SPATIAL COMPETITION AND THE PRICE OF COLLEGE

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This article provides the first evidence that universities compete directly on price, and that the market for students depends on the proximity of competitors. Exploiting detailed data from private U.S. universities, price competition is tested by introducing geographic proximity into a spatial-autoregressive tuition model. Standard spatial models show that list and net tuition are inversely related to distance between institutions, consistent with price competition in higher education. An extension to the spatial-econometrics literature relaxes a constraint that estimated spatial relationships are common across all observations, implying that spatial effects differ across qualitative classes of institutions. (*JEL* C21, I2, L11)

I. INTRODUCTION

Over the last half century, the U.S. higher educational system has been transformed from a collection of local, independent college fiefdoms into a regionally and nationally integrated market in which universities compete for both resources and students as in Hoxby (1997a). Concurrently, Duffy and Goldberg (1998) contend that the most salient feature of the U.S. higher education market has been tuition increases that exceed both the rate of inflation and income growth combined with financial aid packages that increasingly emphasize merit over need. The rising real cost of college in the midst of growing competition has become a source of considerable angst for parents, university administrators, and public policy analysts who are concerned that need-blind admission goals are being sacrificed in favor of strategic enrollment management policies designed to attract the best and the brightest. Thus, McPherson and Shapiro (1998) have asked if the rapidly rising cost of college begs the question of whether universities compete on price as opposed to some other metric such as reputation or resources. This article is the first to empirically examine price-setting practices among universities by questioning whether list tuitions (i.e., the posted price) or net tuitions (i.e., the posted price minus financial aid) of private universities respond to the geographic and qualitative proximity of competitors.

There are theoretical reasons to expect that the increasing integration of the higher education sector might affect tuitions, particularly for selective private universities that are relatively unfettered by outside pricing constraints as discussed in Bowen (1967). For example, Hoxby (1997b) models integration as the opening of trade among autarkic colleges of varying quality; trade is found to reduce the monopsony power of universities over local consumers and intensify their competition for high-quality students who, because they are both inputs into and consumers of a college education, can improve institutional quality. Thus, despite applicant pools well in excess of the number of enrollment slots, Ehrenberg (2000) has documented that most selective and well-endowed institutions increasingly spend significant sums recruiting top applicants and use a combination of enrollment management tools such as merit aid, early decision

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ABBREVIATIONS

CPI: Consumer Price Index
GMM: Generalized Method of Moments
ML: Maximum Likelihood
OLS: Ordinary Least Squares
SAT: Scholastic Assessment Test

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policies, and campus amenities to lure top applicants to enroll.

The advent of individual college rankings further raised the enrollment management stakes by providing an easily observed quality metric. As this measure has been found in Monks and Ehrenberg (1999) to influence a student's college choice, one may anticipate that select institutions may have been afforded an ability to ramp up their list tuitions, using their substantial endowments and the tuition revenue collected from the most financially able students to price discriminate in favor of needy, academically able students as discussed in Cook and Frank (1993), Ehrenberg and Rizzo (2004), and Hill, Winston, and Boyd (2004). Nonetheless, Heller (2004) notes that the collective impact of such enrollment management practices in higher education as a whole is of particular policy concern because empirical evidence suggests needy students increasingly rely on non-need-based aid, often in the form of loans, to finance their college educations.

On the other hand, a number of studies, including those of Allen and Shen (1999), Moore et al. (1991), and Parker and Summers (1993), have documented that less-selective private institutions also appear to be cognizant that their more selective competitors have greater resources and deeper applicant pools, which yield greater demand elasticities for these institutions. Moreover, as discussed in Kane and Orszag (2003) and Rizzo (2004), less-selective private institutions must increasingly ward off the potential flight of students to lower cost public institutions that have also been forced to manage enrollments in response to declining state government support. In fact, Ehrenberg (2000) describes how, in the 1990s, a number of less-selective private institutions (e.g., Wells College, Wesleyan College, Muskingum College) found they could not fill out their freshman classes and responded by cutting tuitions for first-year students by between 23% and 30%. In general, the descriptive evidence is supportive of the theoretical predictions in De Fraja and Iossa (2002), Epple et al. (2002), and Martin (2002) that price competition should vary with selectivity.

This article speaks to the potential importance of enrollment management in college access by introducing spatial proximity into empirical models of tuition. In particular, using a detailed cross section of private universities, we first propose a spatial-autoregressive model of tuition that is common in the larger spatial-econometric literature. Given our particular questions of interest, our baseline is to regress an individual institution's tuition on the tuition levels of other institutions within the sample, which allows the data to reveal both the sign and magnitude of any spatial dependence between tuition levels. For example, an estimated spatial-lag coefficient of zero would indicate that after controlling for a detailed list of cost and demand-side factors, there is no systematic variation in tuition levels that is explained by the observed tuition levels of "nearby" institutions. In particular, as each institution's set of nearby competitors varies, our model is primed to test whether being in the neighborhood of the high-tuition institutions within the sample is associated with a given institution posting a tuition different from that would be predicted given other observable characteristics.

