identical logic establishes that the right-hand side is strictly decreasing in $p_{i,g}^{n}$. Next, observe that the derivative of the left-hand side with respect to $r_{i,g}$ (using the chain rule to account for $\frac{\partial p_{i,g}^{r}}{\partial r_{i,g}}$) is

$$\alpha_r \frac{\psi\beta_i(1 - p_{i,g}^{r})}{(1 - \psi\beta_i(1 - p_{i,g}^{r})(r_{i,g} - c))^2} > 0,$$

so the left-hand side is strictly increasing in $r_{i,g}$. Identical logic establishes that the right-hand side is strictly increasing in $n_{i,g}$. Finally, since $\frac{\partial p_{i,g}^{r}}{\partial n_{i,g}} = \frac{\partial p_{i,g}^{n}}{\partial r_{i,g}} = \psi\beta_i p_{i,g}^{r} p_{i,g}^{n} > 0$, the left-hand side is strictly decreasing in $n_{i,g}$ and the right-hand side is strictly decreasing in $r_{i,g}$.

Start from the equilibrium that arises from some δ_0. Fix the equilibrium tuition prices from the δ_0 equilibirum and consider a small increase in travel costs to δ_1. Since $\frac{\partial p^r_{i,g}}{\partial \delta} = \psi p^r_{i,g} p^n_{i,g} > 0$ and $\frac{\partial p^n_{i,g}}{\partial \delta} = -\psi p^n_{i,g}(1 - p^n_{i,g}) < 0$, the increase to δ_1 causes the left-hand side of (40) to decrease and the right-hand side of (40) to increase. To reestablish equality in the δ_1 equilibrium, the tuition prices must change so as to increase the left-hand side and decrease the right-hand side of (40). Given the signs of the derivatives discussed above (left-hand side increasing in $r_{i,g}$ and decreasing in $n_{i,g}$, right-hand side increasing in $n_{i,g}$ and decreasing in $r_{i,g}$), this must be accomplished by increasing resident tuition $r_{i,g}$ and decreasing nonresident tuition $n_{i,g}$ for the (arbitrarily chosen) (i, g) type. All equilibrium resident tuition prices are thus strictly increasing in δ.

A.4.3 Monotonicity of Equilibrium Merit-Based Aid

Residents Now establish the merit-based comparative statics in Proposition 3, i.e., that equilibrium merit-based for resident students (for both income types) is strictly decreasing in δ.

Start at the equilibrium that arises from some δ_0. Choosing some $i \in \{H, L\}$ and taking first-order conditions with respect to $r_{i,A}$ and $r_{i,B}$ for the state's optimization problem in (9), we obtain:

$$\alpha_A \frac{\partial p^r_{i,A}}{\partial r_{i,A}} + \lambda \left(\frac{\partial p^r_{i,A}}{r_{i,A}} (r_{i,A} - c) + p^r_{i,A} \right) = 0, \tag{68}$$

$$\frac{\partial p^r_{i,B}}{\partial r_{i,B}} + \lambda \left(\frac{\partial p^r_{i,B}}{r_{i,B}} (r_{i,B} - c) + p^r_{i,B} \right) = 0, \tag{69}$$

where λ is the Lagrange multiplier on the budget constraint. Combining (68)-(69), using the fact that $\frac{\partial p^r_{i,g}}{\partial r_{i,g}} = -\psi \beta_i p^r_{i,g}(1 - p^r_{i,g})$, and simplifying, we obtain:

$$\frac{1 - p^r_{i,A}}{1 - p^r_{i,B}} = \frac{1 + \lambda(r_{i,B} - c)}{\alpha_A + \lambda(r_{i,A} - c)} \tag{70}$$

Now, fixing the tuition values from the δ_0 equilibrium (and thus the rightmost multiplicative term on each side of (70)), consider the effect of a small increase in travel costs from δ_0 to δ_1. Using the fact that $\frac{\partial p^r_{i,g}}{\partial \delta} = \psi p^r_{i,g} p^n_{i,g}$, the proportional decrease in the numerator on the left-hand side of (70) is

$$\frac{\partial \log(1 - p^r_{i,A})}{\partial \delta} = \frac{\psi p^r_{i,A} p^n_{i,A}}{1 - p^r_{i,A}}, \tag{71}$$

and the proportional decrease in the denominator of the left-hand side of (70) is

$$\frac{\partial \log(1 - p^r_{i,B})}{\partial \delta} = \frac{\psi p^r_{i,B} p^n_{i,B}}{1 - p^r_{i,B}}. \tag{72}$$

Since $p^r_{i,A} > p^r_{i,B}$ and $p^n_{i,A} > p^n_{i,B}$, the derivative in (71) is larger in magnitude than the derivative in (72). Thus, fixing the tuition values from the δ_0 equilibrium, the increase in travel costs to δ_1 causes the left-hand side of (70) to decrease. To reestablish equality in the δ_1 equilibrium, the tuition values must change so as to increase the left-hand side and decrease the right-hand side of (70).

Now consider the tuition changes that must occur to decrease the right-hand side of (70). Let $dr_{i,A}$ and $dr_{i,B}$ be the tuition changes that occur to increase the right-hand side of (70) and reestablish equality in the δ_1 equilibrium. The proportional change in the numerator must be smaller than the proportional change in the denominator, so we must have:

$$\frac{\lambda dr_{i,B}}{1 + \lambda(r_{i,B} - c)} < \frac{\lambda dr_{i,A}}{\alpha_A + \lambda(r_{i,A} - c)} \tag{73}$$

Since all equilibrium resident tuition prices are strictly increasing in δ (see Section A.4.2 above), we must have $dr_{i,A} > 0$ and $dr_{i,B} > 0$, so both sides of (73) are positive. Note also that since $1 - p^r_{i,A} < 1 - p^r_{i,B}$, from (70), we have

$$1 + \lambda(r_{i,B} - c) < \alpha_A + \lambda(r_{i,A} - c).$$

Therefore, in order for (73) to hold, we must also have:

$$\begin{aligned} \lambda dr_{i,B} &< \lambda dr_{i,A} \\ \implies dr_{i,B} &< dr_{i,A} \end{aligned}$$

Thus, in moving from the δ_0 equilibrium to the δ_1 equilibrium, $r_{i,B}$ increases strictly less than $r_{i,A}$. Resident merit-based aid $r_{i,B} - r_{i,A}$ for (the arbitrarily chosen) income group i is therefore strictly lower in the δ_1 equilibrium, and more generally, resident merit-based aid is strictly decreasing in δ. This establishes the merit-based comparative static in Proposition 3.

Nonresidents As a lemma to be used below in Section A.4.4, observe also that *non*resident merit aid is strictly *increasing* in δ. To see this, write the nonresident version of the optimality condition in (70):

$$\frac{1 - p^n_{i,A}}{1 - p^n_{i,B}} = \frac{1 + \lambda(n_{i,B} - c)}{\alpha_A + \lambda(n_{i,A} - c)} \tag{74}$$

Consider again a small increase in travel costs from some δ_0 to δ_1. Fixing the tuition values from the δ_0 equilibrium, the proportional increase in the numerator of the left-hand side of (74) is

$$\frac{\partial \log(1 - p^n_{i,A})}{\partial \delta} = \frac{\psi p^n_{i,A}(1 - p^n_{i,A})}{1 - p^n_{i,A}} = \psi p^n_{i,A},$$

and the proportional increase in the denominator of the left-hand side of (74) is

$$\frac{\partial \log(1 - p^n_{i,B})}{\partial \delta} = \frac{\psi p^n_{i,B}(1 - p^n_{i,B})}{1 - p^n_{i,B}} = \psi p^n_{i,B}.$$

Since $p^n_{i,A} > p^n_{i,B}$, the increase in travel costs to δ_1 causes the left-hand side of (74) to increase. To reestablish equality in the δ_1 equilibrium, the tuition values must change so as to decrease the left-hand side and increase the right-hand side of (74). Again denoting these tuition changes with $dn_{i,A}$ and $dn_{i,B}$, in order for the right-hand side of (74) to increase, we must have:

$$\frac{\lambda dn_{i,B}}{1+\lambda(n_{i,B}-c)} > \frac{\lambda dn_{i,A}}{\alpha_A+\lambda(n_{i,A}-c)} \tag{75}$$

