The Out-of-State Tuition Distortion*

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Abstract

Public universities typically charge much higher tuition to non-residents. We first investigate the welfare implications of this tuition gap in a simple model. While the social planner does not distinguish between residents and non-residents, state governments set higher tuition for non-residents. The welfare gains from reducing the tuition gap can be characterized by a sufficient statistic relating out-of-state enrollment to the tuition gap. We estimate this sufficient statistic via a border discontinuity design using data on the geographic distribution of students by institution.

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1 Introduction

This research examines economic distortions associated with differences between resident and non-resident tuition at public universities in the United States. It is well-known that public institutions charge much higher tuition to non-residents, with the University of California System, for example, charging $12,294 in tuition and fees for California residents and $38,976 for non-residents.[1] Perhaps due, at least in part, to these differences in tuition, roughly 75 percent of students nationwide attend in-state institutions (NCES, 2012).

While distinguishing between residents and non-residents is consistent with state welfare maximization, it may lead to economic inefficiencies from a national perspective. To see this, consider a hypothetical example of two students, one living in Illinois and one in Wisconsin. Suppose that both have competitive application profiles so that neither is constrained by admissions processes. In addition, assume that the student from Illinois finds the University of Wisconsin-Madison to be a better fit and that the student from Wisconsin finds the University of Illinois to be a better fit. Given this, in the absence of tuition differences, both would attend out-of-state institutions. But, suppose that, due to much higher out-of-state tuition, both students choose to attend the home-state institution. Then, both students would be better off, with universities receiving identical tuition revenue, if they could pay in-state tuition rates at the out-of-state institution. As should be clear, there are two crucial ingredients underlying this inefficiency. First, students must have heterogeneous preferences over institutions, with rankings, absent tuition differences, differing across students. Second, in choosing institutions, students must be responsive to tuition differences.

While this example is extreme, it illustrates a more general point. Distinguishing between residents and non-residents when setting tuition may lead to inefficiencies from a national perspective, with students attending institutions that may not be the best fit for them. We first formalize this idea in the context of a simple model in which students choose between in-state and out-of-state institutions. A social planner maximizing national welfare does not distinguish between residents and non-residents for tuition purposes. We then consider how state governments, accounting for enrollment responses, set tuition policies, under the assumption that they maximize the welfare of their residents. By ignoring the welfare of non-residents, state governments cross-subsidize in-state students by charging higher tuition for out-of-state students. Finally, we show that narrowing the gap between resident and non-resident tuition leads to a welfare gain, and this gain can be characterized by a sufficient statistic relating out-of-state enrollment patterns to non-resident tuition.[2]

[1] See http://admission.universityofcalifornia.edu/paying-for-uc/tuition-and-cost/ (accessed October 21, 2016).

[2] The sufficient statistics approach involves using well-identified estimates of behavioral responses in order to

In estimating this sufficient statistic, a key identification problem that we face involves separating these distortionary effects of tuition policies from geography. That is, students may disproportionately attend in-state institutions due to either discounted tuition for in-state students or due to a preference for attending institutions close to home. To isolate the distortionary effects of this out-of-state tuition markup, we use a border discontinuity design, comparing attendance at institutions for students living close to state borders.[3] That is, by comparing in-state students and out-of-state students living near each other, we can remove the effects of geography and isolate the effects of tuition. To implement this border discontinuity design, our baseline analysis uses data on the geographic distribution of students by institution. The key data source is the Freshman Survey, administered by the Higher Education Research Institute (HERI). The survey includes a question on zip code of permanent residence, allowing us to measure the geographic distribution of enrollment at institutions. We find large discontinuities, with a sharp jump in enrollment at the border.

Complementing these baseline findings, we present four additional pieces of evidence. First, we address two alternative explanations for our documented border discontinuities, one based upon differential admissions standards and another based upon endogenous sorting around the border. Second, using information on tuition, we document larger discontinuities along borders with larger differences between out-of-state and in-state tuition. Third, using separate survey data on student choice sets, we find that, conditional on being admitted and geography, students are more likely to select in-state institutions from their choice sets and especially so when there are large tuition discounts for residents. Fourth, we document smaller border discontinuities for private institutions, which do not provide tuition discounts to residents.

Finally, we use our estimates of enrollment responses to tuition in order to conduct a welfare analysis. In particular, we consider a marginal reduction in out-of-state tuition, offset by a budget balancing increase in resident tuition. The welfare gains from this policy change are substantial, implying significant distortions associated with the existing gap between in-state and out-of-state tuition.

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quantify the welfare implications of policy changes. Representative studies include **?** on unemployment insurance, **?** on Medicaid, and **?** on income taxation. **?** provides an overview of this literature.

[3]For an analysis of how housing prices differ along school district attendance zones borders, using similar variation, see **?**.

2 Literature Review

This is, of course, not the first study examining the gap between out-of-state tuition and in-state tuition in the U.S.[4,5] **?** evaluates a program offering residents of the D.C. up to $10,000 per year to cover tuition at select out-of-state institutions. He finds increases in the number of first-time federal financial aid applicants, the number of first-year college students receiving Pell Grants, and college attendance. Likewise, **?** document that the program increased the likelihood that students applied to eligible institutions and also increased college enrollment rates. Other studies on out-of-state tuition include **?**, **?**, and **?**. Relative to existing studies, our paper is the first in this literature to attempt to estimate the effect of non-resident tuition on enrollment via a border discontinuity design, and, more importantly, to use these estimates to calculate any welfare gains associated with reducing the gap between non-resident and resident tuition.

Our study is also related to research on merit aid programs in the United States, which provide incentives for students to attend in-state institutions via reductions in resident tuition. There is substantial evidence that the Hope scholarship, an early program that provided scholarships to residents at public and private institutions in Georgia, led to increased in-state enrollment.[6] Likewise, **?** analyze a program in Massachusetts that provided academically strong students with tuition waivers at in-state public colleges and find that eligible students disproportionately attended in-state institutions and had lower college completion rates. **?** document similar findings with respect to resident enrollment in a national study of state aid programs.

This research is also related to a literature on interstate migration. Studies in this literature include **?**, who study migration responses to state labor market shocks. **?** examine the role of state licensing requirements for nurses in interstate migration and other labor market outcomes. **?** documents that highly educated individuals in the U.S. are more mobile, and our results suggest that this difference could be even larger were the gap between out-of-state and in-state tuition to be lowered. **?** also argues that mobility is inefficiently low and makes the case for relocation vouchers. A related literature examines the likelihood that students remain in the state when transitioning from college to the workforce. State governments often justify higher tuition for non-residents based upon the argument that out-of-state students tend to return to their state of residence and thus neither contribute to the future tax base nor generate human

[4] There is also a literature examining student enrollment patterns within and across countries in Europe. **?** examine enrollment responses to the introduction of tuition in some German states. **?** analyze the Bologna process, which harmonized higher education within the European Union in the hopes of increasing student mobility.

[5] More broadly, this paper contributes to a literature on the role of tuition and financial aid in college attendance. Representative studies in this literature include **?**, **?**, and **?**. While this literature is often focused on the decision of whether or not to attend college, our study focuses on the choice between in-state and out-of-state institutions, conditional on attending college.

[6] See **?**, **?**, **?**, and **?**.

capital externalities for state residents. **?** examine this issue in the context of state merit aid programs. They find that such programs lead to a small increase in the likelihood that eligible students remain in the state when entering the workforce. However, the effect is small, is not driven by college graduates, and appears to reflect in part a delay in college graduation by residents. In a structural approach, **?** estimates a dynamic migration model in which students decide where to go to college, accounting for, among other factors, differences between resident and non-resident tuition. He finds that reductions in tuition lead to increases in college enrollment and the subsequent stock of college educated workers. This is in contrast to **?**, who find little relationship between the production of college graduates and the subsequent stock of college educated workers.

This paper also contributes to a literature on federalism. A key issue in the design of federations involves the vertical delegation of authorities between different levels of government. A common argument against decentralization is that, in setting policy, localities maximize the welfare of residents and thus fail to internalize cross-jurisdiction externalities.[7] Like this work, the welfare loss in our model is generated by the assumption that local policymakers only value resident welfare. Our paper contributes to this literature by examining differential pricing between resident and non-residents, a novel mechanism through which decentralization creates welfare losses.

3 Theoretical Model

This section develops a simple theoretical model in which students, accounting for tuition policies and geography, choose between colleges.[8] We first develop expressions for welfare and then consider how a social planner maximizing national welfare would set policies. We then consider a positive model in which state governments set in-state and out-of-state tuition. After linking our expressions for welfare to a literature on sufficient statistics, we consider several extensions of the model.

[7] Among others, see **?**, **?**, **?**, **?**, and **?**.

[8] This model is related to **?**, who consider resident and non-resident tuition but also private and public universities. While their model takes tuition rates as given, public universities face incentives to admit out-of-state students for both financial and non-financial reasons. One key finding of their analysis is that increases in tuition at public institutions leads to a reduction in college attendance, with little switching to private universities.

3.1 Setup

Consider two states (s), East ($s = E$) and West ($s = W$), each with population normalized to one.[9] Each state has a public college (c), and each college sets two variables: resident (in-state) tuition (r_c) and non-resident (out-of-state) tuition (n_c). Student i receives the following monetary payoff from attending college c:

$$u_{ic} = \alpha q_c - t_{ic} - \delta_{ic} + (1/\rho)\varepsilon_{ic} \tag{1}$$

where q_c represents (exogenous) quality of college c, δ_{ic} represent travel costs, and ε_{ic} is assumed to be distributed type-1 extreme value. Tuition for student i attending college c is represented by t_{ic}, and this equals r_c for in-state students and n_c for out-of-state students. The parameter α reflects valuation of quality, and the parameter $\rho > 0$ represents the precision of unobserved preferences (i.e. $\rho = 1/\sigma$). When there is a significant degree of heterogeneity in preferences, ρ will be small, and students will be relatively unresponsive to tuition. Conversely, with a small degree of heterogeneity, then ρ will be large, and students will be relatively responsive to tuition. Finally, assume that out-of-state students face higher travel costs, relative to in-state students. In particular, we normalize travel costs for in-state students to zero ($\delta_{ic} = 0$ for in-state colleges) and assume uniform travel costs ($\delta_{ic} = \delta > 0$) for students attending out-of-state colleges.

Let P_s denote the probability that a student from s attends the in-state institution:

$$P_W = \frac{\exp(\alpha\rho q_W - \rho r_W)}{\exp(\alpha\rho q_W - \rho r_W) + \exp(\alpha\rho q_E - \rho n_E - \rho\delta)} \tag{2}$$

$$P_E = \frac{\exp(\alpha\rho q_E - \rho r_E)}{\exp(\alpha\rho q_E - \rho r_E) + \exp(\alpha\rho q_W - \rho n_W - \rho\delta)} \tag{3}$$

Otherwise, students attend out-of-state institutions, with probabilities $1 - P_W$ and $1 - P_E$.

We next consider the budget constraint facing colleges. Let f_c denote the fraction of in-state students attending college c.[10] Assume that educating a student requires a constant expenditure, or marginal cost, equal to m.[11] Then, college W faces the following budget constraint:

$$f_W r_W + (1 - f_W) n_W = m \tag{4}$$

That is, the weighted average of resident and non-resident tuition must equal the unit cost of

[9] We later consider an extension to more than two states.

[10] For state W, this equals $P_W/[P_W + (1 - P_E)]$.

[11] We later consider extensions with alternative cost structures.

educating a student.

3.2 Welfare

We begin by developing expressions for welfare and the associated responses to changes in tuition policy. Utilitarian welfare, averaged across states, equals $0.5(V_E + V_W)$, where V_W and V_E are the inclusive values for a representative student, after scaling by ρ so that welfare is money metric:

$$V_W(r_W, n_E) = (1/\rho)\ln[\exp(\alpha\rho q_W - \rho r_W) + \exp(\alpha\rho q_E - \rho n_E - \rho\delta)] \tag{5}$$

$$V_E(r_E, n_W) = (1/\rho)\ln[\exp(\alpha\rho q_E - \rho r_E) + \exp(\alpha\rho q_W - \rho n_W - \rho\delta)] \tag{6}$$

Then, consider equal changes in non-resident tuition ($\Delta n_W = \Delta n_E = \Delta n$), offset by budget-balancing changes in resident tuition. In this case, the change in welfare equals:

$$0.5\left[\frac{\partial V_W}{\partial n_W}\Delta n + \frac{\partial V_E}{\partial n_W}\Delta n + \frac{\partial V_E}{\partial n_E}\Delta n + \frac{\partial V_W}{\partial n_E}\Delta n\right] \tag{7}$$

Further, let $\frac{\partial r_W}{\partial n} = \frac{\partial r_W}{\partial n_W} + \frac{\partial r_W}{\partial n_E}$ represent the combined change in required resident tuition at W and likewise for $\frac{\partial r_E}{\partial n}$. Then, using the envelope condition, Equation 7 can be re-written as:

$$0.5\Delta n\left[-P_W\frac{\partial r_W}{\partial n} - (1-P_E) - P_E\frac{\partial r_E}{\partial n} - (1-P_W)\right] \tag{8}$$

Thus, evaluating changes in welfare requires information on the change in resident tuition associated with an increase in non-resident tuition. In the Appendix, we show that, using the institution budget constraints, these required changes in resident tuition can be characterized by the following two equations:

$$\left(\frac{\partial P_W}{\partial r_W}(\frac{\partial r_W}{\partial n} - 1)\right)[r_W - m] + P_W\frac{\partial r_W}{\partial n} - \frac{\partial P_E}{\partial r_E}(\frac{\partial r_E}{\partial n} - 1)[n_W - m] + (1-P_E) = 0 \tag{9}$$

$$\left(\frac{\partial P_E}{\partial r_E}(\frac{\partial r_E}{\partial n} - 1)\right)[r_E - m] + P_E\frac{\partial r_E}{\partial n} - \frac{\partial P_W}{\partial r_W}(\frac{\partial r_W}{\partial n} - 1)[n_E - m] + (1-P_W) = 0 \tag{10}$$

In order to build intuition, we next consider three special cases. First, if tuition is at non-discriminatory levels (i.e. $r_W = n_W = m$ and $r_E = n_E = m$), then $\frac{\partial r_W}{\partial n} = \frac{-(1-P_E)}{P_W}$ and $\frac{\partial r_E}{\partial n} = \frac{-(1-P_W)}{P_E}$. Inserting these into Equation 8, the change in welfare equals zero. This is consistent with non-discriminatory tuition being socially optimal, as will be shown more formally below. Second, consider the case of no behavioral responses (i.e. $\frac{\partial P_E}{\partial r_E} = \frac{\partial P_W}{\partial r_W} = 0$). In this case, we again have that $\frac{\partial r_W}{\partial n} = \frac{-(1-P_E)}{P_W}$ and $\frac{\partial r_E}{\partial n} = \frac{-(1-P_W)}{P_E}$. Then, following standard logic, there is no welfare loss in the absence of behavioral responses, and any prospects for increasing welfare will require a behavioral response.