In short, our baseline results yield significant positive spatial relationships for both list and net tuitions, conditioned on detailed cost and demand-side controls. We then extend the spatial-econometrics literature by allowing the estimated strengths of any spatial dependence to differ across exogenous categories or groupings of observations. In our sample, this approach reveals asymmetric tuition responses, indicating that the positive estimates from the restricted spatial model are not common across qualitative classifications of institutions. Asymmetric price competition is important from a policy perspective, as it suggests that blanket rules directed at curbing the possible ill effects of rising tuition by limiting price competition may yield unintended consequences.

In the following section, we motivate and discuss the results of the restricted spatial model of tuition, where we report estimates for both list and net tuitions in order to examine if spatial price competition differs when institutional aid is taken into account. Section III then motivates the richer spatial-econometric approach that relaxes the assumption that the estimated strength of the spatial relationship be the same across all observations, in particular, across comprehensive institutions versus national and regional institutions, and reports the results of these empirical specifications for list and net tuition. Concluding remarks in Section IV summarize how the analysis contributes to a better understanding of the nature of price competition in higher education, which is currently not well understood. Overall, given the trend toward greater enrollment management and its potential influence on college access, we see our analysis as particularly timely.

II. A SPATIAL-AUTOREGRESSIVE ANALYSIS OF TUITION

In our analysis, we draw primarily on 1994 institution-level data from the National Center for Educational Statistics and its Integrated Post-Secondary Education Data System. While the potential observations are, therefore, the entire population of colleges and universities in the United States, we limit our analysis to not-for-profit private institutions. We focus on private institutions primarily due to these institutions being self-governing, especially with regard to their tuition setting. For example, unlike private colleges and universities, public institutions are constrained through legislative mandates that weigh access more heavily. Moreover, public institutions commonly operate cooperatively under state systems that fundamentally alter their tuition-setting game through interdependency.[1] Of course, fully incorporating public institutions into the analysis is further complicated by tuition and aid programs that tend to favor in-state over out-of-state students, leading to two distinct tuition levels.

Having restricted our analysis to not-for-profit private institutions within the continental United States, the sample includes a cross section of 929 institutions. Control variables not available in the above data sources are incorporated using U.S. Census data from the Bureau of Economic Analysis. We also incorporate institution-specific Pell-award data provided by the U.S. Department of Education. Sample characteristics are reported in Table 1.

A. Empirical Specification: Single Spatial-Autoregression Coefficient

In modeling list and net tuitions, we include controls for the institution's endowment, whether the institution offers graduate degrees, size (i.e., enrollment), the institution's classification in Petersen's (i.e., most selective, very selective, moderately selective, minimally selective, noncompetitive), and the proportion of undergraduate students receiving federal financial aid. For notational purposes, we capture these control variables with the matrix X. Also included in X are state-level attributes such as median disposable income, the proportion of population that is college aged, state-level unemployment rate, and performance on verbal and math Scholastic Assessment Test (SAT) (included separately), and local variants such as city size and amenities.[2] While we do not model public-tuition levels, in estimating private tuition levels, we include average in-state tuition at same-state public institutions and average out-of-state tuition at public institutions in the same Census region.[3]

In particular, we estimate the following spatial-autoregressive model of tuition:

1. While in 1991, the U.S. Department of Justice accused a group of the most selective private institutions of fixing tuitions, Carlton, Bamberger, and Epstein (1995) find no evidence that the alleged cooperative behavior raised prices. As such, we do not discard those institutions formally named or in the "overlap" group. See Netz (1998) and Hoxby (2000) for additional information on the case against MIT and the Ivy League.

2. The merged 1994 data consists of 5,726 institutions, of which 1,277 are private, not-for-profit institutions. Note also that by dropping public and for-profit private institutions, the sample does not include 2-yr institutions. Of these observations, however, missing information on city size (140), tuition (75), freshman SAT scores (20), endowment (58), proportion of students coming from out of state (12), proportion of students receiving Pell assistance (2), and state appropriations (1) accounts for a smaller sample size. Further, we discard 34 observations where enrollment is less than 100, 4 where list tuition is less than \$500, and 2 where list tuition is reported to be negative. Missing observations on endowment were imputed in five cases using endowment reported in surrounding sample years.