Recall from Section A.4.2 that all equilibrium nonresident tuition prices are strictly decreasing in δ, so $dn_{i,A} < 0$ and $dn_{i,B} < 0$. Multiplying both sides of (75) by -1, we obtain:

$$\frac{\lambda |dn_{i,B}|}{1+\lambda(n_{i,B}-c)} < \frac{\lambda |dn_{i,A}|}{\alpha_A+\lambda(n_{i,A}-c)}$$

Again, since $1-p^n_{i,A} < 1-p^n_{i,B}$, from (74), we have

$$1+\lambda(n_{i,B}-c) < \alpha_A+\lambda(n_{i,A}-c).$$

Therefore, in order for (75) to hold, we must also have:

$$\begin{aligned} \lambda|dn_{i,B}| &< \lambda|dn_{i,A}| \\ \implies |dn_{i,B}| &< |dn_{i,A}| \end{aligned}$$

Thus, in moving from the δ_0 equilibrium to the δ_1 equilibrium, $n_{i,B}$ decreases strictly less than $n_{i,A}$. Nonresident merit-based aid $n_{i,B}-n_{i,A}$ for (the arbitrarily chosen) income group i is therefore strictly higher in the δ_1 equilibrium, and more generally, nonresident merit-based aid is strictly increasing in δ.

A.4.4 Comparison of Equilibrium and Socially Optimal Merit-Based Aid

Finally, establish the merit-based comparison between equilibrium and socially optimal financial aid in Proposition 2, i.e., that resident merit-based aid for both income types is strictly higher in the equilibrium than in the social optimum.

Two Sufficient Inequalities Begin with the logit choice probability definition that gives resident enrollment $p^r_{i,g}$ for (i,g) students:

$$p^r_{i,g} = \frac{\exp(\psi(\gamma-\beta_i r_{i,g}))}{1+\exp(\psi(\gamma-\beta_i r_{i,g}))+\exp(\psi(\gamma-\beta_i n_{i,g}-\delta))} \tag{76}$$

Taking the log of both sides of (76), fixing an income group i, and combining the expressions for A and B students, we obtain:

$$\begin{aligned} \log(p^r_{i,A})-\log(p^r_{i,B}) &= \log(\exp(\psi(\gamma-\beta_i r_{i,A}))) - \log(\exp(\psi(\gamma-\beta_i r_{i,B}))) \\ &\quad - \log\Big(1+\exp(\psi(\gamma-\beta_i r_{i,A}))+\exp(\psi(\gamma-\beta_i n_{i,A}-\delta))\Big) \\ &\quad + \log\Big(1+\exp(\psi(\gamma-\beta_i r_{i,B}))+\exp(\psi(\gamma-\beta_i n_{i,B}-\delta))\Big) \end{aligned}$$

Simplifying, and using the fact that $1 + \exp(\psi(\gamma - \beta_i r_{i,g})) + \exp(\psi(\gamma - \beta_i n_{i,g} - \delta)) = \frac{1}{p^x_{i,g}}$, we obtain an expression for merit-based aid (which, since it was derived only with choice probability definitions, applies in both the equilibrium and social optimum):

$$r_{i,B} - r_{i,A} = \frac{\log\left(\frac{p^r_{i,A}}{p^r_{i,B}}\right) - \log\left(\frac{p^x_{i,A}}{p^x_{i,B}}\right)}{\psi\beta_i} \tag{77}$$

Therefore, to establish the desired result that $r^{eq}_{i,B} - r^{eq}_{i,A} > r^*_{i,B} - r^*_{i,A}$, it suffices to show that

$$\log\left(\frac{p^{r,eq}_{i,A}}{p^{r,eq}_{i,B}}\right) - \log\left(\frac{p^{x,eq}_{i,A}}{p^{x,eq}_{i,B}}\right) > \log\left(\frac{p^{r*}_{i,A}}{p^{r*}_{i,B}}\right) - \log\left(\frac{p^{x*}_{i,A}}{p^{x*}_{i,B}}\right),$$

which is in turn true if both of the following inequalities hold:

$$\frac{p^{x,eq}_{i,A}}{p^{x,eq}_{i,B}} < \frac{p^{x*}_{i,A}}{p^{x*}_{i,B}}, \tag{78}$$

$$\frac{p^{r,eq}_{i,A}}{p^{r,eq}_{i,B}} > \frac{p^{r*}_{i,A}}{p^{r*}_{i,B}}. \tag{79}$$

Establishing the First Inequality To show that the inequality in (78) holds, consider the optimality conditions that govern merit-based aid in the social optimum and the equilibrium. Taking first-order conditions for the social planner's problem in (11) gives the following condition:

$$\frac{p^{x*}_{i,A}}{p^{x*}_{i,B}} = \frac{1 + \lambda(r^*_{i,B} - c)}{\alpha_A + \lambda(r^*_{i,A} - c)} \tag{80}$$

As established above in Section A.4.3, the equilibrium optimality condition can be written as (70):

$$\frac{1 - p^{r,eq}_{i,A}}{1 - p^{r,eq}_{i,B}} = \frac{1 + \lambda(r^{eq}_{i,B} - c)}{\alpha_A + \lambda(r^{eq}_{i,A} - c)}$$

Substituting for $1 - p^r_{i,g}$ in the equilibrium optimality condition, we obtain:

$$\frac{p^{x,eq}_{i,A} + p^{n,eq}_{i,A}}{p^{x,eq}_{i,B} + p^{n,eq}_{i,B}} = \frac{1 + \lambda(r^{eq}_{i,B} - c)}{\alpha_A + \lambda(r^{eq}_{i,A} - c)}$$

$$\frac{p^{x,eq}_{i,A}\left(1 + \frac{p^{n,eq}_{i,A}}{p^{x,eq}_{i,A}}\right)}{p^{x,eq}_{i,B}\left(1 + \frac{p^{n,eq}_{i,B}}{p^{x,eq}_{i,B}}\right)} = \frac{1 + \lambda(r^{eq}_{i,B} - c)}{\alpha_A + \lambda(r^{eq}_{i,A} - c)}$$

$$\frac{p^{x,eq}_{i,A}}{p^{x,eq}_{i,B}} < \frac{1 + \lambda(r^{eq}_{i,B} - c)}{\alpha_A + \lambda(r^{eq}_{i,A} - c)},$$

where the last line follows from having $p^{n,eq}_{i,A} > p^{n,eq}_{i,B}$ and $p^{x,eq}_{i,A} < p^{x,eq}_{i,B}$. Thus, with the tuition variables and choice probabilities at their equilibrium values, the social planner's optimality condition does not hold; in particular, the left-hand side of the planner's condition in (80) is strictly less than the right-hand side. Thus, relative to the equilibrium, the planner must change the tuition variables so as to increase the left-hand side and decrease the right-hand side of (80). We must therefore have:

$$\frac{p_{i,A}^{x,eq}}{p_{i,B}^{x,eq}} < \frac{p_{i,A}^{x*}}{p_{i,B}^{x*}}$$

Thus the first sufficient inequality in (78) holds.