Third, in the symmetric case ($q_W = q_E$, $r_E = r_W = r$, and $n_E = n_W = n$), attendance probabilities are also symmetric ($P_E = P_W = P$), and the required change in resident tuition can be written more compactly as:

$$\frac{\partial r}{\partial n} = \frac{-(1-P) - \frac{\partial P}{\partial r}(n-r)}{P - \frac{\partial P}{\partial r}(n-r)} \tag{11}$$

Based upon Equation 11, Figure 1 plots the relationship between resident and non-resident tuition. In the absence of a behavioral response ($\frac{\partial P}{\partial r} = 0$), this relationship is linear, with a slope equal to $-(1-P)/P$. That is, resident tuition can be reduced by an amount equal to $(1-P)/P$ when increasing non-resident tuition by one dollar. This simply reflects the mechanical effect through which, by increasing non-resident tuition by one dollar, the institution raises a per-student amount equal to $1-P$, which is then re-distributed to the resident students, which comprise a fraction P. Also, note that it is always feasible for colleges to set non-discriminatory tuition such that $r = n = m$. With a behavioral response, the relationship is no longer linear. At the point of non-discriminatory tuition ($r = n = m$), the slope again equals $-(1-P)/P$, regardless of the size of the behavioral response. Behavioral responses play no role in this case since residents and non-residents pay equal tuition. As non-resident tuition increases beyond m, the relationship flattens and the ability to cross-subsidize resident students is weakened. This is due to the financial loss associated with losing non-resident students, who cross-subsidize resident students. Eventually, "profits" from non-residents are maximized at $n = m + (1/\rho)$ and additional increases in non-resident tuition require increases in resident tuition.[12] That is, beyond $n = m + (1/\rho)$, there is no additional scope for reducing in-state tuition, reflecting the fact that, beyond this minimum feasible resident tuition, the behavioral response by non-resident students, which leads to a reduction in total tuition revenue collected from non-residents, more than offsets the mechanical effect associated with increasing non-resident tuition, which leads to an increase in total tuition revenue collected from non-residents.

Further, in the symmetric case, the change in welfare in Equation 8 can be written more

[12] This can be derived by setting the numerator of $\frac{\partial r}{\partial n}$ equal to zero (i.e., $-(1-P) = \frac{\partial P}{\partial r}(n-r)$) and noting both that $\frac{\partial P}{\partial r} = -\rho P(1-P)$ and that the institutional budget constraint can be written as $P(n-r) = (n-m)$.

compactly as:

$$\Delta n \left[-P \frac{\partial r}{\partial n} - (1-P) \right] \tag{12}$$

This simple expression reflects the envelope condition for the discrete choice case. In particular, a fraction $1-P$ of students attending out-of-state institutions are directly affected by the change in non-resident tuition. Likewise, a fraction P of students attending in-state institutions are directly affected by the change in resident tuition according to $\frac{\partial r}{\partial n}$. While some students do switch institutions in the event of a change in tuition, they were indifferent between institutions and thus their utility is not directly affected by marginal changes in tuition policies.

Inserting Equation 11 into Equation 12, we then have the following change in welfare in the symmetric case:

$$\Delta n \left[-P \left(\frac{-(1-P) - \frac{\partial P}{\partial r}(n-r)}{P - \frac{\partial P}{\partial r}(n-r)} \right) - (1-P) \right] \tag{13}$$

Since $\frac{\partial r}{\partial n} > \frac{-(1-P)}{P}$ when $n > r$, we have that welfare is reduced when non-resident tuition is further increased. Equivalently, we can say that welfare will increase when reducing existing gaps between non-resident and resident tuition. This is consistent with the initial idea that gaps between non-resident and resident tuition may lead to economic inefficiencies and that reducing these gaps may lead to welfare gains.

Finally, from an empirical perspective, the change in welfare can be characterized by a sufficient statistic relating in-state enrollment to resident tuition ($\frac{\partial P}{\partial r}$). That is, to measure the change in welfare, one does not need to separately estimate the underlying parameters (ρ, δ, q_W, q_E). Instead, the response of enrollment to tuition is a sufficient statistic for the change in welfare and, given this, the key objective of our empirical analysis will involve estimating this sufficient statistic via a border discontinuity design.

3.3 Socially optimal policies

Returning to the more general case, in which we allow for non-symmetric quality, we have that the social planner chooses the set of policies (r_W, n_W, r_E, n_E) in order to maximize national social welfare, subject to the two institutional budget constraints. As above, we consider changes in non-resident tuition, offset by changes in resident tuition. Building upon intuition from the prior section, marginal changes in non-resident tuition do not induce distortions in the absence of pre-existing differences between resident and non-resident tuition. Thus, non-discriminatory tuition is optimal. This result is summarized in the following Proposition, and the Proof is provided in the Appendix.

Proposition 1: Socially optimal tuition policies are non-discriminatory in nature. That is, optimal policies are given by $n_W = r_W = m$ and $n_E = r_E = m$.

3.4 Policies under decentralization

For comparison with policies set by a national planner, we next consider how states set tuition policies under decentralization. From a positive perspective, this analysis also sheds light on why states distinguish between residents and non-residents when setting tuition.

While the previous results were agnostic with respect to university objectives, this analysis requires additional assumptions. In particular, for comparison with maximization of national welfare, we assume that states choose policies to maximize the welfare of their residents and do not account for the welfare of non-residents. As will be shown below, this objective is equivalent to universities maximizing "profits", the difference between revenue and costs, on non-resident students and using the proceeds to cross-subsidize resident students via lower in-state tuition.

In particular, taking the policies of E as given, states set out-of-state tuition in order to minimize in-state tuition ($\frac{\partial r_W}{\partial n_W} = 0$). Using the state budget constraint, and taking the derivative with respect to non-resident tuition, holding fixed tuition in state E, one can show that:

$$\frac{\partial P_W}{\partial r_W}\frac{\partial r_W}{\partial n_W}[r_W - m] + P_W \frac{\partial r_W}{\partial n_W} + (1 - P_E) - \frac{\partial P_E}{\partial n_W}[n_W - m] = 0 \tag{14}$$

Since $\frac{\partial r_W}{\partial n_W} = 0$ in equilibrium, we have that non-resident tuition can be characterized by:

$$n_W = m + \frac{(1 - P_E)}{\partial P_E / \partial n_W} \tag{15}$$

Thus, since $\partial P_E / \partial n_W$ is positive, we have that states set higher tuition for non-residents ($n_W > m > r_W$) in equilibrium. These results, along with additional results in the symmetric case, are summarized in the following Proposition, with a proof in the Appendix.

Proposition 2: In equilibrium, states set higher tuition for non-residents ($n_W > m > r_W$ and $n_E > m > r_E$). In the symmetric case ($q_W = q_E$), there is a unique equilibrium. In this equilibrium, increases in the response of enrollment to tuition, as captured by the parameter ρ, lead to reductions in non-resident tuition. That is, $\frac{\partial n}{\partial \rho} < 0$.

The intuition for this comparative static is that, when students are responsive to tuition, $\frac{\partial P}{\partial n}$ is large, and there is stiff competition for students. Due to this competition, states lower non-resident tuition. When students are unresponsive to tuition, by contrast, $\frac{\partial P}{\partial n}$ is small, the demand curve is steep, and there is sufficient variation in student preferences that states can extract some of the rents earned by non-resident students. Moreover, one can show that this decentralized problem is equivalent to states maximizing “profits” on out-of-state students, defined by $(n_W - m)(1 - P_E)$, and using the proceeds to cross-subsidize in-state students. Again, profits are maximized by setting out-of-state tuition such that in-state tuition is minimized.

While universities in this model use tuition from non-residents to cross-subsidize residents, there may be alternative explanations for why universities set higher tuition for non-residents. It could be, for example, that universities simply maximize profits (revenues net of costs) on both residents and non-residents and price discriminate, charging higher tuition to students with a higher willingness to pay. As **?** argues, however, profit-maximizing universities would actually charge higher prices to residents than to non-residents, and a similar result can be generated in our model.[13] In particular, due to travel costs, students are willing to pay more to attend in-state institutions than to attend out-of-state institutions, and universities thus charge higher tuition to residents. Thus, price discrimination cannot explain observed higher tuition for non-residents, at least in the context of this model.

As a summary, Figure 2 depicts how welfare changes as a function of non-resident tuition in state W. For the purposes of this figure, we focus on the symmetric case and assume that policies in E are fixed at Nash equilibrium levels and then consider changes in policies in state W. The x-axis depicts non-resident tuition in state W (n_W), with resident tuition adjusting such that the budget remains balanced. The Figure depicts the welfare of residents (V_W), the welfare of non-residents (V_E), and combined welfare ($V_W + V_E$). At Nash equilibrium non-resident tuition $(n_W = n^*)$, the welfare of residents (V_W) is maximized and, by symmetry, equals the welfare of state E (V_E). Decreases in non-resident tuition from this point generate first-order welfare gains for residents of E but only second-order welfare losses for residents of W. Thus, reductions in non-resident tuition generate gains in national welfare (V_W+V_E). Further reductions in non-resident welfare generate national welfare gains until the point at which policies are non-discriminatory ($n_W = r_W = m$), at which point national welfare is maximized.

3.5 Extensions

We next consider four extensions of the model: 1) alternative cost structures 2) appropriations/subsidies from state governments, and 3) more than two states, and 4) international students. A brief overview is provided here and readers are referred to the Appendix for further details.

[13] A profit maximizing university would set non-resident tuition, as documented above, according to $n_W = m + \frac{(1-P_E)}{\partial P_E/\partial n_W}$ and, likewise, would set resident tuition according to $r_W = m + \frac{P_W}{\partial P_W/\partial r_W}$. Then, using the fact that $\partial P_E/\partial n_W = \rho P_E(1-P_E)$ and that $\partial P_W/\partial r_W = -\rho P_W(1-P_W)$, one can show that non-resident tuition is lower than resident tuition ($n_W < r_W$) in a symmetric equilibrium.

First, while the baseline model focuses on a simple cost structure with only marginal costs, we consider alternative cost structures, beginning with fixed costs and then separate consideration of increasing marginal costs. Given that fixed costs must be paid by institutions regardless of student enrollment patterns, the key welfare calculations are unchanged in this case. That is, it remains the case that equating resident and non-resident tuition is socially optimal. Moreover, the welfare gains associated with reducing out-of-state tuition can be characterized by the sufficient statistic relating enrollment to tuition policies. We also consider decentralization with fixed costs. It remains the case that universities attempt to maximize variable profits from non-residents and charge non-resident tuition in excess of m. Moreover, so long as fixed costs are sufficiently small, institutions charge higher tuition to non-residents, when compared to resident tuition. To summarize, the introduction of fixed costs does not change the welfare analysis, and the tuition gap remains in equilibrium so long as these fixed costs are sufficiently small.

To allow for increasing marginal costs, we assume that marginal costs are quadratic in enrollment. In the context of this extension, we show that all of key results remain unchanged, at least in the symmetric case. That is, it remains the case that equating resident and non-resident tuition is socially optimal. Moreover, the welfare gains associated with reducing out-of-state tuition can be characterized by the sufficient statistic relating enrollment to tuition policies. Finally, under decentralization, universities continue to charge higher tuition to non-residents. An additional strategic factor in this case involves the fact that universities may want to reduce out-of-state enrollment in order to reduce costs and thus resident tuition. Given this, universities face an additional incentive to set high non-resident tuition.

Second, we extend the model to include state appropriations in the form of subsidies for public universities. A common argument for higher non-resident tuition involves the idea that institutions are partially funded via these subsidies, which are financed by resident taxes. Thus, the higher price charged to non-residents simply reflects a fee paid by non-residents that is equal to the taxes paid by residents.[14] We incorporate these considerations into the model via an exogenous appropriation for each resident student equal to σ. The assumption of exogenous per-resident appropriations implies that total financial support falls with the fraction of enrollees who are residents, capturing the idea that state support of public universities is decreasing in resident enrollment.[15] Then, one can consider the current equilibrium in the United States as resident students paying tuition equal to $r = m - \sigma$ and non-residents paying the true cost

[14] In a dynamic context, state taxes could also be interpreted as pre-paid tuition.

[15] We have also considered a version of the model in which per-student appropriations are decreasing in the gap between non-resident and resident enrollment. That is, $\sigma = n - r$. In this case, the institution budget constraint requires that non-resident tuition always equals costs ($n = m$). While one thus cannot consider reductions in non-resident tuition (since $n = m$), it is the case that welfare increases when resident tuition is increased and subsidies are decreased.

($n = m$). Thus, the gap between resident and non-resident tuition equals the taxes paid by residents. That is, $n = r + \sigma$. In the context of this extension, with subsidies financed via non-distortionary resident taxes, we show that, in the symmetric case, reducing non-resident tuition from these high levels ($n = r + \sigma$) continues to generate a welfare gain. The intuition behind this result is that these student subsidies are not portable across states. Given this, student choices continue to be distorted, in the sense that out-of-state students must pay higher non-resident tuition in addition to paying taxes to finance subsidies for other students. Indeed, we also show that making these subsidies portable across state lines would justify higher non-resident tuition from a welfare perspective. That is, there is no welfare gain when reducing non-resident tuition from $n = r + \sigma$ so long as students can use their subsidy to cover tuition at out-of-state institutions.

Third, we examine the case of more than two states. The key difference here is that students have a greater degree of choice among out-of-state institutions, potentially yielding increased competition between institutions for non-resident students. From a normative perspective, we find that the key welfare lesson is again unchanged: equating resident and non-resident tuition remains socially optimal. Moreover, the welfare gains associated with reducing out-of-state tuition can be characterized by the same sufficient statistic relating enrollment to tuition policies, under the interpretation that $1 - P$ reflects out-of-state attendance aggregated over all out-of-state institutions. Turning to decentralization, we show, in a calibrated version of the model, that an increase in the number of states leads to a reduction in non-resident tuition due to competition for non-resident students. This decrease is small, however, and resident tuition falls more quickly, reflecting the financial windfall to institutions associated with a mechanical increase in out-of-state attendance due to the increased choice set. Moreover, non-resident tuition is bounded from below, above m, even as the number of states grows large. This reflects the fact that universities retain market power due to product differentiation. To summarize, an increase in the number of states beyond two does not change the welfare analysis, and the tuition gap remains in the decentralized equilibrium even with a large number of states.