3. Data on net tuitions for public institutions in our sample are largely unavailable. We, therefore, use average list tuition at public institutions in predicting both list and net tuitions at private institutions. We also ran all specifications adopting a measure of public institutions density, which is the number of public institutions in each state. This proved insignificant in explaining private tuition levels. Beyond this simple count, we explored the possibility that other measures of the potential penetration of publics may explain variation in tuitions. For example, we included the total enrollment at neighboring public institutions, the average enrollment at neighboring public institutions, total public enrollment relative to state population, and total public enrollment relative to the 18- to 19-yr-old state population. In all cases, there was no significant explanatory power in such measures. Further, we investigated the variation of several other controls as potential factors in explaining variation in tuitions. Specifically, we allowed for the interaction of the institution's classification (as either national/regional or comprehensive) with proximate public tuitions. This reveals no systematic relationship in proximate public-tuition levels by national/regional versus comprehensive institution.

TABLE 1
Descriptive Statistics

Variable	Mean	Standard Deviation	Minimum	Maximum
Log list tuition	9.074	0.431	6.270	10.030
Log tuition less average aid	8.671	0.478	5.693	9.788
Top research university	0.047	0.213	0	1
Top liberal arts	0.108	0.310	0	1
Other research or liberal arts	0.100	0.300	0	1
Offers advanced degrees	0.325	0.469	0	1
Enrollment $<$ 2,000	0.802	0.399	0	1
Enrollment $\geq$ 10,000	0.008	0.087	0	1
Proportion full-time enrollment receiving PELL[a]	0.395	0.237	0.029	3.127
Log of endowment	15.869	2.381	0	21.745
Proportion out of state	0.417	0.259	0	0.994
Log of state disposable income	9.751	0.109	9.477	10.089
Lagged state unemployment rate	6.635	1.404	2.700	10.900
Proportion of state aged 18–24	0.097	0.006	0.084	0.123
State population (1,000s)	9,148.126	7,331.988	565	3,1317
State average verbal SAT score	517.607	32.299	473	582
State average math SAT score	518.455	32.233	468	586
Located in small metro area	0.214	0.410	0	1
Located in medium metro area	0.108	0.310	0	1
Located in large metro area	0.296	0.457	0	1
Good arts opportunities	0.352	0.478	0	1
Good recreational opportunities	0.341	0.474	0	1
Good climate	0.346	0.476	0	1
South	0.312	0.464	0	1
Midwest	0.302	0.460	0	1
West	0.102	0.303	0	1
Log average in-state tuition	9.049	0.225	8.126	9.530
Log average out-of-state tuition	9.043	0.180	8.723	9.376

[a]Our data do not permit the separation of the number of Pell recipients by full- or part-time status. As such, the proportion can exceed one (which happens in 15 cases).

$$(1) \qquad Y = X\beta + \rho WY + u,$$

where Y is a vector of either list tuition or net tuition (i.e., list tuition net of institution-provided financial assistance). Equation (1) differs from an ordinary regression model due to the spatial-autoregressive term, ρWY, where ρ is a parameter to be estimated and W is an $n \times n$ "contiguity matrix" with off-diagonal elements, W_{ij}, that specify the effect of Y_j on Y_i. While results are qualitatively robust across a number of alternative specifications, we focus on and report results using a discrete weighting mechanism such that

$$(2) \qquad W_{ij} = \begin{cases} 1 \text{ if} d_{ij} \leq 400 \text{ and } i \neq j \\ 0 \text{ otherwise} \end{cases},$$

where d_{ij} is the distance between institutions i and j in miles. That is, we place equal weight on all institutions within 400 miles of institution i in predicting Y_i. Of course, to keep Y_i from predicting itself, all diagonal elements of W are zero. We adopt a 400-mile distance as the base specification because it approximates the distance of a 1-day drive from most campuses, a metric by which parents and institutions are likely to consider institutions as possible substitutes. Letting $Z = WY$, Equation (1) can be rewritten as $Y = X\beta + \rho Z + u$. After following the standard practice of row standardizing the contiguity matrix, W, such that all rows sum to one, Z_i is a simple weighted average of all values of Y (other than Y_i itself) that are within 400 miles of institution i.

In the standard spatial model, the error terms are typically assumed to be normally distributed with constant variance, which implies the following log-likelihood function:

$$\text{(3)} \quad \log L = -(n/2)\log(2\pi) - (1/2\sigma^2)\sum_{i=1}^{n} u_i^2 - \frac{n}{2}\log\sigma^2 + \log|I - \rho W|,$$

where I is an $n \times n$ identity matrix.[4] Equation (3) differs from a standard log-likelihood function for a linear regression model through the last term, $\log|I - \rho W|$, which is the Jacobian of the transformation from u to Y. In particular, where the standard model adopts the implicit restriction that $\rho = 0$, we relax this constraint and estimate ρ for a given W. That is, we do not restrict the Jacobian to $\log|I| = 0$. Substituting the first-order condition for σ^2 into Equation (3), which implies that $\hat{\sigma}^2 = n^{-1}\sum_{i=1}^{n}(Y_i - \rho Z_i - X_i\beta)^2$, the log-likelihood function can be written as

$$\text{(4)} \quad \log L_c = -(n/2)\log(2\pi + 1) - (n/2)\log\hat{\sigma}^2 + \log|I - \rho W|.$$