Lemma: Equilibrium Merit Aid Larger for Residents than Nonresidents Next, establish a helpful lemma: equilibrium merit-based aid is strictly larger for residents than nonresidents. To do so, begin by fixing an income group i and writing the equivalent of (77) for nonresidents:

$$n_{i,B} - n_{i,A} = \frac{\log\left(\frac{p_{i,A}^{n}}{p_{i,B}^{n}}\right) - \log\left(\frac{p_{i,A}^{x}}{p_{i,B}^{x}}\right)}{\psi\beta_i} \tag{81}$$

Note that the right-hand side of (81) differs from the right-hand side of (77) only in the numerator's first term. Since migration becomes prohibitively costly in the limit as $\delta \to \infty$, we have

$$\lim_{\delta\to\infty} p_{i,A}^{n} = \lim_{\delta\to\infty} p_{i,B}^{n} = 0.$$

Using $\frac{\partial p_{i,g}^{n}}{\partial \delta} = -\psi p_{i,g}^{n}(1 - p_{i,g}^{n})$ and applying L'Hopital's rule (twice) gives

$$\lim_{\delta\to\infty} \frac{p_{i,A}^{n}}{p_{i,B}^{n}} = 1. \tag{82}$$

Since high achievers must have strictly lower non-attendance rates (including in the limit as $\delta \to \infty$), we must therefore have

$$\lim_{\delta\to\infty} \frac{p_{i,A}^{x}}{p_{i,B}^{x}} < 1,$$

which, given (82), implies

$$\lim_{\delta\to\infty} \frac{p_{i,A}^{r}}{p_{i,B}^{r}} > 1. \tag{83}$$

Given the merit aid expressions in (77) and (81), the inequalities in (82) and (83) in turn imply

$$\lim_{\delta\to\infty} r_{i,B} - r_{i,A} > \lim_{\delta\to\infty} n_{i,B} - n_{i,A}.$$

Recall from Section A.4.3 that equilibrium merit aid for residents is strictly decreasing in δ, and equilibrium merit aid for nonresidents is strictly increasing in δ. We have thus established that

$$\frac{\partial}{\partial \delta}[r_{i,B} - r_{i,A}] < 0, \quad \frac{\partial}{\partial \delta}[n_{i,B} - n_{i,A}] > 0, \quad \lim_{\delta \to \infty} r_{i,B} - r_{i,A} > \lim_{\delta \to \infty} n_{i,B} - n_{i,A}.$$

Therefore, applying the same logic as in Section A.3.4 above, there cannot exist any δ value for which nonresident merit aid weakly exceeds resident merit aid. Equilibrium merit aid (for both income types) is thus strictly larger for residents than nonresidents.

Establishing the Second Inequality Finally, show that the second sufficient inequality in (79) holds. Proceed by contradiction and suppose instead that

$$\begin{aligned} \frac{p^{r,eq}_{i,A}}{p^{r,eq}_{i,B}} &\leq \frac{p^{r*}_{i,A}}{p^{r*}_{i,B}} \\ \implies \frac{p^{r,eq}_{i,A}}{p^{r*}_{i,A}} &\leq \frac{p^{r,eq}_{i,B}}{p^{r*}_{i,B}}. \end{aligned}$$

Recall from the above lemma that equilibrium merit aid is larger for residents than nonresidents. From (77) and (81), we therefore have:

$$\begin{aligned} r^{eq}_{i,A} - r^{eq}_{i,B} = \frac{\log\left(\frac{p^{r,eq}_{i,A}}{p^{r,eq}_{i,B}}\right) - \log\left(\frac{p^{x,eq}_{i,A}}{p^{x,eq}_{i,B}}\right)}{\psi \beta_i} &> n^{eq}_{i,B} - n^{eq}_{i,A} = \frac{\log\left(\frac{p^{n,eq}_{i,A}}{p^{n,eq}_{i,B}}\right) - \log\left(\frac{p^{x,eq}_{i,A}}{p^{x,eq}_{i,B}}\right)}{\psi \beta_i} \\ \implies \log\left(\frac{p^{r,eq}_{i,A}}{p^{r,eq}_{i,B}}\right) &> \log\left(\frac{p^{n,eq}_{i,A}}{p^{n,eq}_{i,B}}\right) \\ \implies \frac{p^{r,eq}_{i,A}}{p^{r,eq}_{i,B}} &> \frac{p^{n,eq}_{i,A}}{p^{n,eq}_{i,B}} \end{aligned}$$

Next, recall that the social planner does not discriminate on the basis of residence status (see again Section A.2.5) and sets $r^*_{i,g} = n^*_{i,g} \, \forall (i,g)$. From (77), we therefore have:

$$\begin{aligned} r^*_{i,B} - r^*_{i,A} = \frac{\log\left(\frac{p^{r*}_{i,A}}{p^{r*}_{i,B}}\right) - \log\left(\frac{p^{x*}_{i,A}}{p^{x*}_{i,B}}\right)}{\psi \beta_i} &= n^*_{i,B} - n^*_{i,A} = \frac{\log\left(\frac{p^{n*}_{i,A}}{p^{n*}_{i,B}}\right) - \log\left(\frac{p^{x*}_{i,A}}{p^{x*}_{i,B}}\right)}{\psi \beta_i} \\ \implies \log\left(\frac{p^{r*}_{i,A}}{p^{r*}_{i,B}}\right) &= \log\left(\frac{p^{n*}_{i,A}}{p^{n*}_{i,B}}\right) \\ \implies \frac{p^{r*}_{i,A}}{p^{r*}_{i,B}} &= \frac{p^{n*}_{i,A}}{p^{n*}_{i,B}} \end{aligned}$$

Our supposition that (79) does not hold thus also implies that

$$\frac{p_{i,A}^{n,eq}}{p_{i,B}^{n,eq}} < \frac{p_{i,A}^{r,eq}}{p_{i,B}^{r,eq}} \le \frac{p_{i,A}^{r*}}{p_{i,B}^{r*}} = \frac{p_{i,A}^{n*}}{p_{i,B}^{n*}}$$
$$\implies \frac{p_{i,A}^{n,eq}}{p_{i,B}^{n,eq}} < \frac{p_{i,A}^{n*}}{p_{i,B}^{n*}}$$
$$\implies \frac{p_{i,A}^{n,eq}}{p_{i,A}^{n*}} < \frac{p_{i,B}^{n,eq}}{p_{i,B}^{n*}}.$$

Now return to the first sufficient inequality in (78), which we showed above is true. Rearranging terms and substituting for $p_{i,g}^{x}$ gives:

$$\frac{p_{i,A}^{x,eq}}{p_{i,B}^{x,eq}} < \frac{p_{i,A}^{x*}}{p_{i,B}^{x*}}$$
$$\frac{p_{i,A}^{x,eq}}{p_{i,A}^{x*}} < \frac{p_{i,B}^{x,eq}}{p_{i,B}^{x*}}$$
$$\frac{1 - p_{i,A}^{r,eq} - p_{i,A}^{n,eq}}{1 - p_{i,A}^{r*} - p_{i,A}^{n*}} < \frac{1 - p_{i,B}^{r,eq} - p_{i,B}^{n,eq}}{1 - p_{i,B}^{r*} - p_{i,B}^{n*}}$$
$$\frac{1 - p_{i,A}^{r*}\left(\frac{p_{i,A}^{r,eq}}{p_{i,A}^{r*}}\right) - p_{i,A}^{n*}\left(\frac{p_{i,A}^{n,eq}}{p_{i,A}^{n*}}\right)}{1 - p_{i,A}^{r*} - p_{i,A}^{n*}} < \frac{1 - p_{i,B}^{r*}\left(\frac{p_{i,B}^{r,eq}}{p_{i,B}^{r*}}\right) - p_{i,B}^{n*}\left(\frac{p_{i,B}^{n,eq}}{p_{i,B}^{n*}}\right)}{1 - p_{i,B}^{r*} - p_{i,B}^{n*}}$$
$$\frac{1 - p_{i,A}^{r*} - p_{i,A}^{n*} + p_{i,A}^{r*}\left(1 - \frac{p_{i,A}^{r,eq}}{p_{i,A}^{r*}}\right) + p_{i,A}^{n*}\left(1 - \frac{p_{i,A}^{n,eq}}{p_{i,A}^{n*}}\right)}{1 - p_{i,A}^{r*} - p_{i,A}^{n*}} < \frac{1 - p_{i,B}^{r*} - p_{i,B}^{n*} + p_{i,B}^{r*}\left(1 - \frac{p_{i,B}^{r,eq}}{p_{i,B}^{r*}}\right) + p_{i,B}^{n*}\left(1 - \frac{p_{i,B}^{n,eq}}{p_{i,B}^{n*}}\right)}{1 - p_{i,B}^{r*} - p_{i,B}^{n*}}$$

$$\frac{p_{i,A}^{x*} + \overbrace{p_{i,A}^{r*}\left(1 - \frac{p_{i,A}^{r,eq}}{p_{i,A}^{r*}}\right) + p_{i,A}^{n*}\left(1 - \frac{p_{i,A}^{n,eq}}{p_{i,A}^{n*}}\right)}^{\equiv z_A}}{p_{i,A}^{x*}} < \frac{p_{i,B}^{x*} + \overbrace{p_{i,B}^{r*}\left(1 - \frac{p_{i,B}^{r,eq}}{p_{i,B}^{r*}}\right) + p_{i,B}^{n*}\left(1 - \frac{p_{i,B}^{n,eq}}{p_{i,B}^{n*}}\right)}^{\equiv z_B}}{p_{i,B}^{x*}}$$
$$\frac{p_{i,A}^{x*}\left(1 + \frac{z_A}{p_{i,A}^{x*}}\right)}{p_{i,A}^{x*}} < \frac{p_{i,B}^{x*}\left(1 + \frac{z_B}{p_{i,B}^{x*}}\right)}{p_{i,B}^{x*}}$$
$$1 + \frac{z_A}{p_{i,A}^{x*}} < 1 + \frac{z_B}{p_{i,B}^{x*}}$$
$$\frac{z_A}{p_{i,A}^{x*}} < \frac{z_B}{p_{i,B}^{x*}} \tag{84}$$