Fourth, we consider the case of international students, using the framework just described for more than two states. In particular, one can consider a subset of the jurisdictions in this extended model as U.S. states and the remainder as foreign countries. From a global welfare perspective, of course, the key results are unchanged: equating resident and non-resident tuition remains globally optimal, where non-resident tuition now applies to students from both other states and from other countries. If the social planner maximized national welfare, by contrast, then there would be an incentive to set non-resident tuition at higher levels in order to use tuition from international students to cross-subsidize domestic students via lower resident tuition.

For similar reasons, a social planner maximizing national welfare would face an incentive to differentiate between domestic out-of-state students and foreign out-of-state students, charging higher tuition to the latter. Finally, in the context of our model, one can interpret the globalization of higher education as an increase in the number of jurisdictions, with the new jurisdictions representing foreign countries. As noted above, resident tuition falls as the number of jurisdictions increases, and, in this case, this reflects the financial windfall to institutions associated with an inflow of foreign students. In a richer model including state appropriations, it is also possible that states would respond to this financial windfall from foreign students by reducing subsidies to state universities rather than reducing resident tuition, and this is consistent with the documented negative relationship between state appropriations and foreign enrollment in U.S. public universities (**?**).[16]

4 Corrective Policies

This section considers two possible solutions to the distortion associated with higher non-resident tuition under decentralization. We first discuss interventions by the federal government followed by reciprocity agreements between state governments.

Given that the federal government internalizes the welfare of both residents and non-residents of a given institution, it is natural that higher-level governments may be able to solve this problem. The judicial branch is one possible forum for this debate, and non-resident students have indeed challenged the constitutionality of state universities discriminating against non-residents when setting tuition. Federal courts, however, have generally ruled in favor of states and against non-resident students due to the fact that non-residents do not pay taxes in the state supporting the public institution. In addition, federal courts have given states significant leeway in defining residency for tuition purposes, allowing, for example, one-year residency requirements (**?**). Importantly, attending the university does not typically count towards the residency requirement, and students thus do not qualify for in-state tuition following their first year of study. Given this, another possibility involves new federal law requiring state institutions to charge the same tuition to non-residents coupled with a plan that would involve a series of payments between states.[17]

[16] On the globalization of higher education, also see **?**.

[17] There are two key details that need to be addressed when designing such a plan. First, while states set symmetric in-state rates in the theoretical model, tuition rates differ across states in the U.S. depending upon the level of subsidies from the state government and other factors. Given this, the incentives for states to subsidize public colleges and universities with tax revenue collected from residents would be diminished. Thus, any transfer plan may need to involve payments from states that have relatively small subsidies to states that have relatively large subsidies. Second, while state inflows and outflows cancel out in the baseline model, some states may in practice

In the absence of federal intervention, and given the hypothesized welfare losses associated with this non-resident tuition distortion, it is natural that state governments may attempt to reduce barriers via reciprocity agreements under which students can pay in-state tuition rates at out-of-state institutions. Four regional exchanges provide discounts to non-resident students from member states: the Western Undergraduate Exchange, the Midwest Student Exchange Program, the Academic Common Market, and Tuition Break (New England). A vast majority of states (44 out of 50) participate in at least one of these exchanges (**?**).[18] There are several limitations of these agreements in practice. First, participation is selective, with not all public institutions in these states participating. Second, slots are not guaranteed and tend to be made available to students only when excess space is available. Third, these exchanges may only be available to students whose major field of study is not offered in their home state. Finally, students receive only discounts from the non-resident rate and pay more than residents.[19] Despite these limitations, we provide some evidence below that these reciprocity agreements are efficiency-enhancing.

5 Data

To estimate the sufficient statistic identified in the model, we use a border discontinuity design, as detailed below, in which we examine institutional enrollment patterns for students living close to state borders. To measure this distribution, we use the restricted access version of the HERI Freshman Survey, covering the years 1997-2011. In this survey, incoming freshman at select institutions are asked a battery of questions involving their demographics, high school

experience net inflows or net outflows. Given this, and in the presence of state subsidies for higher education, any transfer plan may also need to involve payments from states that are net exporters of students to states that are net importers of students. See **?** for more details.

[18]In addition, specific state universities sometimes provide discounts to students living in nearby border areas. The University of Massachusetts-Dartmouth, for example, offers discounts to residents of Rhode Island. See http://www.umassd.edu/undergraduate/tuition/ (accessed October 16, 2015). Also, the most comprehensive reciprocity agreement is between Minnesota and three of their neighbors, Wisconsin, North Dakota, and South Dakota. This program is designed to completely remove tuition and admissions barriers. During the fall of 2013, over 40,000 students participated in this program.

[19]In some cases, these discounts are substantial and participating students pay tuition that is close to resident rates, while in other cases participating students receive relatively small discounts. For example, students participating in Tuition Break during the 2015-16 academic year and attending the University of Maine pay $12,570 in tuition, substantially less than the $26,640 paid by non-residents not participating and closer to the resident rate of $8,370. At the University of New Hampshire, by contrast, participants pay $24,588, closer to the non-resident rate of $27,320 than to the resident rate of $11,128. These figures are taken from http://www.nebhe.org/info/pdf/tuitionbreak/2015-16_RSP_TuitionBreak_TuitionRates.pdf (accessed October 16, 2015).

experience, and, importantly for our analysis, the zip code of their permanent residence.[20] In addition, we can distinguish between public and private institutions, and the restricted access version also includes a measure of the state in which the institution is located. Further, our restricted access version also includes measures of in-state and out-of-state tuition and fees for each institution included in the analysis.[21] To summarize, our analysis uses information on student permanent residence (zip code and state), institution state, institutional status (public or private), and tuition and fees, separately for residents and non-residents.

Given the survey design, note that this is a sample of institutions, not a sample of students. Hence, our unit of analysis to follow involves institutions, rather than students. Further, this is not necessarily a representative sample of institutions as colleges choose to participate in the survey in order to gather information about their incoming students. Nonetheless, participation is widespread, with over 1,000 institutions participating at least once during our sample period.[22]

To implement the border discontinuity design, we use zip code maps to first calculate the distance from each zip code centroid to every state border.[23] For each zip code, we then focus on the closest state border. More formally, let δ_z be the distance from zip code z to the closet border. Then, we code distance as negative ($d_{zc} = -\delta_z$) for students attending institutions in the closest border state and code distance as positive ($d_{zc} = \delta_z$) for students attending in-state colleges. We focus on bandwidths of 20km (about 12.5 miles), and, as a robustness check, we also present results for bandwidths of 10km and 30km.

Using this sample, we then collapse zip codes into larger geographic units based on distance to the border, which we refer to as distance bins. Specifically, we partition the area around each border into a set of two kilometer (1.25 miles) distance bins and assign each zipcode to the bin in which it is located. For example, for the baseline bandwidth of 20 kilometers on each side of the border there are 10 two kilometer distance bins on each side, the first between 18 and 20 kilometers from the border, the second between 16 and 18 kilometers, and so on. We use these distance bins in figures depicting the discontinuity, as well as in a robustness check of our empirical specification. However, in most of our empirical analysis we further aggregate zip codes to each side of the border (an in-state side and an out-of-state side) and run regressions

[20]We exclude institutions that had fewer than 100 respondents to the survey in a given year. In addition, to focus on a consistent set of institutions, we exclude two-year institutions.

[21]These tuition measures are taken from the Integrated Postsecondary Education Data System (IPEDS) at the National Center for Education Statistics (NCES).

[22]This is an unbalanced panel of institutions as few participate in all 15 years of the sample.

[23]We use 2000 Census zip code maps for the 1997-2000 HERI data and 2010 Census zip code maps for the 2001-2011 HERI data. We also considered using the 2000 map for the years 2001-2004 but would have lost a substantial number of observations due to zip codes not included in the 2000 map.

with these "border-sides" as our spatial unit. Appendix Figure 7 illustrates how zip codes are assigned to distance bins and border-sides for a bandwidth of 20km.

We complement this analysis of HERI data with two additional datasets. First, we analyze information on student payments from the restricted access version of the National Postsecondary Student Aid Study (NPSAS), collected by the NCES. [24] These data have information on both official tuition and fees, separately for residents and non-residents, and as well as actual payments made by students surveyed. While our baseline HERI data include the former measure, they do not include the latter measure. In the analysis to follow, we use two measures of payments, one being tuition and fees paid and the second being net tuition and fees, which subtracts out any grants received by the student.

Second, as a further complement to our analysis of the baseline HERI data, we examine the Educational Longitudinal Study (ELS 2002-2006). These data consist of a nationally representative longitudinal study of 10th graders in 2002 and 12th graders in 2004. In addition to measures of the zip code of permanent residence, these data include information on the set of colleges to which students applied and the set of colleges to which they were accepted.[25] We then infer the choice from this set of acceptances based upon the school that they chose to attend. Using these data, we then examine both admissions decisions by institutions and student enrollment decisions given these choice sets.

6 Methods

As described above, the goal of the empirical analysis involves estimating the responsiveness of out-of-state enrollment to out-of-state tuition (i.e. $\frac{\partial P}{\partial n}$). We begin by describing a simple border discontinuity (BD) design, which compares enrollment between residents and non-residents, both living close to the border. While the border discontinuity design does not use any information on tuition, we also develop a tuition discontinuity design (TD). This design also compares enrollment between residents and non-residents, both living close to the border, but also uses information on the drop in tuition when crossing the border. Finally, we discuss a hybrid design, which compares the border discontinuity in enrollment between institutions with large and small differences between resident and non-resident tuition.

A key identification challenge involves separately measuring the effects of distance and the effects of the tuition gap. In particular, to separate distance and responses to the tuition gap,

[24] We analyze data from the following waves: 1999-2000, 2003-2004, 2007-2008, and 2011-2012.

[25] These choice sets are based upon retrospective survey questions during the third wave, conducted in 2006, during which students were attending college.

we estimate the responsiveness of non-resident enrollment to the tuition gap via the following sharp border discontinuity (BD) design:

$$\ln(N_{bct}) = g(d_{bct}) + \rho^{BD} 1[d_{bct} > 0] + \theta_{ct} + \theta_{bt} + \varepsilon_{bct} \tag{16}$$

where N_{bct} is the number of students from border-side or distance bin b attending college c in year t, and d_{bct} represents the distance from b to the border associated with c. The function g is smooth in distance, which, as described above, is negative (positive) for out-of-state (in-state) students. Note that, in our border-sides specification, distance to the border is not considered. Additionally, θ_{ct} represents college-by-year fixed effects, and θ_{bt} represents border-side-by-year (or bin-by-year) fixed effects. College-by-year fixed effects capture college attributes that would be attractive to both residents and non-residents. Border-side-by-year fixed effects capture factors that might influence college attendance, such as the number of high school students, high school quality, and demographic factors, such as race. We are able to include both destination (college) and source (residence) fixed effects due to the fact that our unit of observation is college-by-source, and responses to tuition are identified by students flowing in both directions across state borders. Finally, ε_{bct} represents unobserved factors that drive enrollment in college c from border-side b in year t.

By focusing on students living close to state borders, we can separate the role of tuition from the role of geography. In particular, ρ^{BD} is the percent change in enrollment when crossing the border:

$$\rho^{BD} = \lim_{d_{bct} \to 0} [E(\ln(N_{bct})|in-state) - E(\ln(N_{bct})|out-of-state)] \tag{17}$$

Using the theoretical model outlined above, we have that, considering college c, this key border discontinuity parameter can be written as:

$$\rho^{BD} = \rho(n_c - r_c) \tag{18}$$

Thus, the key coefficient from this border discontinuity design identifies the product of ρ, the responsiveness of enrollment to tuition, and $(n_c - r_c)$, the tuition gap between residents and non-residents. That is, any border discontinuity reflects both an underlying difference in tuition and student responses to this difference in tuition. As in all discontinuity designs, the parameter is identified by students living close to state borders.

In order to separate these two channels, tuition differences and enrollment responses to these differences, behind any border discontinuity, we next discuss the tuition discontinuity design, which incorporates information on tuition for residents and non-residents. In particular, we estimate the following tuition discontinuity design regression:

$$\ln(N_{bct}) = f(d_{bct}) - \rho^{TD} t_{bct} + \theta_{ct} + \theta_{bt} + \varepsilon_{bct} \tag{19}$$

where t_{bct} represents tuition for students attending institution c from border-side (distance bin) b at time t. This equals in-state tuition for residents and out-of-state tuition for non-residents. More formally, $t_{bct} = n_{ct} 1[d_{bct} < 0] + r_{ct} 1[d_{bct} > 0]$. Thus, this tuition discontinuity design is identified by measuring the change in enrollment associated with the discontinuous drop in tuition when crossing the border from neighboring states into the institution state.

As before, the key measured discontinuity can be interpreted as follows.

$$\rho^{TD}(n_c - r_c) = \lim_{d_{bct} \to 0} [E(\ln(N_{bct})|in-state) - E(\ln(N_{bct})|out-of-state)] \tag{20}$$

Given the results above, in the context of the border discontinuity design, we have that:

$$\rho^{TD} = \rho \tag{21}$$

Thus, by incorporating measures of resident and non-resident tuition, the tuition discontinuity design allows us to identify the key theoretical parameter measuring the responsiveness of enrollment to tuition.

Finally, we investigate whether any measured effects in our tuition discontinuity design are driven by tuition differences or other reasons that students may attend in-state institutions (in addition to geography). For example, if public institutions primarily recruit in-state students, then our tuition discontinuity design will attribute this recruiting to lower in-state tuition. To separate these other reasons why students may attend in-state institutions from both tuition and geography, we also estimate the following hybrid discontinuity design that includes both distance and tuition:

$$\ln(N_{bct}) = f(d_{bct}) - \rho^{TD} t_{bct} + \rho^{BD} 1[d_{bct} > 0] + \theta_{ct} + \theta_{bt} \tag{22}$$

As shown, this hybrid design is identified both by border discontinuities and by differences in the tuition gap across institutions. In particular, this design now compares the enrollment discontinuity between institutions with large and small tuition gaps. The parameter from the border discontinuity design (ρ^{BD}) captures all non-tuition factors, such as recruiting, contributing to the border discontinuity, and the parameter from the tuition discontinuity design (ρ^{TD}) isolates the role of tuition.

7 Results

Before estimating the border discontinuity models developed above, we provide evidence on differences in tuition between residents and non-residents using information on both posted tuition prices and actual payments by students. Having established that non-residents pay more than residents, we then describe the results from our border discontinuity design. Next, we address several alternative explanations for our border discontinuity. We then present results from the tuition discontinuity design and the hybrid discontinuity design. We also investigate whether reciprocity agreements reduce border discontinuities. We then conduct a similar analysis using a separate dataset on student choice sets.