Letting $\theta = (\beta, \rho)'$ and $A = (I - \rho W)^{-1}$, the score vector and information matrix implied by Equation (4) are

$$\text{(5)} \quad \partial L_c/\partial\theta = (1/\sigma^2)\begin{pmatrix} X'u \\ Z'u - tr(AW) \end{pmatrix} = G,$$

and

$$\text{(6)} \quad -E(\partial^2 L_c/\partial\theta\partial\theta') = (1/\sigma^2)\begin{pmatrix} X'X & X'Z \\ Z'X & Z'Z + \sigma^2 tr(AWAW) \end{pmatrix} = V.$$

The presence of the $tr(AW)$ and $tr(AAWW)$ terms implies that the change in coefficients across iterations j and $j + 1$ cannot be calculated via a simple regression of u on X and Z. As such, standard iterative maximum-likelihood (ML) estimation procedures use the above matrices to calculate the change in θ across iterations such that $\theta_{j+1} = \theta_j + V^{-1}G$, after which V^{-1} forms the covariance estimate.[5]

Recall, the specification in Equation (4) permits the estimation of a spatial-lag coefficient, ρ, that speaks to both the sign and magnitude of the spatial dependence of tuition levels within our sample of institutions. It follows that a spatial-lag coefficient of zero will indicate that after controlling for a detailed list of cost and demand-side factors, there is no systematic variation in tuition levels to be explained by neighborhood effects, that is, by the tuition levels of "nearby" institutions. As each institution's set of nearby competitors varies, our model is, therefore, able to test whether being in the neighborhood of the high-tuition institutions within the sample is associated with a given institution posting higher (i.e., $\hat{\rho} > 0$) or lower (i.e., $\hat{\rho} < 0$) tuition levels than would be predicted given all other observable characteristics.

B. Results: List and Net Tuition

The empirical estimates of ordinary least squares (OLS) and baseline spatial models of list and net tuitions are presented in Table 2. The empirical specifications include a detailed list of explanatory variables to limit the extent to which any estimated spatial relationship among dependent variables could result from omitted variables that enter the error term and that could be spuriously correlated with the spatial proximity of universities. In general, although our findings indicate significant spatially dependent relationships between tuition levels, the coefficients on the other explanatory variables included in the model seldom differ in sign or significance from those in the OLS specification.

Generally, the results indicate that institutions with qualities related to higher institution-specific demand or costs charge higher tuition. For example, institutions that enroll a higher proportion of needy students have

4. Standard spatial models are discussed in detail in Anselin (1988). Good examples of applications include Anselin, Varga, and Acs (1997), Brueckner (1998), and Brueckner and Saavedra (2001).

5. Results are qualitatively robust to a generalized method of moments (GMM) estimator of the model, $Y = \rho WY + XB + u$, using WX as an instrument for WY. Also note that, while estimable, the Jacobian term makes the estimation of Equation (4) difficult as finding the determinant of an $n \times n$ matrix is computationally burdensome. The procedure may be simplified, however, by first calculating the eigenvalues of W, ω_i, and using the property $\log|I - \rho W| = \sum_{i=1}^{n} \log(1 - \rho\omega_i)$. Although calculating eigenvalues of an $n \times n$ matrix is likewise costly, this property allows the calculation to be made only once.

lower tuition, whereas the well endowed or those that attract a higher proportion of out-of-state students have higher list tuition. Further, institutions with undergraduate enrollments exceeding 10,000 students have approximately 22.7% lower list tuition and 29.0% lower net tuition than those with enrollments below 2,000. This is consistent with substantial scale economies in higher education that imply a $2,151 ($1,857) lower list (net) tuition for larger private institutions in 1994 dollars. Using a CPI adjustment, this implies a $2,885 ($2,490) change in 2006 dollars, which is likely to understate the savings because tuition at private universities has risen at twice the rate of inflation over the last several decades.