Since $p_{i,A}^{x*} < p_{i,B}^{x*}$, the denominator on the left-hand side of (84) is smaller than the denominator on the right-hand side. Additionally, since $p_{i,A}^{r*} > p_{i,B}^{r*}$, $p_{i,A}^{n*} > p_{i,B}^{n*}$, and by supposition,

$$\frac{p_{i,A}^{r,eq}}{p_{i,A}^{r*}} \le \frac{p_{i,B}^{r,eq}}{p_{i,B}^{r*}},$$
$$\frac{p_{i,A}^{n,eq}}{p_{i,A}^{n*}} < \frac{p_{i,B}^{n,eq}}{p_{i,B}^{n*}},$$

we have $z_A > z_B$, so the numerator on the left-hand side of (84) is larger than the numerator on the right-hand side. (84) is thus a contradiction, and our supposition cannot be true.

The second sufficient inequality in (79) must therefore hold, and we must therefore have $r^{eq}_{i,B} - r^{eq}_{i,A} > r^*_{i,B} - r^*_{i,A}$. Resident merit aid for (the arbitrarily chosen) income group i is thus strictly higher in the equilibrium than in the social optimum. ■

A.5 Proof of Corollary 2

Let $\{\{r^{\delta_0}_{i,g}\}, \{n^{\delta_0}_{i,g}\}\}$ be the equilibrium tuition profile that arises from some travel cost δ_0, and similarly let $\{\{r^{\delta_1}_{i,g}\}, \{n^{\delta_1}_{i,g}\}\}$ be the equilibrium tuition profile that arises from some larger travel cost $\delta_1 > \delta_0$. The difference in the income progressivity of resident tuition between the δ_1 equilibrium and the δ_0 equilibrium can be rewritten as:

$$\begin{aligned}
&\big(r^{\delta_1}_{H,B} - r^{\delta_1}_{L,B} - (r^{\delta_0}_{H,B} - r^{\delta_0}_{L,B})\big) \\
-&\phi_H\big(r^{\delta_1}_{H,B} - r^{\delta_1}_{H,A} - (r^{\delta_0}_{H,B} - r^{\delta_0}_{H,A})\big) \\
+&\phi_L\big(r^{\delta_1}_{L,B} - r^{\delta_1}_{L,A} - (r^{\delta_0}_{L,B} - r^{\delta_0}_{L,A})\big).
\end{aligned} \tag{85}$$

Because need-based aid (for both achievement groups) is strictly increasing in δ, the first term in (85) is positive. Since merit-based aid (for both income groups) is strictly decreasing in δ, the second term (including the minus sign in front) is positive and the third term is negative. If ϕ_H is sufficiently large relative to ϕ_L (including, if necessary, the extreme case where $\phi_L = \epsilon$ for some arbitrarily small $\epsilon > 0$), then the second term is larger in magnitude than the third term, the sum of the second and third terms is positive, and the entire expression is positive. This in turn implies that with ϕ_H sufficiently large relative to ϕ_L, the income progressivity of of resident tuition is strictly higher in the δ_1 equilibrium than in the δ_0 equilibrium, and more generally is strictly increasing in δ. ■

Appendix B Additional Empirical Results (For Online Publication)

The following tables provide summary statistics for the NPSAS data, as well as falsification and robustness results for the regression analysis of Section 3.

Table B1: NPSAS Summary Statistics

	Overall	By Survey Year			
		1993, 1996	2000, 2004	2008	2012, 2016
Tuition and Fees	5,135	3,720	4,507	5,616	6,942
	(3,604)	(2,951)	(3,295)	(3,139)	(4,134)
Total COA	16,434	14,199	15,455	17,509	19,034
	(8,256)	(7,702)	(8,284)	(7,873)	(8,280)
Nonzero Need Aid	0.24	0.21	0.18	0.26	0.30
	(0.42)	(0.41)	(0.38)	(0.44)	(0.46)
Nonzero Merit Aid	0.14	0.06	0.12	0.17	0.22
	(0.35)	(0.23)	(0.33)	(0.38)	(0.41)
Need Aid in $					
State	476	291	310	588	726
	(1,408)	(963)	(1,056)	(1,546)	(1,840)
Institutional	310	267	211	363	413
	(1,380)	(1,272)	(1,108)	(1,517)	(1,592)
Total	787	558	521	952	1,138
	(2,064)	(1,640)	(1,598)	(2,306)	(2,517)
Cond. Nonzero	3,332	2,644	2,903	3,719	3,742
	(3,092)	(2,687)	(2,707)	(3,237)	(3,329)
Need Aid/COA					
State	0.03	0.02	0.02	0.03	0.04
	(0.07)	(0.06)	(0.06)	(0.08)	(0.09)
Institutional	0.02	0.02	0.01	0.02	0.02
	(0.06)	(0.06)	(0.06)	(0.06)	(0.07)
Total	0.04	0.04	0.03	0.05	0.06
	(0.10)	(0.09)	(0.09)	(0.11)	(0.11)
Cond. Nonzero	0.18	0.17	0.17	0.19	0.18
	(0.14)	(0.14)	(0.13)	(0.13)	(0.14)
Merit Aid in $					
State	182	40	131	292	264
	(906)	(376)	(738)	(1,167)	(1,095)
Institutional	395	131	392	405	621
	(1,973)	(942)	(2,345)	(1,721)	(2,329)
Total	577	171	523	697	885
	(2,212)	(1,024)	(2,478)	(2,140)	(2,621)
Cond. Nonzero	4,005	3,019	4,310	4,004	4,038
	(4,498)	(3,147)	(5,858)	(3,615)	(4,313)
Merit Aid/COA					
State	0.01	0.00	0.01	0.02	0.01
	(0.05)	(0.03)	(0.05)	(0.07)	(0.06)
Institutional	0.02	0.01	0.02	0.02	0.03
	(0.08)	(0.06)	(0.09)	(0.08)	(0.10)
Total	0.03	0.01	0.03	0.04	0.04
	(0.10)	(0.07)	(0.10)	(0.11)	(0.12)
Cond. Nonzero	0.21	0.21	0.22	0.22	0.19
	(0.24)	(0.32)	(0.28)	(0.21)	(0.19)
Institutions	1,123	427	478	513	665
Students	174,140	38,960	50,430	40,170	44,580

Note: Standard deviations are in parentheses. Statistics are for resident students only. All monetary values are given in 2016 dollars. Total cost of attendance (COA) includes room and board, books and supplies, and other expenses budgeted by the institution.

Table B2: Proximity to Out-of-State Institutions and the Merit-Need Allocation of Financial Aid: Distance Measures Inclusive of In-State Institutions

	Nonzero Merit	Merit/ COA	Nonzero Need	Need/ COA	Merit Share of Grant Aid
	(1)	(2)	(3)	(4)	(5)
Panel A:					
Enrollment within 500 Miles	0.012	0.007**	0.014**	0.005**	0.015
(S.D.: 753,403)	(0.011)	(0.003)	(0.007)	(0.002)	(0.014)
Panel B:					
Avg. Distance	0.000	-0.003	-0.026***	-0.009***	0.016
(S.D.: 141.79)	(0.008)	(0.002)	(0.007)	(0.002)	(0.013)
Panel C:					
Avg. Flagship Distance	-0.016	-0.006*	0.020**	0.006**	-0.034**
(S.D.: 146.70)	(0.012)	(0.003)	(0.008)	(0.003)	(0.017)
Mean Dep. Var.	0.145	0.030	0.238	0.042	0.361
Observations	171,980	153,220	171,980	153,220	58,390

Note: This table has the same setup as Table 1, except that it uses alternative distance measures that are inclusive of in-state institutions (i.e., with the summations in (17)-(19) taken over all public institutions in state s's region, including those in state s itself).