7.1 Differences in Tuition Payments

As a starting point, we document differences in posted tuition and fees, which we also refer to as sticker prices since they are not adjusted for any discounts in the form of grants. Table 1 provides average tuition and fees (2011 dollars), separately by year and for residents and non-residents, in the sample of institutions included in the HERI data. As shown, in-state tuition rose from just over $5,000 in 1997 to just over $8,000 in 2011. For non-residents, by contrast, tuition rose from roughly $13,500 in 1997 to over $19,000 in 2011. As shown in the final column, tuition levels rose more rapidly for non-residents, as the gap rose from just over $8,000 in 1997 to just over $11,000 in 2011. In terms of growth rates, by contrast, resident tuition rose more quickly (56 percent) than non-resident tuition (43 percent). Averaged across all years, and as shown in the final row, resident tuition is roughly $6,000 and non-resident tuition is roughly $15,000, implying an average gap of $9,000 during our sample period.

Of course, student payments are often well below these posted tuition prices due to grants and other forms of financial aid. To examine student payments, we turn to evidence from the NPSAS, which, as described above, includes information on both tuition payments and payments net of grants. We begin by analyzing payments by students to public institutions in Table 2. As shown in the first column, in-state students pay around $7,200 less than out-of-state students, and this difference is statistically significant at conventional levels. This gap is similar in magnitude to, but a bit lower than, the $9,000 average gap across the HERI sample years, as documented in Table 1. We next regress payments on the sticker price adjusted for whether or not the student is a resident or a non-resident. If payments are perfectly correlated with sticker prices, then we expect a coefficient of one. If payments are uncorrelated with sticker prices, by contrast, then we expect a coefficient of zero. As shown in column 2, we find that there is a correlation, with an increase in the sticker price of one dollar associated with an increase in student tuition payments of 76 cents. Column 3 controls for both this sticker price and a simple indicator for whether or not the student is in-state. As shown, even after controlling for residency status, sticker prices matter. Said differently, the difference in tuition payments between residents and non-residents is larger at institutions with larger differences between resident and non-resident tuition. Columns 4-6 provide results from analogous specifications in which the dependent variable is net tuition and fees, which adjust for all grants received by the student. As shown, resident pay about $6,400 less than non-residents on net. Likewise, sticker prices also matter, with an increase in the sticker price of one dollar associated with a 70 cent increase in student net payments. Finally, as in column 3, the difference in net tuition payments between residents and non-residents is also larger when the difference in sticker prices is larger.

7.2 Border Discontinuity Design

Having established that residents pay less than non-residents at public institutions, we next provide results from our border discontinuity design. We begin with graphical evidence. Figure 3 plots the number of students in the HERI data attending a given institution in a given year from a given 2km distance bin. The x-axis depicts distance, in kilometers, from the border, where negative distance represents out-of-state bins and positive distance represents in-state bins. Naturally, as distance on the x-axis crosses zero, bins change from being non-resident to resident. Each bar represents the average enrollment in that distance bin across all public institutions. For example, on average across public institutions and years 1997-2011, there are roughly 4 students in bins between 0 and 2 kilometers inside the border.[26]

As shown, there is a striking discontinuity in enrollment, jumping from below one on the out-of-state side of the border to around 6 on the in-state side of the border. Also, there is no discernible slope in enrollment on either side of the border, with fewer than one out-of-state student on average and roughly 6 in-state students, regardless of distance to the border. As the HERI data combine large and small institutions, we next present results in which the number of students in a given bin attending a given institution is scaled by the total number of students attending that institution and within 20 kilometers of the border. As shown, we see a similar discontinuity, with an increase of 8 percentage points, from roughly one percent of enrollment in

[26]Note that there are fewer students living very close to the border (within two kilometers). This is due to the fact that there are few zip codes with centroids within two kilometers of the state border. Note that all regressions at the bin level include bin fixed effects, which control for this pattern.

each two-kilometer bin on the non-resident side of the border to roughly 9 percent of enrollment in a given bin on the in-state side of the border.

Table 3 presents regression versions of these figures. The first three columns show results for border sides, which, as noted above, aggregate the ten 2km distance bins into a single geographic unit of observation. Also, as noted above, these specifications all include institution-year fixed effects and border side-year fixed effects. As shown, using a baseline bandwidth of 20km, there is an increase of roughly 60 students when crossing the border. Column 2 presents results using the percentage of students in each border side (i.e., dividing enrollment in each border side by the total enrollment around the border). As shown, there is an increase in enrollment of 81 percentage points when crossing the border. Finally, in order to measure the percent change in enrollment when crossing the border, column 3 presents results using $\ln(N_{bct}+1)$ as the dependent variable.[27] The coefficient on in-state in this specification represents the product $\rho(n-r)$ from our theoretical model, evaluated at the average tuition gap across colleges and over time. As shown, we again have that enrollment increases substantially when crossing from the out-of-state side of the border to the in-state side.

We next consider three robustness checks. First, we examine results using our baseline bandwidth of 20km but using 2km distance bins, our smaller geographic unit. These specifications allow for us to separately control for distance to the border, which, as noted above, is negative on the out-of-state side of the border and positive on the in-state side. The results are presented in columns 4-6 of Table 3. As shown, we continue to find statistically significant border discontinuities after controlling for distance to the border. As a second robustness check, we return to using our baseline larger geographic unit, border sides, but consider alternative bandwidths. As shown in Appendix Table 14, the results are robust to both a smaller bandwidth of 10 kilometers around the border and a large bandwidth of 30 kilometers around the border. As a third robustness check, we drop institutions that are close to state borders since the non-resident side of the border may no longer be comparable to the resident side of the border. For example, differences in travel times could be substantial for an institution located 10 kilometers inside the border. To do so, we drop institutions within 30 kilometers of the border, and, as shown in Appendix Table 15, the results are robust to dropping these institutions.

Taken together, the graphical and regression estimates point towards a strong and robust border discontinuity, with large increases in enrollment at public institutions when crossing the border. This suggests that there may be substantial welfare gains associated with reducing the gap between resident and non-resident tuition.

[27]Note that we use $\ln(N_{bct}+1)$ rather than $\ln(N_{bct})$ since some border sides have zero enrollment. Results dropping these bins and using $\ln(N_{bct})$ yield similar results.

7.3 Alternative Explanations

We next consider three alternative explanations, beyond geography, for our border discontinuity. The first alternative explanation involves differential admissions thresholds. While our theoretical model does not include an admissions margin, state universities maximizing resident welfare may, in addition to setting differential tuition, have an incentive to set lower admissions standards for residents, relative to non-residents. Indeed, an analysis of self-reported student acceptance decisions, as detailed in Section 7.5 below, documents that in-state applicants are more likely to be accepted by colleges, and especially so at public institutions.[28] Given this, our border discontinuity in enrollment could be explained by a difference in student composition when crossing the border, with high ability students on both sides of the border but only low ability students on the in-state side of the border.

We address this alternative explanation in three ways. First, we restrict the sample to high ability students, defined as students with SAT/ACT test scores that are above the institutional median, defined separately for each year in our data. Presumably these students were unconstrained, or at least less constrained, by the admissions process at the institution. As shown in the first three columns of Table 4, our results remain economically and statistically significant when focusing on this sub-population. Based upon this border discontinuity for the high ability sample, we conclude that our baseline border discontinuity cannot be explained solely by a sharp change in student ability when crossing the state border.

Second, we next include all students but restrict our sample to less selective institutions, those with median test scores below the corresponding median across all institutions in our sample. At these non-selective institutions, admissions processes are less salient, and thresholds should thus be less binding for non-residents. However, the second three columns of Table 4 show that our results for these less selective institutions are similar to those in the baseline specification. This again suggests that our baseline results are not driven by differences in admissions criteria for residents and non-residents.

Third, as detailed in Section 7.5 below, we use information on student applications and admissions to construct choice sets. Then, conditional on being accepted, we find that students are more likely to attend in-state institutions and especially so when there is a large difference between resident and non-resident tuition. This also suggests that our baseline results are not driven by admissions advantages for residents.

A second alternative explanation involves endogenous sorting around state borders. That is, students (or parents) with a strong preference for a specific institution may choose to live inside the state border in order to access in-state tuition. For two reasons, we feel that this is

[28] See also **?**

unlikely to explain our large estimated border discontinuities. First, students apply for college admissions during their senior year of high school, and accessing in-state tuition requires one year of residency prior to enrolling at the university. Thus, in order to access in-state tuition for the first year of college, parents would need to change their residence in advance of the college applications process. Second, we see neither any bunching of students just inside of the state border nor a corresponding drop in students just outside of the state border, a pattern that would naturally be expected under endogenous sorting.

A third alternative explanation involves other factors, beyond tuition and geography, that might differ between resident and non-resident students. While we have accounted for differences in admissions standards, it could be that university recruiting efforts target resident students. Likewise, student information sets about universities may also change at the border, and it is also possible that students identities are tied to their state of residence via college sports or other factors. Finally, while students attending out-of-state institutions do not need to change their drivers license, there could be other transactions costs associated with moving across state borders. For example, students often vote on campus and may thus need to change their voter registration, and students who are employed may need to file taxes in multiple states.

To address these other factors that might change at state borders, we next compare public institutions to private institutions, where tuition does not differ between residents and non-residents. In particular, we include both public and private institutions and allow the border discontinuity to differ between public and private institutions. Then, the border discontinuity for private institutions should capture non-tuition factors that change at state borders, and the difference in the border discontinuities should capture the role of tuition policy. As shown in Table 5, we do find that the border discontinuity is larger for public institutions than for private institutions in all three specifications, and these differences are statistically significant at conventional levels.[29]

While the border discontinuity is larger for public institutions, we do find discontinuities that are both statistically and economically significant for private institutions (see also Figures 5 and 6). While these discontinuities may capture the other factors described above, we can fully explain the pattern of coefficients in Table 5 based upon financial differences between residents and non-residents. In particular, while residents and non-residents pay the same sticker price, we show in Appendix Section B.1 that residents receive substantially more financial aid than non-residents at private institutions, leading their net payments to be roughly $2,800 less.[30]

[29]Note that the much larger discontinuity in column 1, when compared to columns 2 and 3, reflects the fact that public institutions tend to have larger enrollments.

[30]The appendix also documents that resident students are slightly more likely to be admitted to private institutions.

This difference is largely due to higher state aid for residents and is consistent with several programs that provide grants to state residents attending private institutions within the state. From a quantitative perspective, recall from Section 6 that the border discontinuity when using log enrollment identifies $\rho(n_c - r_c)$. Thus, since non-residents pay \$6,400 more on net at public institutions and \$2,800 more at private institutions, the border discontinuity for public institutions should be roughly 2.3 times as large as the border discontinuity for private institutions. Remarkably, as shown in column 3 of Table 5, the border discontinuity for public institutions is exactly 2.3 times as large (1.694 for public institutions and 0.729 for private institutions). Thus, the pattern of border discontinuities for public and private institutions can be fully explained by the pattern of financial advantages for residents at public and private institutions.

7.4 Variation in Tuition Policies

To further explore the role of tuition, we next present results exploiting variation in tuition policies. In this case, we measure the change in enrollment associated with the decrease in tuition when crossing from the out-of-state side to the in-state side of the border. Following that, we also present results from the hybrid discontinuity design, in which we combine the border discontinuity design and the tuition discontinuity design. Finally, we compare discontinuities along borders with and without reciprocity agreements, which reduce the gap between resident and non-resident tuition.

These tuition discontinuity design results are presented in the first three columns of Table 6, in which tuition is measured as tuition and fees (in thousands of 2011 dollars). As described above, tuition equals the non-resident rate for the out-of-state side of the border and the resident rate for the in-state side of the border. As shown in column 1, an increase in tuition of \$1,000 is associated with an decrease of roughly 6 students. Thus, achieving the baseline border discontinuity of 60 students in column 1 of Table 3 requires a tuition gap of roughly \$10,000. As shown in column 2, which uses the percent of enrollment as the dependent variable, an increase in tuition of \$1,000 is associated with an decrease of 8 percentage points, when compared to the total border population. Finally, column 3 documents that an increase in tuition of \$1,000 is associated with an decrease in enrollment of roughly 19 percent; as discussed in Section 6, this coefficient corresponds to ρ from the theoretical model.

We next present results in columns 4-6 of Table 6 from our hybrid discontinuity design, in which we control for both the simple border discontinuity and the tuition discontinuity. This specification compares enrollment discontinuities along borders with large tuition gaps to borders with smaller tuition gaps. As shown, and consistent with our hypotheses, the coefficient on tuition remains negative and statistically significant in all three specifications. At the same time, it is worth noting that when comparing the tuition and hybrid specifications, the coefficient on tuition falls significantly in the hybrid specification and the coefficient on in-state is economically and statistically significant. While this is consistent with the existence of other costs associated with crossing borders, it is also consistent with measurement error in our tuition measures, which are based upon sticker prices, not the prices that students actually face. Indeed, as shown in the final column of Table 2, the R-squared from a regression of payments on sticker prices and fixed effects in the NPSAS data is only 0.33. Due to this measurement error and the negative correlation between the in-state indicator and tuition, the coefficient on tuition will be biased downwards, and the coefficient on in-state will be biased upwards in the hybrid specification even when the true parameter associated with the in-state indicator equals zero. This is due to the fact that the in-state indicator serves as a proxy for the missing signal associated with lower tuition for in-state students.[31]

Finally, we return to our border discontinuity design but compare reciprocity borders to non-reciprocity borders. Reciprocity borders are those in which the two states participate in the same exchange, defined as one of the four regional exchanges described in Section 4. Likewise, non-reciprocity borders are defined as those in which the two states do not participate in the same exchange, even if one or both do participate in an exchange.[32] We hypothesize that, due to tuition discounts, border discontinuities should be smaller along reciprocity borders. As noted above, out-of-state students still pay higher tuition when compared to residents. Given this and other limitations associated with these exchanges discussed in Section 4, we expect that a discontinuity will remain along reciprocity borders.[33] As shown in Table 7, discontinuities are indeed smaller along reciprocity borders, when compared to non-reciprocity borders, although this difference is only statistically significant in the first column. Consistent with the discussion above, border discontinuities, while smaller when compared to non-reciprocity borders, remain significant for reciprocity borders.

[31] See **?**.