Most state attributes such as disposable income, the unemployment rate, and age composition are not significantly related to the tuition charged at private universities. These results suggest that private institutions may be insulated from state-specific economic factors, which would be consistent with being relatively less dependent on in-state students and funding than public institutions or having excess applicant demand for their enrollment slots. On the other hand, list tuition is inversely related to verbal SAT scores in the state but positively related to math SAT scores. The opposing signs on the state-level SAT may reflect that the curriculum was formed early in the institution's history in response to local and regional demands and reflects the fact that relatively technical course offerings are more costly to provide (e.g., engineering and science versus social sciences and humanities). However, SAT scores are statistically insignificant in explaining variation in net tuition across institutions, which may indicate that universities use institutional aid to lessen tuition heterogeneity across qualitatively similar institutions with different strengths, as measured by SAT performance.[6]

Most location-specific attributes of the institutions such as city size, the quality of arts, recreational and climate-related amenities, and region of the country are not significant in the OLS specifications. Moreover, location-specific attributes that do yield significant coefficients in the OLS specifications (i.e., climate in the list tuition model and region in the net tuition model) are each insignificant in the spatial specifications. Thus, the results suggest that failing to include a spatial component directly, as in Equation (1), may attribute explanatory power to other geographically based factors through an omitted-variable bias.

The coefficient on out-of-state tuition at public institutions is significant in the list tuition model but not in the net tuition model. This result may not be surprising, however, given the sequential matriculation process of application decisions, where out-of-state students may have more complete information on list tuition but be less informed about the financial aid available at a given institution. Private list tuition may correlate with public out-of-state list tuition to the extent that sticker price is an important factor in determining the institution's applicant pool. An institution's net tuition, however, may depend more on the attributes of the institution's own applicant pool and their ability to pay. Specifically, we find that a 10% increase in the average public out-of-state tuition (a percentage increase that has occurred nearly every year and a half over the past decade) is associated with a 2.2% higher list tuition at private universities, or $280 in the 2006 dollars.

On the other hand, the coefficient for average in-state public tuition is positive and significant in both the list and net tuition models. Specifically, a 10% increase in the average in-state tuition of public institutions in the same state yields nearly a 2.7% ($343) increase in list tuition and a 3.6% ($309) increase in net tuition in both the OLS and spatial specifications. Thus, unlike that for out-of-state tuition levels, private universities appear to use both list and net tuitions to compete for in-state students and respond relatively more to in-state public-tuition levels in competing for students with institutional financial aid.

The differential findings for in-state and out-of-state tuition suggest that, even for private universities, the market for students from an institution's home state is treated differently from that for students from a different state. For example, there may be political benefits to private universities subsidizing in-state students with institutional aid, or there could

6. With respect to being able to effectively estimate differences by state math and verbal SAT scores (due to potential multicollinearity) note that a sensitivity analysis suggests no qualitative difference across models that include state-level math SAT and state-level verbal SAT, state-level total SAT alone, state-level math SAT alone, or state-level verbal SAT alone. While estimated coefficients on SAT controls vary across alternatives and therefore may suggest that one should exercise caution in interpreting point estimates of SAT-based covariates, the effect does not spill over onto other variables.

TABLE 2
List Tuition and Net Tuition: Private U.S. Institutions[a]

Independent Variable	Log[List Tuition] 1	Log[List Tuition] 2	Log[Net Tuition] 3	Log[Net Tuition] 4
Institution offers advanced degree	0.018 (0.019)	0.015 (0.019)	0.001 (0.026)	−0.003 (0.026)
Undergraduate enrollment <2,000	0.023 (0.021)	0.011 (0.025)	−0.050 (0.030)	−0.075 (0.034)**
Undergraduate enrollment >10,000	−0.260 (0.062)**	−0.176 (0.099)*	−0.345 (0.086)**	−0.302 (0.137)**
Proportion of undergraduate enrollment receiving Pell	−0.260 (0.045)**	−0.253 (0.045)***	−0.260 (0.062)**	−0.244 (0.062)***
Log[institutional endowment]	0.034 (0.004)**	0.034 (0.004)***	0.025 (0.006)**	0.025 (0.006)***
Proportion of undergraduate enrollment out of state	0.118 (0.042)**	0.108 (0.042)**	0.131 (0.058)*	0.099 (0.057)*
Log[state disposable income]	0.106 (0.125)	0.040 (0.128)	0.128 (0.173)	0.008 (0.176)
State unemployment rate	0.012 (0.009)	0.013 (0.009)	0.000 (0.012)	0.001 (0.012)
State population: proportion between 18 and 24	−2.973 (2.063)	−3.365 (2.045)	−4.937 (2.862)	−5.884 (2.820)***
State population	−0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Verbal SAT: state mean	−0.005 (0.002)*	−0.005 (0.002)**	−0.004 (0.003)	−0.004 (0.003)
Math SAT: state mean	0.006 (0.002)*	0.006 (0.002)**	0.005 (0.003)	0.005 (0.003)
Small city	−0.015 (0.023)	−0.017 (0.023)	−0.016 (0.032)	−0.016 (0.031)
Medium city	−0.033 (0.031)	−0.034 (0.030)	0.029 (0.043)	0.034 (0.042)
Large city	−0.036 (0.025)	−0.044 (0.024)*	0.007 (0.034)	−0.001 (0.034)
City offers good arts environment	0.001 (0.022)	0.000 (0.022)	−0.017 (0.031)	−0.016 (0.030)
City offers good recreational activities	−0.020 (0.022)	−0.019 (0.022)	−0.020 (0.030)	−0.016 (0.030)
City offers good climate	−0.051 (0.024)*	−0.031 (0.025)	−0.027 (0.034)	0.005 (0.034)
South	−0.063 (0.035)	−0.016 (0.039)	−0.119 (0.048)*	−0.042 (0.054)
Midwest	−0.067 (0.038)	−0.025 (0.041)	−0.142 (0.052)**	−0.068 (0.057)
West	−0.063 (0.041)	−0.042 (0.041)	−0.041 (0.057)	−0.027 (0.056)
Log[mean public in-state tuition in region]	0.267 (0.067)**	0.272 (0.067)***	0.358 (0.093)**	0.374 (0.092)***
Log[mean public out-of-state tuition in region]	0.317 (0.101)**	0.199 (0.110)*	0.229 (0.140)	0.050 (0.151)
Ranking: most difficult	0.646 (0.063)**	0.620 (0.063)***	0.466 (0.088)**	0.435 (0.087)***
Ranking: very difficult	0.780 (0.047)**	0.769 (0.047)***	0.564 (0.066)**	0.553 (0.065)***
Ranking: moderately difficult	0.502 (0.035)**	0.495 (0.035)***	0.368 (0.048)**	0.363 (0.048)***
Ranking: minimally difficult	0.242 (0.037)**	0.238 (0.037)***	0.206 (0.051)**	0.199 (0.050)***
Spatial-lag coefficient (ρ)		0.223 (0.100)**		0.339 (0.126)***
Constant	1.581 (1.473)	1.429 (1.468)	1.415 (2.043)	1.413 (2.015)
	$R^2 = 0.67$		$R^2 = 0.48$	
Observations	929	929	929	929