Table B3: Proximity to Out-of-State Institutions and the
Income Progressivity of Financial Aid:
Distance Measures Inclusive of In-State Institutions

	Grant Aid	Grant Aid Net of Demonstrated Need	Grant Aid/COA
	(1)	(2)	(3)
Panel A:			
Enrollment within 500 Miles	334.56***	-328.05	0.015***
(S.D.: 753,403)	(82.58)	(206.34)	(0.004)
* Income Quartile 2	68.07**	38.03	0.002
	(34.43)	(107.28)	(0.002)
* Income Quartile 3	-52.15	171.25	-0.004
	(47.61)	(131.36)	(0.002)
* Income Quartile 4	-153.81*	312.75*	-0.009**
(highest)	(80.42)	(165.84)	(0.004)
Panel B:			
Avg. Distance	-430.66***	60.12	-0.022***
(S.D.: 141.79)	(91.66)	(195.38)	(0.004)
* Income Quartile 2	51.27**	-257.93***	0.003**
	(26.12)	(96.29)	(0.001)
* Income Quartile 3	283.23***	-41.81	0.017***
	(46.57)	(127.47)	(0.003)
* Income Quartile 4	371.00***	220.80	0.022***
(highest)	(76.05)	(155.63)	(0.004)
Panel C:			
Avg. Flagship Distance	-111.44	491.01**	-0.005
(S.D.: 146.70)	(99.55)	(218.64)	(0.005)
* Income Quartile 2	80.93**	-355.72***	0.003**
	(36.06)	(99.67)	(0.002)
* Income Quartile 3	151.52***	-331.25**	0.010***
	(42.78)	(142.16)	(0.002)
* Income Quartile 4	64.68	-66.17	0.006
(highest)	(78.61)	(180.35)	(0.004)
Mean Dep. Var.	1,370	-8,108	0.072
Observations	171,980	152,300	153,220

Note: This table has the same setup as Table 2, except that it uses alternative distance measures that are inclusive of in-state institutions (i.e., with the summations in (17)-(19) taken over all public institutions in state s's region, including those in state s itself).

Table B4: Proximity to Out-of-State Institutions and the Merit-Need Allocation of Financial Aid: Students at Private Institutions

	Nonzero Merit	Merit/ COA	Nonzero Need	Need/ COA	Merit Share of Grant Aid
	(1)	(2)	(3)	(4)	(5)
Panel A:					
Enrollment within 500 Miles	0.025*	0.007	0.031***	0.005	-0.011
(S.D.: 700,365)	(0.014)	(0.004)	(0.012)	(0.003)	(0.014)
Panel B:					
Avg. Distance	-0.021	-0.008	-0.024	-0.006	0.013
(S.D.: 199.36)	(0.027)	(0.008)	(0.024)	(0.007)	(0.028)
Panel C:					
Avg. Flagship Distance	-0.061***	-0.016***	-0.059***	-0.008*	-0.004
(S.D.: 186.99)	(0.018)	(0.005)	(0.016)	(0.005)	(0.019)
Mean Dep. Var.	0.289	0.069	0.313	0.063	0.498
Observations	80,600	72,920	80,600	72,920	38,850

Note: This table has the same setup as Table 1, except that it uses an alternative sample of resident students at private institutions.

Table B5: Proximity to Out-of-State Institutions and the
Income Progressivity of Financial Aid:
Students at Private Institutions

	Grant Aid	Grant Aid Net of Demonstrated Need	Grant Aid/COA
	(1)	(2)	(3)
Panel A:			
Enrollment within 500 Miles	-40.84	2276.26***	0.006
(S.D.: 700,365)	(268.29)	(510.20)	(0.006)
* Income Quartile 2	-12.73	-939.80***	0.000
	(106.61)	(260.89)	(0.003)
* Income Quartile 3	172.52	-924.76***	0.007**
	(126.76)	(295.08)	(0.003)
* Income Quartile 4	665.96***	-953.73***	0.017***
(highest)	(159.60)	(367.67)	(0.004)
Panel B:			
Avg. Distance	-326.74	-1574.49*	-0.017
(S.D.: 199.36)	(500.27)	(902.66)	(0.012)
* Income Quartile 2	48.02	140.70	0.002
	(120.87)	(274.17)	(0.003)
* Income Quartile 3	120.09	417.77	0.003
	(147.24)	(328.77)	(0.003)
* Income Quartile 4	385.52*	799.89**	0.011**
(highest)	(198.68)	(377.91)	(0.005)
Panel C:			
Avg. Flagship Distance	-641.87*	-1576.69**	-0.025***
(S.D.: 186.99)	(353.71)	(712.00)	(0.008)
* Income Quartile 2	-47.21	199.00	-0.001
	(114.67)	(280.42)	(0.003)
* Income Quartile 3	-15.86	412.91	-0.001
	(139.05)	(332.44)	(0.003)
* Income Quartile 4	279.62	763.59**	0.008*
(highest)	(196.85)	(386.58)	(0.005)
Mean Dep. Var.	4,919	-14,958	0.132
Observations	80,600	72,670	72,920

Note: This table has the same setup as Table 2, except that it uses an alternative sample of resident students at private institutions.

Table B6: Proximity to Out-of-State Institutions and the Merit-Need Allocation of Financial Aid: State-Government Grants Only

	Nonzero Merit	Merit/ COA	Nonzero Need	Need/ COA	Merit Share of Grant Aid
	(1)	(2)	(3)	(4)	(5)
Panel A:					
Enrollment within 500 Miles	0.021	0.007*	-0.016***	-0.005***	0.059**
(S.D.: 775,952)	(0.014)	(0.004)	(0.006)	(0.001)	(0.026)
Panel B:					
Avg. Distance	-0.041**	-0.011**	0.004	0.002	-0.118***
(S.D.: 196.88)	(0.019)	(0.005)	(0.011)	(0.002)	(0.041)
Panel C:					
Avg. Flagship Distance	-0.011	-0.005	-0.004	0.001	-0.028
(S.D.: 185.26)	(0.016)	(0.004)	(0.008)	(0.002)	(0.031)
Mean Dep. Var.	0.058	0.011	0.169	0.026	0.246
Observations	171,980	153,220	171,980	153,220	58,390

Note: This table has the same setup as Table 1, except that it limits the dependent variables to grants from state-government sources.

Table B7: Proximity to Out-of-State Institutions and the
Income Progressivity of Financial Aid:
State-Government Grants Only

	Grant Aid	Grant Aid Net of Demonstrated Need	Grant Aid/COA
	(1)	(2)	(3)
Panel A:			
Enrollment within 500 Miles	22.02	-487.67**	0.000
(S.D.: 775,952)	(51.92)	(229.85)	(0.003)
* Income Quartile 2	-26.28	253.63**	-0.001
	(26.00)	(112.87)	(0.001)
* Income Quartile 3	21.20	510.76***	0.001
	(38.50)	(138.61)	(0.002)
* Income Quartile 4	180.78***	376.48**	0.009***
(highest)	(54.11)	(186.33)	(0.003)
Panel B:			
Avg. Distance	-307.15***	84.56	-0.016***
(S.D.: 196.88)	(92.40)	(318.65)	(0.005)
* Income Quartile 2	108.48***	-367.30***	0.005***
	(25.25)	(103.75)	(0.001)
* Income Quartile 3	211.40***	-326.64**	0.012***
	(36.64)	(145.81)	(0.002)
* Income Quartile 4	134.02***	133.33	0.010***
(highest)	(51.60)	(192.81)	(0.003)
Panel C:			
Avg. Flagship Distance	-229.95***	438.09	-0.012***
(S.D.: 185.26)	(80.11)	(284.08)	(0.004)
* Income Quartile 2	108.73***	-354.69***	0.005***
	(24.73)	(104.47)	(0.001)
* Income Quartile 3	239.88***	-327.51**	0.014***
	(29.00)	(148.75)	(0.002)
* Income Quartile 4	175.60***	72.80	0.012***
(highest)	(47.93)	(198.27)	(0.003)
Mean Dep. Var.	662	-8,821	0.037
Observations	171,980	152,300	153,220

Note: This table has the same setup as Table 2, except that it limits the dependent variables to grants from state-government sources.