[32] In order to classify borders, we compiled a list of state entry years for each exchange from the exchange websites and state government publications and then categorized every border, in every year, as reciprocity or non-reciprocity. The exchange websites are http://msep.mhec.org (MSEP), http://www.nebhe.org/programs-overview/rsp-tuition-break/overview/ (NEBHE), http://www.sreb.org (SREB), and http://www.wiche.edu/wue (WUE). Also helpful was Abbott's history of the WUE **?**.

[33] One important limitation of this analysis is that our HERI data do not include institution identifiers and, given that participation by institutions is incomplete, we code many institutions as reciprocity even when they do not offer tuition discounts. This measurement error provides an additional reason for why a border discontinuity may remain along reciprocity borders.

7.5 Analysis of Admissions and Choice Sets

As a complement to our analysis of HERI data, we next analyze data from the Educational Longitudinal Study (ELS 2002-2006), as described above. Unlike our baseline HERI survey, these ELS data have information on student applications and acceptances. We use these data to first analyze the role of residency status in admissions decisions. Then, using these measures of admissions to create choice sets, we can identify the role of tuition in student choices via revealed preference (**?**). As described above, these analyses shed further light on the admissions margin in our baseline enrollment discontinuities.

We begin by analyzing whether admissions standards differ between residents and non-residents. In particular, Table 8 provides the results from our analysis of acceptance decisions at public institutions. In this analysis, we treat student-application pairs as the unit of observation and then estimate a linear probability model for whether or not the student is accepted at a given institution. Both specifications include institution fixed effects, which control for selectivity.[34] Column 1 provides an analysis of public institutions, controlling for SAT and GPA scores, which increase admissions probabilities (not reported in the table). Conditional on these measures, we find that in-state applicants are 4 percentage points more likely to be admitted to public institutions, when compared to out-of-state applicants, and these differences are statistically significant at conventional levels. Column 2 includes student fixed effects, and identification in this case comes from students who applied to both in-state and out-of-state institutions. As shown, the results are even stronger in this case, with admissions rates for residents 7 percent points higher than admissions rates for non-residents.

Next, using the set of schools to which students were admitted, we construct student choice sets and then estimate alternative-specific conditional logit models of student enrollment decisions. These models include institution fixed effects, and identification thus comes from institutions that are both chosen by at least one accepted student and not chosen by at least one accepted student.[35] Note that these data do not include enough student respondents to conduct a border discontinuity design. Instead, we control for the distance, in thousands of kilometers, between the student, based upon the zip code of the permanent residence, and the institution. Analogously to our border discontinuity design, column 1 of Table 9 reports results from a specification including an indicator for in-state institutions and a quadratic measure of distance. As shown, conditional on distance, students are more likely to attend in-state institutions than

[34]We restrict attention to students reporting both GPA and SAT/ACT scores, and the sample of institutions consists of four-year institutions with at least 10 appearances in student application sets.

[35]We restrict attention to students reporting a choice set of at least two and attending a single institution. The sample of institutions consists of four-year institutions and, due to computational considerations, at least 10 appearances in student choice sets.

out-of-state institutions, and this difference is statistically significant. Analogously to our tuition discontinuity design, column 2 reports results from a specification including tuition, in thousands of dollars and adjusted for whether the student is in-state or out-of-state. As shown, conditional on distance, students are more likely to attend institutions with tuition discounts for residents. Finally, in analogue to our hybrid discontinuity design, column 3 reports results from a specification controlling for both an in-state indicator and tuition. As shown, the coefficient on in-state falls and becomes statistically insignificant, and the coefficient on tuition is relatively stable and remains statistically significant at conventional levels.[36] To summarize, this analysis of choice sets using a separate data set corroborates our baseline results, with students more likely to choose in-state institutions from their choice sets and especially so when large discounts are offered to residents.

8 Welfare Consequences

We next use our parameter estimates from the tuition and hybrid discontinuity designs as inputs into measures of welfare changes associated with reducing the tuition gap between non-residents and residents. Using the fact that $\frac{\partial P}{\partial r} = -\rho P(1-P)$, the change in welfare associated with a one dollar *decrease* in non-resident tuition ($\Delta n = -1$) in the symmetric case can be written as:

$$P\left(\frac{-(1-P)+\rho(n-r)P(1-P)}{P+\rho(n-r)P(1-P)}\right)+(1-P) \tag{23}$$

Thus, the parameter ρ is a sufficient statistic for the change in resident tuition given a change in non-resident tuition, and this is itself a sufficient statistic for the change in welfare.

To measure these key parameters, we use the estimate of the parameter ρ from both the tuition design and hybrid design specifications in Table 6. Given that this parameter estimate is local to the border, our welfare estimates can be best interpreted as applying to border populations. Also, we assume an in-state fraction of 75 percent, which is similar to the national fraction of students attending in-state institutions. Finally, the researcher must also specify a tuition gap, and we use a gap of \$6,416, as reported using data on net payments for residents and non-residents at public institutions in Table 2.

As shown in the second panel of Table 10, there is a mechanical benefit for non-residents, whose welfare rises by 25 cents, reflecting the fraction attending out-of-state institutions, when

[36] In all three specifications, it is clear that distance enters non-linearly, with distance becoming a positive factor in student decisions at roughly 2,500 kilometers. Given this limitation of the quadratic specification, we have also estimated specifications controlling for the natural log of distance, which guarantees a monotonic relationship, and the results are similar in this alternative specification.

reducing non-resident tuition by one dollar. In the absence of a behavioral responses, resident tuition must rise by 33 cents, leading to a welfare reduction for residents equal to 25 cents (third panel). Thus, in the absence of a behavioral response, there is no aggregate change in welfare. With a behavioral response, by contrast, resident tuition needs to be increased by only 3 cents (column 1), leading to a welfare decline for residents equal to 2 cents, as shown in the bottom panel. Thus, aggregate welfare rises by 23 cents. Note that this large increase in welfare is driven by the fact that resident tuition needs to increased only slightly following a reduction in non-resident tuition. This is in turn driven by the large behavioral response, an increase in out-of-state enrollment and a reduction in in-state enrollment, and the associated financial windfall received by institutions. Given that student responses to tuition are based upon our parameter estimates, we next allow for uncertainty in our welfare estimates. To do so, we use the delta method, as outlined in Appendix B. As shown in the final row, the 95 percent confidence interval for our welfare estimate ranges from 22 to 24 cents, a relatively tight interval. Given that the estimated tuition discontinuity may include factors other than tuition, we next use a more conservative estimate of -0.0610 from the hybrid discontinuity design (column 6 of Table 6). As shown, the welfare gain is somewhat smaller, equal to 9 cents in aggregate, as resident tuition must increase by 21 cents in this case, and the 95 percent confidence interval in this case ranges from 6 to 11 cents.

9 Conclusion

We view this paper as a first step in measuring welfare losses associated with higher non-resident tuition. Future work could extend this in several directions. First, while reducing the tuition gap may improve efficiency, it may be detrimental from an equity perspective. This would be the case, for example, if low-income students tend to attend in-state institutions due to the low tuition and higher income students tend to disproportionately attend out-of-state institutions. In this case, when reducing the gap between non-resident and resident tuition, low income students would tend to experience tuition increases. Thus, there may be a standard trade-off between equity and efficiency. Second, our welfare estimates are local in nature, and we thus cannot calculate the welfare consequences of large policy changes, such as interventions designed to completely eliminate differences between resident and non-resident tuition. Consideration of these larger policy changes would require estimates of the full set of structural parameters (**?**).

To summarize, we show that, in the context of a simple model, state governments inefficiently distinguish between residents and non-residents when setting tuition policy. The welfare gain from reducing the tuition gap can be estimated as a sufficient statistic measuring the responsiveness of enrollment to tuition. We estimate this statistic using a border discontinuity design, which documents a substantial enrollment discontinuity. These results are corroborated using a separate dataset that includes information on student choice sets. Finally, back-of-the envelope calculations suggest substantial welfare gains from reducing the tuition gap.