[a]Estimates in Columns 1 and 3 are OLS coefficients. Estimates in Columns 2 and 4 are ML coefficients. Standard errors are in parentheses.

*Significant at 10%; **Significant at 5%; ***Significant at 1%.

be informational asymmetries such that in-state students are relatively more aware of institutional aid programs for colleges in their home state. Regardless, the public-tuition results suggest that private universities are cognizant of their public competitors even to the point of responding asymmetrically to the net prices charged to in-state and out-of-state students.

Qualitative attributes of private universities also appear to be important determinants of tuition. Specifically, four variables from Petersen's Guide that rank the difficulty of admission are included in the model. The rankings indicate that list tuition is roughly 86%, 116%, 64%, and 27% higher at most difficult, very difficult, moderately difficult, and minimally difficult institutions relative to the excluded, noncompetitive institutions. Likewise, net tuition is, respectively, 54%, 74%, 44%, and 22% higher across this measure of the competitiveness of the admission process. Thus, to the extent that these admission rankings are monotonic in quality, quality seems to relate to tuition nonlinearly, with very difficult admission criterion (but not the most difficult) yielding the highest tuition levels, all else equal. The lower tuition levels at the most exclusive institutions is consistent with such institutions having greater interest in attracting the most academically able students, with less regard for average revenue. Nonetheless, the decline in the differential between list and net tuition across quality suggests that all private universities with competitive admissions use financial aid to compete for students.[7]

The coefficients on the spatial lags are positive and significant in both the net and list tuition specifications. In short, this indicates that after controlling for a detailed list of cost and demand-side factors, the tuition of a university is related to that of neighboring institutions. Specifically, spatial-lag coefficients indicate that list tuition is 2.1% higher at the average institution for every 10% increase in a weighted index of tuitions at neighboring institutions. Net tuition is 3.5% higher for the similar comparison. These percentage changes imply a \$227 increase in list tuition and a \$301 increase in net tuition for the average private institution in 2006. The fact that the spatial-autoregressive relationship is larger in percentage and absolute terms for net versus list tuition suggests that, in general, tuition prices across neighboring institutions correlate more closely when institutional aid is taken into account.

That we find a significant and positive spatial-autoregression coefficient over the pooled sample of private universities is instructive. However, to consider the potential for spatial dependence across the entire population of private universities without paying any regard to the potential for significant asymmetries may be misleading, particularly because private universities in the United States have historically been segmented into a relatively small number of national and regional universities that recruit students over a relatively wide and diverse area and a more numerous set of comprehensive universities that primarily serve students from smaller, relatively homogenous areas. It follows that these two classes of institution may compete for a largely different set of students, and, in general, an institution's sensitivity to competitors' prices may depend on this classification.