Table B8: Proximity to Out-of-State Institutions and the
Merit-Need Allocation of Financial Aid:
Institutional Grants Only

	Nonzero Merit	Merit/ COA	Nonzero Need	Need/ COA	Merit Share of Grant Aid
	(1)	(2)	(3)	(4)	(5)
Panel A:					
Enrollment within 500 Miles	0.018***	0.004***	-0.023***	-0.004***	0.090***
(S.D.: 775,952)	(0.005)	(0.001)	(0.005)	(0.001)	(0.014)
Panel B:					
Avg. Distance	-0.017*	-0.002	0.031***	0.005***	-0.099***
(S.D.: 196.88)	(0.009)	(0.002)	(0.008)	(0.002)	(0.025)
Panel C:					
Avg. Flagship Distance	-0.021***	-0.003***	0.032***	0.006***	-0.102***
(S.D.: 185.26)	(0.006)	(0.001)	(0.007)	(0.002)	(0.021)
Mean Dep. Var.	0.101	0.019	0.110	0.016	0.479
Observations	171,980	153,210	171,980	153,220	58,390

Note: This table has the same setup as Table 1, except that it limits the dependent variables to grants from institutional sources.

Table B9: Proximity to Out-of-State Institutions and the Income Progressivity of Financial Aid: Institutional Grants Only

	Grant Aid	Grant Aid Net of Demonstrated Need	Grant Aid/COA
	(1)	(2)	(3)
Panel A:			
Enrollment within 500 Miles	-94.45**	-611.16***	-0.005***
(S.D.: 775,952)	(44.03)	(225.14)	(0.002)
* Income Quartile 2	43.08*	327.29***	0.002**
	(22.58)	(113.33)	(0.001)
* Income Quartile 3	156.80***	659.23***	0.008***
	(28.63)	(132.74)	(0.001)
* Income Quartile 4	237.93***	454.79***	0.011***
(highest)	(42.38)	(163.75)	(0.002)
Panel B:			
Avg. Distance	146.78**	536.47*	0.007**
(S.D.: 196.88)	(70.52)	(313.16)	(0.003)
* Income Quartile 2	-25.21	-499.77***	-0.002**
	(21.67)	(105.41)	(0.001)
* Income Quartile 3	-100.68***	-644.44***	-0.005***
	(28.42)	(141.44)	(0.001)
* Income Quartile 4	-182.01***	-216.23	-0.010***
(highest)	(43.46)	(182.10)	(0.002)
Panel C:			
Avg. Flagship Distance	128.21**	810.38***	0.007***
(S.D.: 185.26)	(64.19)	(267.75)	(0.003)
* Income Quartile 2	-32.48	-496.81***	-0.003***
	(20.92)	(105.71)	(0.001)
* Income Quartile 3	-116.51***	-693.42***	-0.006***
	(27.33)	(141.17)	(0.001)
* Income Quartile 4	-186.59***	-328.51*	-0.010***
(highest)	(44.42)	(181.95)	(0.002)
Mean Dep. Var.	708	-8,771	0.035
Observations	171,980	152,300	153,220

Note: This table has the same setup as Table 2, except that it limits the dependent variables to grants from institutional sources.

Table B10: Proximity to Out-of-State Institutions and the Merit-Need Allocation of Financial Aid: Achievement Control Included

	Nonzero Merit	Merit/ COA	Nonzero Need	Need/ COA	Merit Share of Grant Aid
	(1)	(2)	(3)	(4)	(5)
Panel A:					
Enrollment within 500 Miles	0.038**	0.012***	-0.028***	-0.009***	0.066***
(S.D.: 775,952)	(0.016)	(0.004)	(0.008)	(0.002)	(0.018)
Panel B:					
Avg. Distance	-0.055**	-0.016**	0.026**	0.008**	-0.089***
(S.D.: 196.88)	(0.023)	(0.006)	(0.013)	(0.004)	(0.028)
Panel C:					
Avg. Flagship Distance	-0.026	-0.010*	0.022*	0.008**	-0.046**
(S.D.: 185.26)	(0.019)	(0.005)	(0.011)	(0.004)	(0.021)
Mean Dep. Var.	0.185	0.038	0.277	0.051	0.384
Observations	101,120	88,750	101,120	88,750	40,850

Note: This table has the same setup as Table 1, except that includes a control for students' ACT/SAT score quartile (and thereby reduces the sample size, since these scores are missing for a large number of students).

Table B11: Proximity to Out-of-State Institutions and the Merit-Need Allocation of Financial Aid: Neighboring States as the Relevant Market

	Nonzero Merit	Merit/ COA	Nonzero Need	Need/ COA	Merit Share of Grant Aid
	(1)	(2)	(3)	(4)	(5)
Panel A:					
Enrollment in	0.021***	0.005***	-0.015***	-0.005***	0.045***
Neighboring States (S.D.: 655,757)	(0.006)	(0.001)	(0.005)	(0.001)	(0.009)
Panel B:					
Avg. Distance,	0.000	-0.001	-0.004	-0.003	0.015
Neighboring States (S.D.: 123.11)	(0.011)	(0.003)	(0.008)	(0.002)	(0.015)
Panel C:					
Avg. Flagship Distance,	-0.005	-0.002	-0.001	0.001	0.003
Neighboring States (S.D.: 130.96)	(0.012)	(0.003)	(0.007)	(0.002)	(0.014)
Mean Dep. Var.	0.145	0.030	0.238	0.042	0.361
Observations	171,980	153,220	171,980	153,220	58,390

Note: This table has the same setup as Table 1, except that it uses enrollment-proximity and average-distance measures that treat institutions in neighboring states as the relevant set of geographic competitors (i.e., with the summations in (17)-(19) taken over institutions in states that border state s, rather than states in the same BEA region as state s).

Table B12: Proximity to Out-of-State Institutions and the Income Progressivity of Financial Aid: Neighboring States as the Relevant Market

	Grant Aid	Grant Aid Net of Demonstrated Need	Grant Aid/COA
	(1)	(2)	(3)
Panel A:			
Enrollment in	-88.72*	-407.41***	-0.005**
Neighboring States (S.D.: 655,757)	(46.61)	(153.12)	(0.002)
* Income Quartile 2	-19.17	233.74**	0.000
	(27.25)	(93.23)	(0.001)
* Income Quartile 3	115.30***	452.41***	0.005***
	(35.86)	(121.21)	(0.002)
* Income Quartile 4	294.07***	552.87***	0.014***
(highest)	(63.04)	(152.93)	(0.003)
Panel B:			
Avg. Distance,	-149.94*	347.01	-0.006
Neighboring States (S.D.: 123.11)	(85.55)	(223.55)	(0.004)
* Income Quartile 2	30.19	-403.62***	0.001
	(35.82)	(97.19)	(0.002)
* Income Quartile 3	84.07**	-461.29***	0.006***
	(42.63)	(137.20)	(0.002)
* Income Quartile 4	-10.03	-140.43	0.003
(highest)	(75.53)	(176.20)	(0.004)
Panel C:			
Avg. Flagship Distance,	-86.19	634.71***	-0.003
Neighboring States (S.D.: 130.96)	(84.07)	(217.89)	(0.004)
* Income Quartile 2	22.40	-436.13***	0.001
	(35.70)	(98.11)	(0.002)
* Income Quartile 3	57.05	-556.38***	0.005**
	(41.97)	(139.46)	(0.002)
* Income Quartile 4	-50.66	-287.90	0.001
(highest)	(77.56)	(180.14)	(0.004)
Mean Dep. Var.	1,370	-8,108	0.072
Observations	171,980	152,300	153,220

Note: This table has the same setup as Table 2, except that uses enrollment-proximity and average-distance measures that treat institutions in neighboring states as the relevant set of geographic competitors (i.e., with the summations in (17)-(19) taken over institutions in states that border state s, rather than states in the same BEA region as state s.)