References

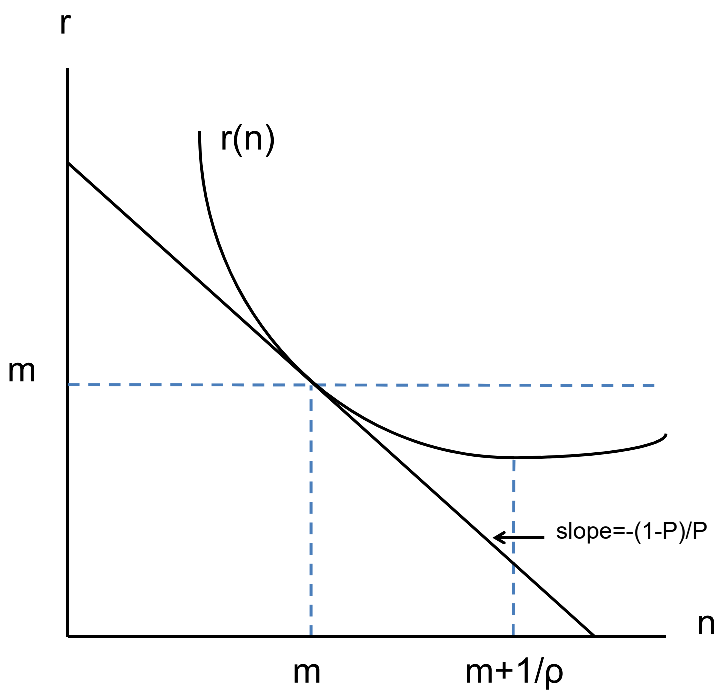

Figure 1: Resident and Non-Resident Tuition

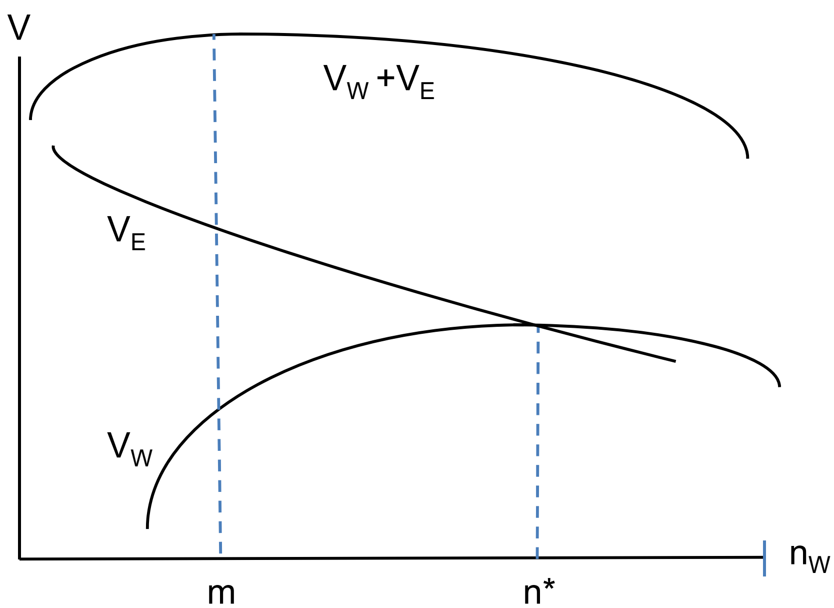

Figure 2: Welfare and Non-Resident Tuition

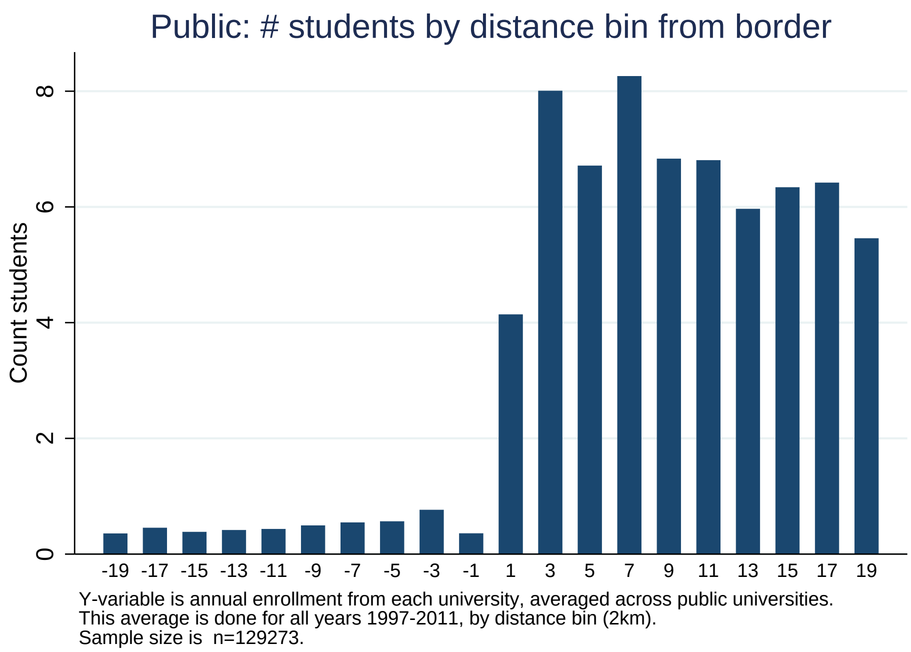

Figure 3: Discontinuity in Enrollment: Public Institutions

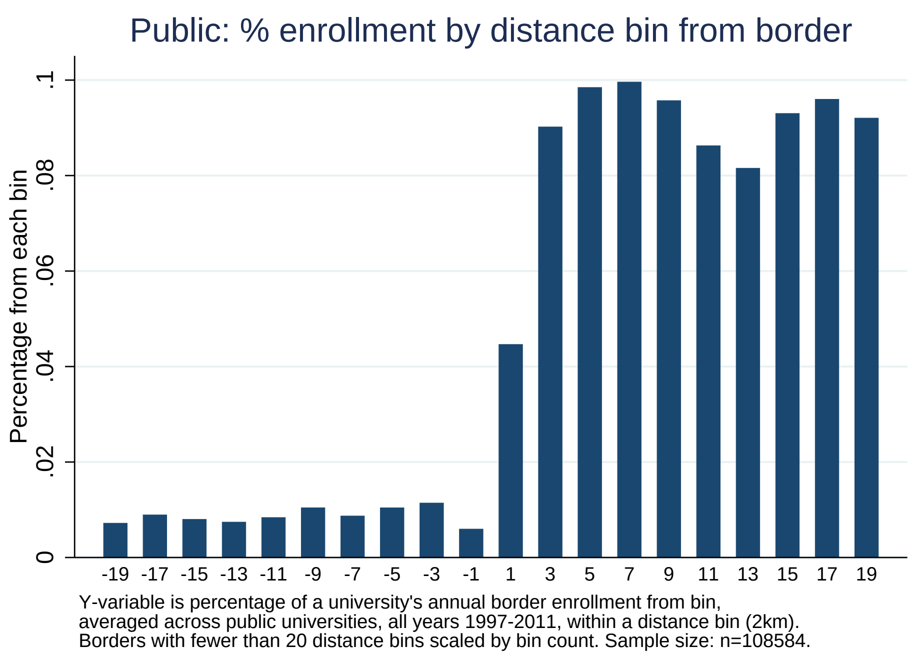

Figure 4: Discontinuity in Percentage Enrollment: Public Institutions

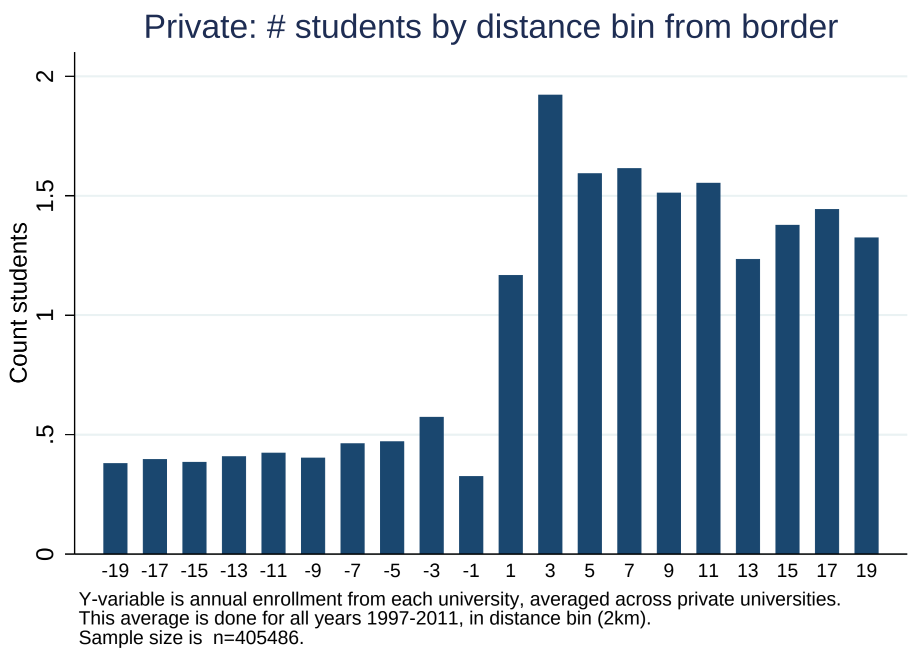

Figure 5: Discontinuity in Enrollment: Private Institutions

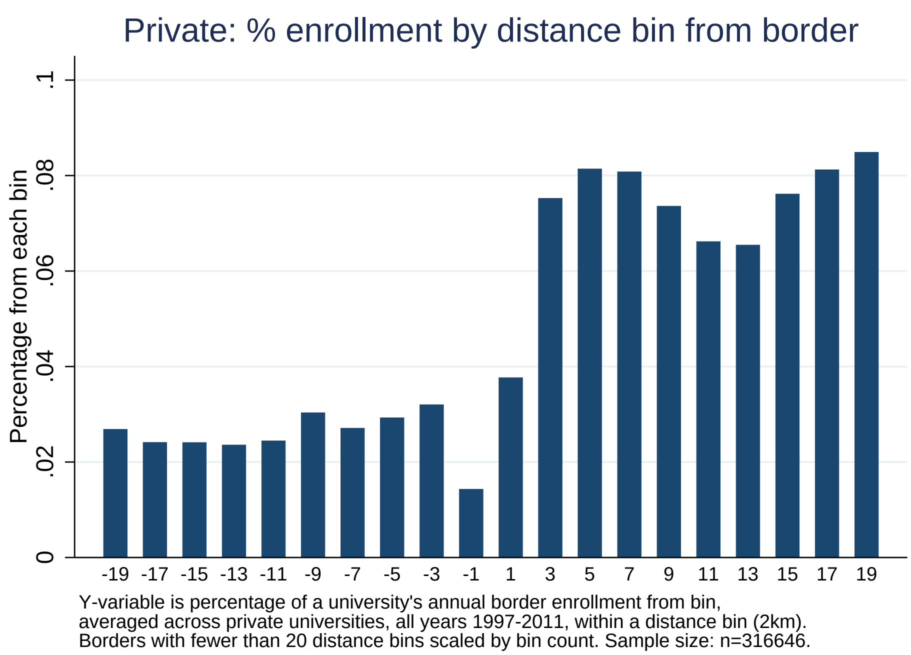

Figure 6: Discontinuity in Percentage Enrollment: Private Institutions

Table 1: Tuition Differences in HERI sample: Public Institutions

year	out-of-state	in-state	gap
1997	13.536	5.324	8.252
1998	13.880	5.361	8.519
1999	13.679	5.190	8.487
2000	13.398	5.194	8.205
2001	13.520	5.336	8.184
2002	14.109	5.643	8.466
2003	14.688	6.023	8.647
2004	15.292	6.517	8.776
2005	16.101	6.771	9.330
2006	16.252	6.859	9.392
2007	16.447	6.956	9.492
2008	16.940	6.938	10.002
2009	17.406	7.320	10.086
2010	18.040	7.608	10.432
2011	19.379	8.338	11.042
average	15.511	6.358	9.154

All dollar values are in thousands of 2011 dollars.

Measures are based upon annual posted tuition and fees for full-time students.

Table 2: Student payments in NPSAS data: public

	(1) tuition/ fees paid	(2) tuition/ fees paid	(3) tuition/ fees paid	(4) net tuition/ fees paid	(5) net tuition/ fees paid	(6) net tuition/ fees paid
sticker price		0.761***	0.699***		0.701***	0.704***
		(0.016)	(0.029)		(0.022)	(0.038)
in-state	-7.174***		-0.771***	-6.416***		0.039
	(0.231)		(0.268)	(0.285)		(0.353)
LHS mean	6.263	6.271	6.271	1.963	1.967	1.967
N	56,110	55,700	55,700	56,110	55,700	55,700
R^2	0.612	0.647	0.648	0.315	0.333	0.333

All specifications include, institution-by-year, state-of-residence-by-year, and cohort fixed effects.

Net tuition and fees paid is net of all grants received by the student.

All dollar values are in thousands of 2011 dollars.

Sticker price represents the price of tuition and fees, adjusted for whether a student is in or out of state.

The sample consists of full-time students attending four-year public institutions.

* p<0.1 ** p<0.05 *** p<0.01

Table 3: 20k Border-sides and distance bins specifications, public institutions

	Border-sides			Distance bins		
	(1) enroll	(2) enroll(%)	(3) ln(enroll)	(4) enroll	(5) enroll(%)	(6) ln(enroll)
in-state	59.954***	0.812***	1.736***	8.255***	0.075***	0.860***
	(5.823)	(0.008)	(0.051)	(0.552)	(0.002)	(0.027)
distance				-0.035	0.000***	0.003***
				(0.022)	(0.000)	(0.001)
Observations	17140	13694	17140	129273	108584	129273
R^2	0.443	0.894	0.758	0.374	0.405	0.616
#Clusters	2876	2514	2876	23807	20924	23807

Coefficient on in-state in columns 3 and 6 corresponds to estimates of $\rho(n-r)$.
Columns 1-3 at border-side level for 20km range; 4-6 at distance-bin level for 20km range.
All specifications include university-year FE and border-side-year or distance bin-year FE.
Sample is public universities, 1997-2011, excluding two-year colleges.
Standard errors clustered at university-border-side or university-distance-bin level
* p<0.1 ** p<0.05 *** p<0.01

Table 4: Above median students and less selective public institutions

	Above median students			Less selective institutions		
	(1) enroll	(2) enroll(%)	(3) ln(enroll)	(4) enroll	(5) enroll(%)	(6) ln(enroll)
in-state	20.624***	0.792***	1.282***	41.192***	0.839***	1.488***
	(2.196)	(0.009)	(0.044)	(6.055)	(0.009)	(0.072)
Observations	17140	11618	17140	8884	6304	8884
R^2	0.441	0.862	0.719	0.477	0.923	0.727
#Clusters	2876	2256	2876	1860	1512	1860

Coefficient on in-state in columns 3 and 6 corresponds to estimates of $\rho(n-r)$.
In columns 1-3 sample restricted to students with above median test score in university-year.
In columns 4-6 the sample restricted to less selective public universities.
All specifications include university-year FE and border-side-year FE; a border-side is 20km.
Sample is public universities, 1997-2011, excluding two-year colleges.
Standard errors clustered at university-border-side level
* p<0.1 ** p<0.05 *** p<0.01

Table 5: Public and private specification

	(1) enroll	(2) enroll (%)	(3) ln(enroll)
in-state	12.107***	0.499***	0.729***
	(1.258)	(0.007)	(0.025)
in-state X public	39.304***	0.328***	0.965***
	(3.837)	(0.009)	(0.047)
Observations	68232	51110	68232
R^2	0.352	0.656	0.675
#Clusters	9160	8040	9160

Regressions run at border-side level for 20km range.
Sample includes public and private universities, 1997-2011;
two-year colleges are excluded.
All specifications include univ-year and border-side-year FE.
Standard errors clustered at university-border-side level.
* p<0.1 ** p<0.05 *** p<0.01

Table 6: Tuition and hybrid specifications

	Tuition Specification			Hybrid Specification		
	(1) enroll	(2) enroll(%)	(3) ln(enroll)	(4) enroll	(5) enroll(%)	(6) ln(enroll)
tuition	-6.260***	-0.081***	-0.186***	-1.343*	-0.008***	-0.061***
	(0.571)	(0.002)	(0.005)	(0.756)	(0.002)	(0.010)
in-state				49.736***	0.748***	1.261***
				(9.352)	(0.020)	(0.100)
Observations	16977	13470	16977	16977	13470	16977
R^2	0.436	0.801	0.743	0.445	0.899	0.763
#Clusters	2876	2500	2876	2876	2500	2876

Coefficient on tuition in columns 3 and 6 corresponds to estimates of ρ.
All specifications include university-year FE and border-side-year FE; a border-side is 20km.
Sample is public universities, 1997-2011, excluding two-year colleges.
Standard errors clustered at university-border-side level
* p<0.1 ** p<0.05 *** p<0.01

Table 7: Tuition reciprocity specifications

	(1) enroll	(2) enroll (%)	(3) ln(enroll)
in-state	68.984***	0.818***	1.753***
	(8.803)	(0.009)	(0.073)
in-state X exchange	-21.979**	-0.015	-0.042
	(10.874)	(0.016)	(0.099)
Observations	17140	13594	17140
R^2	0.445	0.893	0.758
#Clusters	2876	2502	2876

Regressions run at border_side level for 20km range.

Sample is public universities only, 1997-2011, excluding two-year colleges.

All specifications include univ-year and border_side-year FE.

Standard errors clustered at university-border-side level.

* p<0.1 ** p<0.05 *** p<0.01

Table 8: Analysis of Institution Acceptance Decisions

	accept	accept
in-state	0.0436***	0.0698***
	(0.0146)	(0.0161)
N	11,510	11,510
R^2	0.1672	0.8380

Linear probability models of student-reported acceptance decisions with institution fixed effects

First column includes controls for SAT and GPA scores. Second column includes student fixed effects

Includes four-year public institutions with at least 10 appearances in student application sets

* p<0.1 ** p<0.05 *** p<0.01

Table 9: Analysis of Choice Set Data

	enroll	enroll	enroll
in-state	0.3763***		0.1972
	(0.1048)		(0.1380)
tuition		-0.0360***	-0.0326**
		(0.0121)	(0.0164)
distance	-0.5226***	-0.4961***	-0.5234***
	(0.1482)	(0.1340)	(0.1486)
distance squared	0.1092***	0.0957***	0.1088***
	(0.0363)	(0.0333)	(0.0364)
cases	8,300	8,300	8,300

Alternative-specific conditional logit models estimated via maximum likelihood

Consists of 2,690 students reporting a choice set of at least two and attending a single institution

Four-year public and private institutions with at least 10 appearances in student choice sets

Tuition adjusted for whether a student is in or out of state. * p<0.1 ** p<0.05 *** p<0.01

Table 10: Welfare calculations

inputs	(1)	(2)
tuition gap $(n-r)$	\$6,416	\$6,416
estimated tuition discontinuity $(-\rho)$	-0.1856	-0.0610
in-state fraction (P)	0.75	0.75
effects on non-residents		
change in tuition	-\$1.00	-\$1.00
welfare change for non-residents	\$0.25	\$0.25
without behavioral response		
change in resident tuition	\$0.33	\$0.33
welfare change for residents	-\$0.25	-\$0.25
combined welfare change	\$0.00	\$0.00
with behavioral response		
change in resident tuition	\$0.03	\$0.21
welfare change for residents	-\$0.02	-\$0.16
combined welfare change	\$0.23	\$0.09
combined welfare change (95 percent CI)	[\$0.22,\$0.24]	[\$0.06,\$0.11]

A Appendix: Theory Proofs and Extensions (For Online Publication)

A.1 Derivation of $\frac{\partial r_W}{\partial n}$ and $\frac{\partial r_E}{\partial n}$

We derive expressions for the change in resident tuition given a uniform increase in non-resident tuition. Note that, for state W, the budget constraint $f_W r_W + (1-f_W)n_W = m$ can be re-written as:

$$P_W(r_W, n_E)[r_W - m] + [1 - P_E(r_E, n_W)][n_W - m] = 0$$

Then, considering a change in n_E, we have that:

$$\left(\frac{\partial P_W}{\partial r_W}\frac{\partial r_W}{\partial n_E} + \frac{\partial P_W}{\partial n_E}\right)[r_W - m] + P_W\frac{\partial r_W}{\partial n_E} - \frac{\partial P_E}{\partial r_E}\frac{\partial r_E}{\partial n_E}[n_W - m] = 0$$

Similarly, considering a change in n_W, we have that:

$$\left(\frac{\partial P_W}{\partial r_W}\frac{\partial r_W}{\partial n_W}\right)[r_W - m] + P_W\frac{\partial r_W}{\partial n_W} - \left(\frac{\partial P_E}{\partial r_E}\frac{\partial r_E}{\partial n_W} + \frac{\partial P_E}{\partial n_W}\right)[n_W - m] + (1 - P_E) = 0$$