Furthermore, while unlikely to fully explain the significance we report, other unobserved attributes that vary systematically with the construction of our spatial relationships may also be contributing to the estimated relationship. For example, given our reduced form in Equation (1), one may posit that institutions facing similar cost pressures behave similarly. However, one should recall that covariation of tuition levels across nearby institutions net of other observable characteristics is the primary determinant of the spatial-lag coefficient. Thus, in order for the spatial relationship identified above to be driven by an omitted-variable bias, a missing variable such as cost pressure must vary with log tuition, and be shared by an institution and its neighboring institutions yet not be explained by other attributes such as region, state population, income and unemployment measures, city size, or institutional quality or rank. This combination of events seems unlikely. However, in our subsequent specifications, we allow for the estimated spatial lag to differ by another exogenous measure of the institution's basin of attraction, whether the institutions if national and/or regional or comprehensive, which further restricts the sources of variation through which an omitted-variable bias may arise.

III. ANALYSIS OF TUITION WITH DIFFERENTIAL SPATIAL-LAG ESTIMATES

Although it is clearly important to consider the potential for asymmetries in the patterns of spatial dependence within institutional classification, it is not clear which pattern of spatial dependence should be expected in the data. The sign and strength of any systematic relationship is ultimately an empirical question. Although negative spatial dependence within classifications would seem at odds with our previous results, finding either positive

7. In a sample of private K-12 schools, Epple, Figlio, and Romano (2004) find evidence of tuition competition, where tuition declines with student ability, in general, as the potential for peer effects increases the benefit to enrolling more able students.

dependence or no dependence would be entirely reasonable. For example, the tuition levels of national and regional universities may be positively correlated geographically with their direct competitors because they compete in prices for an overlapping set of students. Alternatively, to the extent that students sort across national and regional institutions based on academic ability, the tuition at such institutions may exhibit less spatial dependence within 400 miles. Likewise, comprehensive-university tuition may be positively correlated over space because they also compete in prices for an overlapping set of students, or may not be correlated over space if the institutions benefit from local monopoly power, which may arise if potential students view travel as prohibitively costly or view comprehensive institutions as relatively homogeneous in quality.

With respect to competition across institution classifications, there again may be important distinctions between national and regional universities and comprehensive universities. National and regional institutions are more likely to capture the upper tail of the distributions of academic and financial ability, while comprehensive institutions have greatest market power over students in the lower tail. As financial and academic ability of students are clearly valued by institutions, these tendencies alone might suggest that their spatial dependence on each other is asymmetric, as institutions compete for students in the overlapping portions of the distributions of both academic and financial ability—national and regional institutions competing from above and comprehensive institutions competing from below.[8] In order to classify institutions as either national and regional or comprehensive, we adopt such classifications as reported in 1994 U.S. News and World Report, which leads to the classification of 237 of the original 929 institutions as national or regional institutions (which we notate N) and the remainder as comprehensive institutions (which we notate C).

A. Empirical Specification: Multiple Spatial-Autoregression Coefficients

Different price sensitivities across the possible classifications of institutions could be modeled in several ways. For example, one could account for a particular differential directly in the specification of the contiguity matrix by assigning a larger weight to institution pairs of common classifications and a smaller weight to institution pairs of different classifications. Although this strategy fits the standard spatial-autoregressive model, it imposes that within-classification sensitivity is larger than the sensitivity across classes. Furthermore, the arbitrary structure of this or any other restriction on the contiguity matrix is unlikely to accurately represent the true relationship of a university's tuition to the tuition levels at other universities. Thus, we instead adopt a common weighting mechanism across all institutions while allowing the estimates of ρ to vary across two classes of institution. Specifically, we allow for possible asymmetries by respecifying the models for list and net tuition to each include two classification-specific spatial-lag coefficients and two cross-classification spatial-lag coefficients.

Given the classification of institutions into national and regional versus comprehensive, this modification yields the model

$$(7)\quad \begin{pmatrix} Y_N \\ Y_C \end{pmatrix} = X\beta + \left[\rho_{NN} \begin{pmatrix} w_{NN} & 0 \\ 0 & 0 \end{pmatrix} + \rho_{NC} \begin{pmatrix} 0 & w_{NC} \\ 0 & 0 \end{pmatrix} + \rho_{CN} \begin{pmatrix} 0 & 0 \\ w_{CN} & 0 \end{pmatrix} + \rho_{CC} \begin{pmatrix} 0 & 0 \\ 0 & w_{CC} \end{pmatrix} \right] \begin{pmatrix} Y_N \\ Y_C \end{pmatrix} + u,$$

where Y_N and Y_C are tuition vectors for institutions of national and regional (N) and comprehensive (C) classifications, respectively.[9] Vector X includes the same institution- and state-level controls as described in the discussion of the standard spatial model. Following

8. Stated missions to provide need-blind access to the academically able provide further evidence of the potential for asymmetric spatial dependence. Further, that tuition growth rates differ by classification has been documented by Schwartz and Scafidi (2004).