Table B13: Proximity to Out-of-State Institutions and the Merit-Need Allocation of Financial Aid: Top Five Migration Destinations as the Relevant Market

	Nonzero Merit	Merit/ COA	Nonzero Need	Need/ COA	Merit Share of Grant Aid
	(1)	(2)	(3)	(4)	(5)
Panel A:					
Enrollment in	0.018***	0.004***	-0.024***	-0.007***	0.049***
Top 5 Migration Dests. (S.D.: 801,360)	(0.004)	(0.001)	(0.005)	(0.001)	(0.008)
Panel B:					
Avg. Distance,	-0.007	-0.002	-0.001	-0.002	-0.009
Top 5 Migration Dests. (S.D.: 170.34)	(0.008)	(0.002)	(0.007)	(0.002)	(0.013)
Panel C:					
Avg. Flagship Distance,	-0.015	-0.004	-0.002	-0.001	-0.017
Top 5 Migration Dests. (S.D.: 166.71)	(0.012)	(0.003)	(0.008)	(0.002)	(0.015)
Mean Dep. Var.	0.145	0.030	0.238	0.042	0.361
Observations	171,980	153,220	171,980	153,220	58,390

Note: This table has the same setup as Table 1, except that it uses observed migration patterns to define college markets (i.e., with the summations in (17)-(19) taken over the five states that enroll the most nonresident students from state s).

Table B14: Proximity to Out-of-State Institutions and the Income Progressivity of Financial Aid: Top Five Migration Destinations as the Relevant Market

	Grant Aid	Grant Aid Net of Demonstrated Need	Grant Aid/COA
	(1)	(2)	(3)
Panel A:			
Enrollment in	-89.24*	178.36	-0.002
Top 5 Migration Dests. (S.D.: 801,360)	(48.90)	(151.15)	(0.002)
* Income Quartile 2	-45.63*	-179.06**	-0.004***
	(23.36)	(88.02)	(0.001)
* Income Quartile 3	27.70	-89.91	0.000
	(30.93)	(102.36)	(0.002)
* Income Quartile 4	94.27*	36.32	0.003
(highest)	(55.78)	(129.98)	(0.003)
Panel B:			
Avg. Distance,	-102.90	848.04***	-0.001
Top 5 Migration Dests. (S.D.: 170.34)	(69.84)	(206.85)	(0.003)
* Income Quartile 2	35.14	-463.11***	-0.001
	(38.52)	(94.98)	(0.002)
* Income Quartile 3	-36.79	-652.91***	-0.003
	(44.31)	(129.62)	(0.002)
* Income Quartile 4	-224.01***	-472.62***	-0.011***
(highest)	(76.01)	(165.36)	(0.004)
Panel C:			
Avg. Flagship Distance,	-117.62	1,005.58***	-0.001
Top 5 Migration Dests. (S.D.: 166.71)	(85.40)	(224.17)	(0.004)
* Income Quartile 2	28.88	-480.20***	-0.001
	(40.36)	(95.35)	(0.002)
* Income Quartile 3	-63.05	-689.49***	-0.003
	(45.10)	(130.63)	(0.002)
* Income Quartile 4	-275.66***	-459.28***	-0.013***
(highest)	(80.10)	(174.40)	(0.004)
Mean Dep. Var.	1,370	-8,108	0.072
Observations	171,980	152,300	153,220

Note: This table has the same setup as Table 2, except that it uses observed migration patterns to define college markets (i.e., with the summations in (17)-(19) taken over the five states that enroll the most nonresident students from state s).

Table B15: Proximity to Out-of-State Institutions and the
Merit-Need Allocation of Financial Aid:
Institution-Specific Distance Measures

	Nonzero Merit	Merit/ COA	Nonzero Need	Need/ COA	Merit Share of Grant Aid
	(1)	(2)	(3)	(4)	(5)
Panel A:					
Enrollment within 500 Miles	0.043***	0.012***	-0.018**	-0.006***	0.074***
(S.D.: 762,314)	(0.010)	(0.003)	(0.007)	(0.002)	(0.014)
Panel B:					
Avg. Distance	-0.012*	-0.003*	-0.012*	-0.002	-0.013
(S.D.: 262.60)	(0.006)	(0.002)	(0.007)	(0.002)	(0.014)
Panel C:					
Avg. Flagship Distance	-0.011*	-0.003*	-0.009	-0.001	-0.012
(S.D.: 250.50)	(0.006)	(0.001)	(0.007)	(0.002)	(0.012)
Mean Dep. Var.	0.144	0.030	0.239	0.042	0.358
Observations	169,180	150,940	169,180	150,940	57,450

Note: This table has the same setup as Table 1, except that it uses alternative institution-specific distance measures (i.e., with the distances to out-of-state competitors in (17)-(19) measured from the location of the student's institution, rather than from the population centroid of the student's state).

Table B16: Proximity to Out-of-State Institutions and the Income Progressivity of Financial Aid: Institution-Specific Distance Measures

	Grant Aid	Grant Aid Net of Demonstrated Need	Grant Aid/COA
	(1)	(2)	(3)
Panel A:			
Enrollment within 500 Miles	-27.70	-645.02***	-0.002
(S.D.: 762,314)	(80.11)	(208.93)	(0.004)
* Income Quartile 2	37.99	335.67***	0.002
	(35.01)	(108.01)	(0.002)
* Income Quartile 3	166.44***	721.64***	0.008***
	(46.60)	(128.44)	(0.003)
* Income Quartile 4	403.39***	724.17***	0.019***
(highest)	(70.50)	(164.18)	(0.004)
Panel B:			
Avg. Distance	-103.47*	336.44**	-0.006**
(S.D.: 262.60)	(61.89)	(151.28)	(0.003)
* Income Quartile 2	22.77	-261.53**	0.001
	(33.09)	(116.25)	(0.002)
* Income Quartile 3	53.02	-345.37**	0.004*
	(41.50)	(144.12)	(0.002)
* Income Quartile 4	-44.49	-170.21	0.000
(highest)	(65.01)	(150.49)	(0.003)
Panel C:			
Avg. Flagship Distance	-94.03	420.45***	-0.006**
(S.D.: 250.50)	(61.18)	(159.17)	(0.003)
* Income Quartile 2	17.35	-265.77**	0.001
	(33.06)	(117.80)	(0.002)
* Income Quartile 3	60.27	-357.56**	0.004*
	(40.99)	(146.50)	(0.002)
* Income Quartile 4	-23.31	-240.19	0.001
(highest)	(63.85)	(151.81)	(0.003)
Mean Dep. Var.	1,363	-8,036	0.072
Observations	169,180	150,050	150,940

Note: This table has the same setup as Table 2, except that it uses alternative institution-specific distance measures (i.e, with the distances to out-of-state competitors in (17)-(19) measured from the location of the student's institution, rather than from the population centroid of the student's state).

Table B17: Proximity to Out-of-State Institutions and the Merit-Need Allocation of Financial Aid: Distance Measures Inclusive of Private Institutions

	Nonzero Merit	Merit/ COA	Nonzero Need	Need/ COA	Merit Share of Grant Aid
	(1)	(2)	(3)	(4)	(5)
Panel A:					
Enrollment within 500 Miles	0.035***	0.010***	-0.032***	-0.008***	0.076***
(S.D.: 896,300)	(0.013)	(0.004)	(0.007)	(0.002)	(0.017)
Panel B:					
Avg. Distance	-0.050***	-0.013**	0.028**	0.008**	-0.097***
(S.D.: 197.59)	(0.019)	(0.005)	(0.012)	(0.003)	(0.027)
Mean Dep. Var.	0.145	0.030	0.238	0.042	0.361
Observations	171,980	153,220	171,980	153,220	58,390

Note: This table has the same setup as Table 1, except that it uses alternative distance measures that are inclusive of private institutions (i.e., with the summations in (17) and (19) taken over both public and private institutions in state s's region).