Now, direct effects are given by $\frac{\partial P_E}{\partial r_E} = -\rho P_E(1-P_E)$ and cross-effects are given by $\frac{\partial P_E}{\partial n_W} = \rho P_E(1-P_E)$. Thus, $\frac{\partial P_E}{\partial r_E} = -\frac{\partial P_E}{\partial n_W}$, and, plugging this into the expressions above, we have:

$$\left(\frac{\partial P_W}{\partial r_W}(\frac{\partial r_W}{\partial n_E} - 1)\right)[r_W - m] + P_W\frac{\partial r_W}{\partial n_E} - \frac{\partial P_E}{\partial r_E}\frac{\partial r_E}{\partial n_E}[n_W - m] = 0$$

$$\left(\frac{\partial P_W}{\partial r_W}\frac{\partial r_W}{\partial n_W}\right)[r_W - m] + P_W\frac{\partial r_W}{\partial n_W} - \left(\frac{\partial P_E}{\partial r_E}(\frac{\partial r_E}{\partial n_W} - 1)\right)[n_W - m] + (1 - P_E) = 0$$

Adding these two conditions together, we have:

$$\left(\frac{\partial P_W}{\partial r_W}(\frac{\partial r_W}{\partial n_E} + \frac{\partial r_W}{\partial n_W} - 1)\right)[r_W - m] + P_W(\frac{\partial r_W}{\partial n_E} + \frac{\partial r_W}{\partial n_W}) - \frac{\partial P_E}{\partial r_E}(\frac{\partial r_E}{\partial n_W} + \frac{\partial r_E}{\partial n_E} - 1)[n_W - m] + (1 - P_E) = 0$$

Letting $\frac{\partial r_W}{\partial n} = \frac{\partial r_W}{\partial n_E} + \frac{\partial r_W}{\partial n_W}$ and $\frac{\partial r_E}{\partial n} = \frac{\partial r_E}{\partial n_E} + \frac{\partial r_E}{\partial n_W}$, we have

$$\left(\frac{\partial P_W}{\partial r_W}(\frac{\partial r_W}{\partial n} - 1)\right)[r_W - m] + P_W\frac{\partial r_W}{\partial n} - \frac{\partial P_E}{\partial r_E}(\frac{\partial r_E}{\partial n} - 1)[n_W - m] + (1 - P_E) = 0$$

Now, by symmetry, for the case of state E, we have:

$$\left(\frac{\partial P_E}{\partial r_E}(\frac{\partial r_E}{\partial n}-1)\right)[r_E-m]+P_E\frac{\partial r_E}{\partial n}-\frac{\partial P_W}{\partial r_W}(\frac{\partial r_W}{\partial n}-1)[n_E-m]+(1-P_W)=0$$

In the symmetric case, these simplify to:

$$\left(\frac{\partial P}{\partial r}(\frac{\partial r}{\partial n}-1)\right)[r-n]+P\frac{\partial r}{\partial n}+(1-P)=0$$

Solving, we have that:

$$\frac{\partial r}{\partial n}=\frac{-(1-P)-\frac{\partial P}{\partial r}(n-r)}{P-\frac{\partial P}{\partial r}(n-r)}$$

A.2 Proof of Proposition 1

Using some results from the prior Appendix, we have that:

$$\left(\frac{\partial P_W}{\partial r_W}(\frac{\partial r_W}{\partial n_E}-1)\right)[r_W-m]+P_W\frac{\partial r_W}{\partial n_E}-\frac{\partial P_E}{\partial r_E}\frac{\partial r_E}{\partial n_E}[n_W-m]=0$$

$$\left(\frac{\partial P_W}{\partial r_W}\frac{\partial r_W}{\partial n_W}\right)[r_W-m]+P_W\frac{\partial r_W}{\partial n_W}-\left(\frac{\partial P_E}{\partial r_E}(\frac{\partial r_E}{\partial n_W}-1)\right)[n_W-m]+(1-P_E)=0$$

When $r_W=n_W=m$, these simplify to:

$$\frac{\partial r_W}{\partial n_E}=0$$

$$\frac{\partial r_W}{\partial n_W}=\frac{-(1-P_E)}{P_W}$$

For the case of the budget of state E, we have that, by symmetry:

$$\frac{\partial r_E}{\partial n_W}=0$$

$$\frac{\partial r_E}{\partial n_E}=\frac{-(1-P_W)}{P_E}$$

Recall the original formula for the change in welfare:

$$0.5\left[\{-P_W\frac{\partial r_W}{\partial n_W}-(1-P_E)-P_E\frac{\partial r_E}{\partial n_W}\}\Delta n_W+\{-P_E\frac{\partial r_E}{\partial n_E}-(1-P_W)-P_W\frac{\partial r_W}{\partial n_E}\}\Delta n_E\right]$$

Plugging in the above expressions, we have that there is no welfare gain when considering changes in non-resident tuition when $r_W = n_W = m$ and $r_E = n_E = m$. Thus, non-discriminatory policies are optimal.

A.3 Proof of Proposition 2

In the symmetric case, we have that $\frac{\partial P}{\partial n} = \rho P(1-P)$ and thus $n - m = 1/\rho P$. Further, using the budget constraint, one can show that $P = (n-m)/(n-r)$. Combining these, we have that:

$$r = n - \rho(n-m)^2$$

Further, note that $P = exp(-\rho r)/[exp(-\rho r) + exp(-\rho n - \rho\delta)]$, which can be re-written as $r = n + \delta - (1/\rho)ln[P/(1-P)]$. Next, note that $n - m = (1/\rho P)$ and thus $P/(1-P) = 1/[\rho(n-m)-1]$. Combining these two expressions, we have that:

$$r = n + \delta + (1/\rho)ln[\rho(n-m)-1]$$

The first expression for r is quadratic in n, with a peak at $n = m + (0.5/\rho)$, at which point $r = m + (0.25/\rho)$. Beyond this peak, the expression in decreasing in n. The second expression for r equals negative infinity when $n = m + (0.5/\rho)$ and is strictly increasing in n. Moreover, when $n = m + (2/\rho)$, $r = m + (2/\rho) + \delta$. This is greater than $m + (0.25/\rho)$, and hence there is a single crossing between $n = m + (0.5/\rho)$ and $n = m + (2/\rho)$. At this single crossing, we have that $r < m < n$.

To show the comparative static, combining the two expressions above, note that n can be implicitly defined by:

$$-\rho^2(n-m)^2 = \rho\delta + ln[\rho(n-m)-1]$$

Considering a change in ρ,we have that:

$$-2\rho(n-m)^2 - 2\rho^2(n-m)\frac{\partial n}{\partial \rho} = \delta + \frac{(n-m) + \rho\frac{\partial n}{\partial \rho}}{\rho(n-m)-1}$$

Re-arranging, we have that

$$(-2\rho(n-m)^2 - \delta)[\rho(n-m)-1] - 2\rho^2(n-m)\frac{\partial n}{\partial \rho}[\rho(n-m)-1] = (n-m) + \rho\frac{\partial n}{\partial \rho}$$

Finally, solving, we have,

$$\frac{\partial n}{\partial \rho} = \frac{(-2\rho(n-m)^2 - \delta)[\rho(n-m)-1] - (n-m)}{\rho + 2\rho^2(n-m)[\rho(n-m)-1]}$$

Thus, since $\rho(n-m)-1 > 0$ and $n > m$, we have that the numerator is negative and the denominator is positive. Thus, $\frac{\partial n}{\partial \rho} < 0$.

A.4 Theoretical Extension: Fixed Costs

We next extend the theoretical model to include fixed costs. In particular, continue to assume that educating a student requires a constant expenditure, or marginal cost, equal to m, but that institutions also incur a fixed cost equal to F. Then, college W faces the following budget constraint:

$$P_W r_W + (1-P_E)n_W = (P_W + 1 - P_E)m + F$$

Then, re-deriving $\frac{\partial r_W}{\partial n}$ and $\frac{\partial r_E}{\partial n}$ in the first appendix, we have that the budget constraint can be re-written as:

$$P_W(r_W, n_E)[r_W - m] + [1 - P_E(r_E, n_W)][n_W - m] = F$$

Then, considering a changes in n_E and n_W we have that the key conditions are unchanged:

$$\left(\frac{\partial P_W}{\partial r_W}\frac{\partial r_W}{\partial n_E} + \frac{\partial P_W}{\partial n_E}\right)[r_W - m] + P_W\frac{\partial r_W}{\partial n_E} - \frac{\partial P_E}{\partial r_E}\frac{\partial r_E}{\partial n_E}[n_W - m] = 0$$

$$\left(\frac{\partial P_W}{\partial r_W}\frac{\partial r_W}{\partial n_W}\right)[r_W - m] + P_W\frac{\partial r_W}{\partial n_W} - \left(\frac{\partial P_E}{\partial r_E}\frac{\partial r_E}{\partial n_W} + \frac{\partial P_E}{\partial n_W}\right)[n_W - m] + (1 - P_E) = 0$$

Thus, the key conclusions from the welfare analysis remain unchanged.

We next consider tuition policies set under decentralization with fixed costs. In the symmetric case, Nash equilibrium out-of-state tuition continues to be characterized by:

$$n = m + \frac{(1-P)}{\partial P / \partial n}$$

Using the institutional budget constraint under symmetry $[Pr + (1-P)n = m + F]$ and using the fact that $\partial P/\partial n = \rho P(1-P)$, this can be re-written as:

$$P(n-r) = -F + \frac{1}{\rho P}$$

Thus, non-resident tuition continues to be higher than resident tuition so long as fixed costs are sufficiently small (i.e., $F < (1/\rho P)$).

A.5 Theoretical Extension: Increasing marginal costs

We next extend the theoretical model to increasing marginal costs. In particular, assume that marginal costs are quadratic in enrollment, with the parameter β capturing the degree of convexity. That is, college W faces the following budget constraint:

$$P_W r_W + (1-P_E)n_W = (P_W + 1 - P_E)m + \beta(P_W + 1 - P_E)^2$$

Then, re-deriving $\frac{\partial r_W}{\partial n}$ and $\frac{\partial r_E}{\partial n}$ in the first appendix, we have that the budget constraint can be re-written as:

$$P_W(r_W, n_E)[r_W - m] + [1 - P_E(r_E, n_W)][n_W - m] = \beta[P_W(r_W, n_E) + (1 - P_E(r_E, n_W))]^2$$

Then, considering a changes in n_E and n_W we have that the key conditions are given by:

$$\left(\frac{\partial P_W}{\partial r_W}\frac{\partial r_W}{\partial n_E} + \frac{\partial P_W}{\partial n_E}\right)[r_W - m] + P_W\frac{\partial r_W}{\partial n_E} - \frac{\partial P_E}{\partial r_E}\frac{\partial r_E}{\partial n_E}[n_W - m] = \\ 2\beta[P_W(r_W, n_E) + (1 - P_E(r_E, n_W))]\left(\frac{\partial P_W}{\partial r_W}\frac{\partial r_W}{\partial n_E} + \frac{\partial P_W}{\partial n_E} - \frac{\partial P_E}{\partial r_E}\frac{\partial r_E}{\partial n_E}\right)$$

$$\left(\frac{\partial P_W}{\partial r_W}\frac{\partial r_W}{\partial n_W}\right)[r_W - m] + P_W\frac{\partial r_W}{\partial n_W} - \left(\frac{\partial P_E}{\partial r_E}\frac{\partial r_E}{\partial n_W} + \frac{\partial P_E}{\partial n_W}\right)[n_W - m] + (1 - P_E) = \\ 2\beta[P_W(r_W, n_E) + (1 - P_E(r_E, n_W))]\left(\frac{\partial P_W}{\partial r_W}\frac{\partial r_W}{\partial n_W} - \frac{\partial P_E}{\partial r_E}\frac{\partial r_E}{\partial n_W} - \frac{\partial P_E}{\partial n_W}\right)$$

In the symmetric case ($P_E = P_W$), these can be written as:

$$\left(\frac{\partial P_W}{\partial r_W}\frac{\partial r_W}{\partial n_E} + \frac{\partial P_W}{\partial n_E}\right)[r_W - m - 2\beta] + P_W\frac{\partial r_W}{\partial n_E} - \frac{\partial P_E}{\partial r_E}\frac{\partial r_E}{\partial n_E}[n_W - m - 2\beta] = 0$$

$$\left(\frac{\partial P_W}{\partial r_W}\frac{\partial r_W}{\partial n_W}\right)[r_W - m - 2\beta] + P_W\frac{\partial r_W}{\partial n_W} - \left(\frac{\partial P_E}{\partial r_E}\frac{\partial r_E}{\partial n_W} + \frac{\partial P_E}{\partial n_W}\right)[n_W - m - 2\beta] + (1 - P_E) = 0$$

Thus, all of the previous results in the symmetric case follow, with m replaced by $m + 2\beta$. Since the key results do not depend upon m, they thus do not depend upon β.

Under decentralization, the relevant version of equation (14) in the symmetric case ($P_W = P_E$) is given by:

$$\frac{\partial P_W}{\partial r_W}\frac{\partial r_W}{\partial n_W}[r_W - m - 2\beta] + P_W \frac{\partial r_W}{\partial n_W} + (1 - P_E) - \frac{\partial P_E}{\partial n_W}[n_W - m - 2\beta] = 0$$

Since $\frac{\partial r_W}{\partial n_W} = 0$ in equilibrium, we have that non-resident tuition can be characterized by:

$$n = m + 2\beta + \frac{(1-P)}{\partial P/\partial n}$$

Moreover, the budget constraint under symmetry is equal to:

$$P(r-m) + (1-P)(n-m) = \beta$$

Thus, under non-distortionary tuition, we have that $n = r = m + \beta$. Since $n > m + \beta$, it is the case that $n > r$.

A.6 Theoretical Extension: State subsidies

Assume that colleges receive an subsidy for each resident student from the state government equal to σ_c. These subsidies are financed via non-distortionary taxes that must be paid by families regardless of college choice. These subsidies are assumed to be exogenous and thus do not respond to changes in tuition policy. In this case, the inclusive value for a resident from state W is given by:

$$V_W(r_W, n_E) = (1/\rho)\ln[\exp(\alpha\rho q_W - \rho r_W) + \exp(\alpha\rho q_E - \rho n_E - \rho\delta)] - P_W \sigma_W$$

where the new term represents welfare costs associated with taxes required to finance subsidies and depend upon the likelihood of all residents attending in-state colleges.