Table B18: Proximity to Out-of-State Institutions and the
Income Progressivity of Financial Aid:
Distance Measures Inclusive of Private Institutions

	Grant Aid	Grant Aid Net of Demonstrated Need	Grant Aid/COA
	(1)	(2)	(3)
Panel A:			
Enrollment within 500 Miles	-39.70	-619.71***	-0.004
(S.D.: 896,300)	(80.91)	(201.90)	(0.004)
* Income Quartile 2	7.53	312.59***	0.001
	(37.45)	(106.34)	(0.002)
* Income Quartile 3	150.61***	675.58***	0.007***
	(46.26)	(129.44)	(0.002)
* Income Quartile 4	384.62***	608.78***	0.018***
(highest)	(72.23)	(168.44)	(0.004)
Panel B:			
Avg. Distance	-149.31	223.49	-0.008
(S.D.: 197.59)	(128.83)	(273.26)	(0.006)
* Income Quartile 2	83.80**	-392.03***	0.003**
	(35.29)	(100.38)	(0.002)
* Income Quartile 3	109.21**	-423.58***	0.007***
	(44.62)	(140.01)	(0.002)
* Income Quartile 4	-51.25	-62.91	0.000
(highest)	(77.53)	(177.55)	(0.004)
Mean Dep. Var.	1,370	-8,108	0.072
Observations	171,980	152,300	153,220

Note: This table has the same setup as Table 2, except that it uses alternative distance measures that are inclusive of private institutions. (i.e., with the summations in (17) and (19) taken over both public and private institutions in state s's region).

Table B19: Proximity to Out-of-State Institutions and the Merit-Need Allocation of Financial Aid: Unweighted Distance Measures

	Nonzero Merit	Merit/ COA	Nonzero Need	Need/ COA	Merit Share of Grant Aid
	(1)	(2)	(3)	(4)	(5)
Panel A:					
Institutions within 500 Miles	0.034**	0.011***	-0.025***	-0.005**	0.070***
(S.D.: 105.61)	(0.015)	(0.004)	(0.007)	(0.002)	(0.020)
Panel B:					
Avg. Distance (Unweighted)	-0.040**	-0.011**	0.032***	0.008**	-0.085***
(S.D.: 181.46)	(0.018)	(0.005)	(0.012)	(0.003)	(0.027)
Panel C:					
Avg. Flagship Distance (Unweighted)	-0.025	-0.009*	0.012	0.002	-0.043*
(S.D.: 168.09)	(0.017)	(0.005)	(0.009)	(0.003)	(0.022)
Mean Dep. Var.	0.145	0.030	0.238	0.042	0.361
Observations	171,980	153,220	171,980	153,220	58,390

Note: This table has the same setup as Table 1, except that it uses alternative distance measures that do not weight competing out-of-state institutions by their undergraduate enrollment.

Table B20: Proximity to Out-of-State Institutions and the Income Progressivity of Financial Aid: Unweighted Distance Measures

	Grant Aid	Grant Aid Net of Demonstrated Need	Grant Aid/COA
	(1)	(2)	(3)
Panel A:			
Institutions within 500 Miles	-33.04	-630.05***	-0.005
(S.D.: 105.61)	(81.17)	(196.90)	(0.004)
* Income Quartile 2	64.52*	182.01*	0.004***
	(37.75)	(99.97)	(0.002)
* Income Quartile 3	280.55***	600.96***	0.015***
	(42.35)	(121.08)	(0.002)
* Income Quartile 4	531.13***	605.66***	0.027***
(highest)	(62.40)	(156.45)	(0.003)
Panel B:			
Avg. Distance (Unweighted)	-72.04	247.00	-0.004
(S.D.: 181.46)	(125.73)	(266.50)	(0.006)
* Income Quartile 2	77.64**	-379.70***	0.003
	(37.26)	(98.88)	(0.002)
* Income Quartile 3	87.30*	-409.91***	0.006**
	(46.13)	(140.41)	(0.003)
* Income Quartile 4	-82.09	-66.51	-0.002
(highest)	(80.57)	(180.27)	(0.004)
Panel C:			
Avg. Flagship Distance (Unweighted)	-266.10**	636.81***	-0.012**
(S.D.: 168.09)	(114.67)	(237.16)	(0.006)
* Income Quartile 2	69.24**	-375.92***	0.003*
	(31.84)	(103.03)	(0.002)
* Income Quartile 3	180.39***	-388.96***	0.011***
	(37.91)	(145.78)	(0.002)
* Income Quartile 4	111.10	-92.13	0.009**
(highest)	(69.24)	(181.78)	(0.004)
Mean Dep. Var.	1,370	-8,108	0.072
Observations	171,980	152,300	153,220

Note: This table has the same setup as Table 2, except that it uses alternative distance measures that do not weight competing out-of-state institutions by their undergraduate enrollment.

Table B21: Proximity to Out-of-State Institutions and the Merit-Need Allocation of Financial Aid: Alternative Distance Cutoffs

	Nonzero Merit	Merit/ COA	Nonzero Need	Need/ COA	Merit Share of Grant Aid
	(1)	(2)	(3)	(4)	(5)
Panel A:					
Enrollment within 300 Miles	0.032**	0.010***	-0.023***	-0.004	0.063***
(S.D.: 555,841)	(0.014)	(0.004)	(0.008)	(0.003)	(0.019)
Panel B:					
Enrollment within 700 Miles	0.049***	0.012***	-0.057***	-0.017***	0.117***
(S.D.: 895,568)	(0.014)	(0.004)	(0.008)	(0.003)	(0.018)
Panel C:					
Institutions within 300 Miles	0.023*	0.008**	-0.015**	-0.001	0.044***
(S.D.: 62.25)	(0.013)	(0.004)	(0.006)	(0.002)	(0.016)
Panel D:					
Institutions within 700 Miles	0.079***	0.021***	-0.081***	-0.021***	0.186***
(S.D.: 133.07)	(0.023)	(0.006)	(0.014)	(0.004)	(0.032)
Mean Dep. Var.	0.145	0.030	0.238	0.042	0.361
Observations	171,980	153,220	171,980	153,220	58,390

Note: This table has the same setup as Table 1, except that it uses enrollment and institution proximity measures with alternative cutoffs of 300 and 700 (rather than 500) miles.

Table B22: Proximity to Out-of-State Institutions and the Income Progressivity of Financial Aid: Alternative Distance Cutoffs

	Grant Aid	Grant Aid Net of Demonstrated Need	Grant Aid/COA
	(1)	(2)	(3)
Panel A:			
Enrollment within 300 Miles	198.12**	-436.45**	0.008*
(S.D.: 555,841)	(95.23)	(211.35)	(0.005)
* Income Quartile 2	-31.99	341.97***	-0.002
	(33.32)	(105.89)	(0.002)
* Income Quartile 3	-72.10*	498.75***	-0.005**
	(41.41)	(133.93)	(0.002)
* Income Quartile 4	29.84	336.39*	-0.002
(highest)	(71.42)	(172.73)	(0.004)
Panel B:			
Enrollment within 700 Miles	-308.44***	-403.73	-0.017***
(S.D.: 895,568)	(100.00)	(250.95)	(0.005)
* Income Quartile 2	36.18	152.94	0.003*
	(36.95)	(102.08)	(0.002)
* Income Quartile 3	274.90***	591.93***	0.015***
	(41.52)	(123.52)	(0.002)
* Income Quartile 4	557.22***	578.00***	0.028***
(highest)	(64.12)	(161.23)	(0.003)
Panel C:			
Institutions within 300 Miles	136.54*	-602.26***	0.004
(S.D.: 62.25)	(73.36)	(187.44)	(0.004)
* Income Quartile 2	27.21	270.71***	0.002
	(35.00)	(100.60)	(0.002)
* Income Quartile 3	65.38	533.13***	0.002
	(46.42)	(129.77)	(0.003)
* Income Quartile 4	199.64***	461.03***	0.008*
(highest)	(74.66)	(168.52)	(0.004)
Panel D:			
Institutions within 700 Miles	-203.49	-483.93	-0.015**
(S.D.: 133.07)	(150.92)	(338.37)	(0.007)
* Income Quartile 2	69.16*	70.39	0.005***
	(36.49)	(97.35)	(0.002)
* Income Quartile 3	347.76***	494.23***	0.020***
	(39.87)	(122.54)	(0.002)
* Income Quartile 4	633.04***	507.59***	0.033***
(highest)	(62.18)	(159.43)	(0.003)
Mean Dep. Var.	1,370	-8,108	0.072
Observations	171,980	152,300	153,220

Note: This table has the same setup as Table 2, except that it uses enrollment and institution proximity measures with alternative cutoffs of 300 and 700 (rather 500) miles.