Also, the college budget constraint for college W is adjusted as follows:

$$f_W(r_W + \sigma_W) + (1 - f_W)n_W = m$$

In the symmetric case, we have that the change in welfare is given by:

$$\Delta n\left[-P\frac{\partial r}{\partial n} - (1-P) - \sigma\frac{\partial P}{\partial r}\frac{\partial r}{\partial n} - \sigma\frac{\partial P}{\partial n}\right]$$

where the two new terms represents the change in taxes required to fund the appropriations due to a response in in-state enrollment probabilities. Under symmetry, we have that $\frac{\partial P}{\partial n} = -\frac{\partial P}{\partial r}$, and the expression can be written more compactly as:

$$\Delta n \left[-P\frac{\partial r}{\partial n} - (1-P) - \sigma \frac{\partial P}{\partial r}(\frac{\partial r}{\partial n} - 1) \right]$$

The required change in resident tuition in this case can be written as:

$$\frac{\partial r}{\partial n} = \frac{-(1-P) - \frac{\partial P}{\partial r}(n-r-\sigma)}{P - \frac{\partial P}{\partial r}(n-r-\sigma)}$$

When $n = r+\sigma$, we have that the required change in tuition equals $-(1-P)/P$, and the welfare gain takes the simple form:

$$\Delta n \left[\frac{\partial P}{\partial r}\frac{\sigma}{P} \right]$$

Since $\frac{\partial P}{\partial r} < 0$, we have that reductions in non-resident tuition from $n = r+\sigma$ lead to an increase in welfare.

With portable subsidies, all residents receive subsidies, regardless of which institution they attend, and taxes simply equal the subsidy. Assume that in-state students pay r_c and the institution receives a subsidy equal to σ_c. For out-of-state students, assume that colleges charge a higher tuition equal to $n_c > r_c$ but that students can use their portable subsidy to help to cover their tuition. Thus, the net payment, for example, for students from W attending college E equals $n_E - \sigma_W$. In this case, the inclusive value for a resident from state W equals:

$$V_W(r_W, n_E) = (1/\rho)\ln[\exp(\alpha\rho q_W - \rho r_W) + \exp(\alpha\rho q_E - \rho(n_E - \sigma_W) - \rho\delta)] - \sigma_W$$

Moreover, the college budget constraint is given by:

$$f_W(r_W + \sigma_W) + (1-f_W)n_W = m$$

In the symmetric case, we have that the key welfare expressions can be written as:

$$\Delta n \left[-P\frac{\partial r}{\partial n} - (1-P) \right]$$

$$\frac{\partial r}{\partial n} = \frac{-(1-P) - \frac{\partial P}{\partial r}(n-r-\sigma)}{P - \frac{\partial P}{\partial r}(n-r-\sigma)}$$

Thus, when $n = r + \sigma$, we have that the required change in tuition again equals $-(1-P)/P$. Given this, there is no welfare gain when reducing non-resident tuition from this higher level.

A.7 Theoretical Extension: More Than Two States

We next extend the model from two states to S states, indexed by s. Let $P_s(t)$ denote the likelihood that a student from state s attends institution t. Then, in-state attendance probabilities are given by:

$$P_s(s) = \frac{\exp(\alpha\rho q_s - \rho r_s)}{\exp(\alpha\rho q_s - \rho r_s) + \sum_{t \neq s} \exp(\alpha\rho q_t - \rho n_t - \rho\delta)}$$

Likewise, attendance at an out-of-state institution $t \neq s$ occurs with the following probability:

$$P_s(t) = \frac{\exp(\alpha\rho q_t - \rho r_t - \delta)}{\exp(\alpha\rho q_t - \rho r_t - \delta) + \exp(\alpha\rho q_s - \rho r_s) + \sum_{r \neq s, r \neq t} \exp(\alpha\rho q_r - \rho n_r - \rho\delta)}$$

Then, the change in welfare given a uniform increase in non-resident tuition equals:

$$(1/S)\Delta n \left[\sum_s -P_s(s) \frac{\partial r_s}{\partial n} - \sum_{t \neq s} (1 - P_s(t)) \right]$$

Under symmetry, this reduces to:

$$\Delta n \left[-P \frac{\partial r}{\partial n} - (1 - P) \right]$$

where P represents the likelihood of in-state attendance and $1 - P$ represents the likelihood of out-of-state attendance, aggregated over all out-of-state institutions. Moreover, it remains the case that:

$$\frac{\partial r}{\partial n} = \frac{-(1-P) - \frac{\partial P}{\partial r}(n - r)}{P - \frac{\partial P}{\partial r}(n - r)}$$

Thus, the welfare calculations are unchanged with more than two states, under the interpretation that $1 - P$ is the out-of-state attendance probability, aggregated over all possible out-of-state institutions.

Turning to decentralization, we have that state s again chooses non-resident tuition to minimize resident tuition. That is, $\partial r_s / \partial n_s = 0$. The institution budget constraint for college s in this case is given by:

$$P_s(s)(r_s - m) + \sum_{t \neq s} P_t(s)(n_s - m) = 0$$

Taking the derivative with respect to non-resident tuition (n_s), we have that:

$$\frac{\partial P_s}{\partial r_s}\frac{\partial r_s}{\partial n_s}[r_s - m] + P_s\frac{\partial r_s}{\partial n_s} + \sum_{t\neq s} P_t(s) + \sum_{t\neq s}\frac{\partial P_t(s)}{\partial n_s}[n_s - m] = 0$$

Since $\frac{\partial r_s}{\partial n_s} = 0$ in equilibrium and using the fact that $\frac{\partial P_t(s)}{\partial n_s} = -\rho P_t(s)[1-P_t(s)]$, we have that:

$$\sum_{t\neq s} P_t(s) = \sum_{t\neq s}\rho P_t(s)[1-P_t(s)][n_s - m]$$

In the symmetric case, we have that $P_t(s) = (1-P)/(S-1)$ for $t \neq s$, where P is the probability of in-state attendance. Then, this can be written as:

$$(1-P) = \frac{\rho(1-P)(S+P-2)(n-m)}{S-1}$$

Solving for non-resident tuition, we have that:

$$n = m + \frac{1}{\rho}\frac{S-1}{(S+P-2)}$$

Since $P \leq 1$, we have that $n \geq m + 1/\rho$, and, moreover, non-resident tuition converges to $m + 1/\rho$ as the number of states grows large.

To further investigate how tuition policies change with the number of states, we next calibrate the model to match current tuition and in-state attendance probabilities. To do so, we first invert the above non-resident pricing rule to solve for ρ as follows:

$$\rho = \frac{1}{n-m}\frac{S-1}{(S+P-2)}$$

We use in-state attendance probabilities of $P = 0.75$. Tuition is taken from the overall averages in Table 1, yielding $n =$15.511 and $r = 6.358$. This implies that $m = 8.646$. Finally, using $S = 50$, we have that $\rho = 0.1464$. With this estimate of ρ, we then choose δ to match $P = 0.75$. This yields $\delta = 24.947$.

With these parameters in hand, we can then estimate how pricing changes given a change in the number of states. As shown in Table 11, increasing the number of states beyond 50 does yield a reduction in non-resident tuition, falling from 15.512 to 15.503 for 90 states. This decrease is quite small however, and, as noted above, non-resident tuition is bounded from below by $m + 1/\rho$, which equals 15.477. Thus, there is little scope in the model for reducing non-resident tuition via an increase in the number of states. In addition, while non-resident tuition does fall as the number of states increases, the gap between non-resident and resident tuition actually rises. This reflects the fact that the choice set also increases for students, yielding an increase in non-resident attendance, allowing universities to reduce in-state tuition. Likewise, as the number states decreases below 50, non-resident tuition increases but so does resident tuition, leading to a reduction in the gap between non-resident and resident tuition.

Table 11: Competition and Tuition Policies

number of states (S)	out-of-state tuition (n)	in-state tuition (r)	in-state attendance (P)
10	15.533	8.097	0.926
20	15.525	7.588	0.867
30	15.520	7.132	0.819
40	15.515	6.728	0.782
50	15.512	6.362	0.750
60	15.509	6.027	0.724
70	15.507	5.718	0.701
80	15.505	5.431	0.681
90	15.503	5.163	0.663

B Appendix: Additional Empirical Results (For Online Publication)

B.1 Student Payments: Private Institutions

In parallel to Section 7.1, we present in Table 12 results on student payments to private institutions using NPSAS data. As shown, residents pay a bit less, around $260, in tuition payments than non-residents. This difference, however, is small when compared to the sample average of over $20,000 in tuition payments. The gap is larger for net payments, with residents paying roughly $2,800 less than residents. This implies that residents receive around $2,500 more in grants than non-residents at private universities. To further explore the source of this difference, we next decompose total grants into their four components: federal grants, state grants, institution grants, and other grants. As shown, the bulk of the difference is explained by state grants. This finding is consistent with several state aid programs that generate financial differences between residents and non-residents at private institutions. For example, the Cal Grant Program is a state-funded program that provides aid to California residents attending California institutions, both public and private.[37] Likewise, the Hope scholarship in Georgia is available to state residents attending either public or private institutions in the state of Georgia. Finally, we note that these differences in payments between residents and non-residents are smaller than those documented for public institutions.

Table 12: Student payments in NPSAS data: private

	(1) tuition/ fees paid	(2) net tuition/ fees paid	(3) federal grants	(4) state grants	(5) institution grants	(6) other grants
in-state	-0.259**	-2.847***	0.634***	1.761***	-0.086	0.278***
	(0.113)	(0.213)	(0.041)	(0.039)	(0.142)	(0.063)
LHS mean	21.435	9.63	1.636	1.195	7.721	1.253
R^2	0.587	0.318	0.164	0.283	0.356	0.110

All specifications include institution-by-year, state-of-residence-by-year, and cohort FE.
Net tuition and fees paid is net of all grants received by the student.
All dollar values are in thousands of 2011 dollars.
The sample consists of 32,130 full-time students attending four-year private institutions.
* p<0.1 ** p<0.05 *** p<0.01

B.2 Analysis of Private Institution Acceptance Decisions

In parallel to Section 7.4, Table 13 presents results on private institution acceptance decisions using ELS data. As shown, private institutions are also more likely to admit residents, when compared to non-residents. The difference is only statistically significant, however, when including applicant fixed effects. In addition, the magnitude of any differences is smaller than the corresponding differences for public institutions.

[37] For further details, see http://www.csac.ca.gov/doc.asp?id=568 (accessed October 16, 2015).

Table 13: Analysis of Private Institution Acceptance Decisions

	(1) accept	(2) accept
in-state	0.0206	0.0396**
	(0.0174)	(0.0198)
sat	0.0007***	
	(0.0001)	
gpa	0.1457***	
	(0.0169)	
R^2	0.2445	0.8206
student FE	no	yes

Linear probability models of acceptance decisions with institution FE
Sample consists of 5,960 students reporting SAT and GPA scores
Four-year institutions with at least 10 appearances in student application sets
* p<0.1 ** p<0.05 *** p<0.01

B.3 Additional Robustness Checks of Main Specification

Table 14: Alternative Border-Side Widths

	10km border-sides			30km border-sides		
	(1) enroll	(2) enroll(%)	(3) ln(enroll)	(4) enroll	(5) enroll(%)	(6) ln(enroll)
in-state	32.997***	0.796***	1.455***	78.606***	0.822***	1.913***
	(3.168)	(0.008)	(0.050)	(6.935)	(0.007)	(0.053)
Observations	16422	11820	16422	17286	14336	17286
R^2	0.439	0.870	0.732	0.457	0.906	0.768
#Clusters	2790	2288	2790	2882	2622	2882

Columns 1-3 at border-side level for 10km border-sides, cols 4-6 use 30km border-sides.
All specifications include university-year FE and border-side-year FE.
Sample is public universities, 1997-2011, excluding two-year colleges.
Standard errors clustered at university-border-side level
* p<0.1 ** p<0.05 *** p<0.01

Table 15: Excluding Border Institutions

	(1) enroll	(2) enroll(%)	(3) ln(enroll)
in-state	46.736***	0.814***	1.652***
	(5.397)	(0.008)	(0.050)
Observations	16092	12536	16092
R^2	0.462	0.892	0.779
#Clusters	2682	2308	2682

Regressions run at border-side level, 20km border-sides.
Sample is public universities only, 1997-2011;
two-year colleges are excluded.
Sample also drops universities within 30km of border.
All specifications include univ-year and border_side-year FE.
Standard errors clustered at university-border-side level.
* p<0.1 ** p<0.05 *** p<0.01

B.4 Confidence Intervals for Welfare Analysis

The statistic for the required increase in resident tuition equals:

$$S(\rho) = \frac{-(1-P)+\rho(n-r)P(1-P)}{P+\rho(n-r)P(1-P)}$$

This can be written as

$$S(\rho) = \frac{g(\rho)}{h(\rho)}$$

To apply the Delta method, we require $S'(\rho)$. Applying the quotient rule, we have that:

$$S'(\rho) = \frac{g'(\rho)h(\rho) - g(\rho)h'(\rho)}{h(\rho)^2}$$

Using the fact that $g'(\rho) = h'(\rho) = (n-r)P(1-P)$ and that $h(\rho) - g(\rho) = 1$, this can be re-written as:

$$S'(\rho) = \frac{(n-r)P(1-P)}{h(\rho)^2}$$

Then, using the delta method, the standard error for the required change in resident tuition equals $\sigma(\rho)|S'(\rho)|$.

Following similar logic the standard error for the change in welfare for resident students equals $P\sigma(\rho)|S'(\rho)$ and this is also the standard error for the change in combined welfare.

B.5 Illustration of Identification Strategy

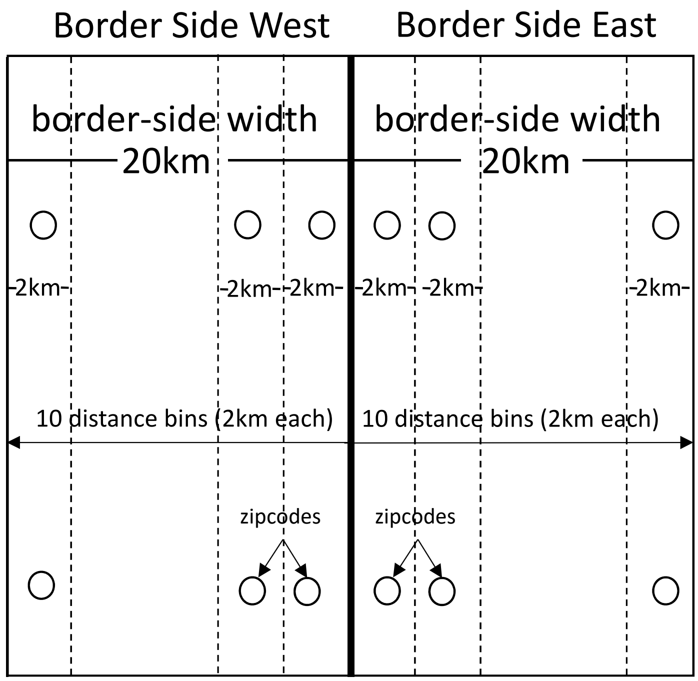

Figure 7: Border-Sides and Distance Bins Diagram