9. Equation (7) is an example of one of the more complicated versions of the "spatial cross-regressive lag" model outlined in Rey and Boarnet (2004). Though applications of spatial simultaneous models are still rare, a good example is Boarnet (1994). Note that by imposing that $\rho_{NN} = \rho_{NC} = \rho_{CN} = \rho_{CC} = \rho$, Equation (7) does not simplify to the standard model of Equation (1), as Equation (7) still assumes a contiguity matrix that is class dependent.

the baseline specification, as outlined in Equation (2), we maintain a structure similar to the weighting scheme, putting weight on institutions within 400 miles and no weight on institutions farther than 400 miles.

Each ρ_{jk} in Equation (7) is a spatial-lag coefficient to be estimated, measuring the strength of the spatial relationship between institutions of classification j in explaining tuition levels for classification k institutions. In similar fashion, each w_{jk} in Equation (7) is a contiguity submatrix that captures the weight that classification k tuitions receive in explaining tuition levels for classification j institutions. As the number of institutions in j and k potentially differ, each w_{jk} is row standardized separately such that the sum of each row within w_{jk} is 1, which holds constant the sum of weights within the four distinct pairings of classification. With respect to the interpretation of coefficient magnitudes across classification, note that following standard practice in row standardizing the weights removes scale effects associated with the number of institutions contributing to the spatial-lag component in Equation (7). The estimated ρ_{jk} does not measure the effect of a change in tuition at a *single* institution of type k on the tuition of an institution of type j; rather, they measure the effect of a change in the *average* tuition at all proximate institutions of type k. Given there are roughly three comprehensive institutions in the sample for every national or regional institution, these scale effects should be borne in mind when interpreting the results. Namely, a 10% change in the mean tuition of one's proximate comprehensive institutions may represent a larger economic change than a 10% change in the mean tuition of proximate national and regional institutions. This issue will be revisited in greater detail in our final consideration of the findings.

With respect to sign patterns, the interpretation of the coefficients ρ_{NN} and ρ_{CC} is similar to the interpretation of the spatial-lag coefficient in the standard model as presented in Section II. For example, a positive value of ρ_{NN} (of ρ_{CC}) would indicate that national and regional (comprehensive) universities respond to higher tuitions at nearby national and regional (comprehensive) universities by increasing their own tuition levels. In contrast, a negative value of ρ_{NN} (of ρ_{CC}) would imply that national and regional (comprehensive) universities respond to higher tuitions at nearby national and regional (comprehensive) universities by lowering their own tuition levels, a result that could occur if universities were using tuition as a tool to increase their share of students by drawing students away from nearby comparable institutions. Our results from the previous section lead us to expect both ρ_{NN} and ρ_{CC} to be positive. However, our more general model allows ρ_{NN} and ρ_{CC} to differ in magnitude and even in sign.

The cross-lag effects, ρ_{NC} and ρ_{CN}, show how one group's tuition responds to changes in tuition levels in the other groups. For example, $\rho_{CN} > 0$ implies that the average comprehensive university increases tuition when it faces higher tuitions at proximate national and regional universities. However, a negative value is also possible, which would imply that the higher is tuition at proximate national and regional universities, the lower is the tuition level at the average comprehensive institution. Such would arise, for example, if comprehensive universities are better able to compete with national and regional institutions on price where national and regional tuitions are higher.

Comparisons of the cross-lag effects across groups can also have interesting implications. For example, a finding that $|\hat{\rho}_{NN}| > |\hat{\rho}_{NC}|$is consistent with national and regional universities being more sensitive to other proximate national and regional universities than to proximate comprehensive universities. This would likewise be the case if $|\hat{\rho}_{CC}| > |\hat{\rho}_{CN}|$, and comprehensive universities responded more to other proximate comprehensive universities than to proximate national and regional universities. All told, Equation (7) allows for a richer characterization of spatially based relationships in tuition by estimating both within-class and across-class price effects.[10]

10. The general spatial model of Equation (7) has many other possible applications. For example, one might use it to analyze the relationship between apartment rents and house prices. In this case, the own-lag terms would indicate the response of apartment rents in an area to changes in nearby rents and the changes in house prices to the changes in prices of nearby houses. The cross-lag terms would indicate how apartment rents responded to changes in nearby house prices and vice versa. Another possible application is to the pricing of gasoline across independents and stations owned by major oil companies.

In general, with J classifications of institution (i.e., $j = 1, \ldots, J$) there are J^2 contiguity matrices W_{jk} that have the submatrices w_{jk} in block row j, block column k, and zero in all other blocks. An equivalent representation of Equation (7) is therefore given by

$$(8)\quad \begin{pmatrix} Y_N \\ Y_C \end{pmatrix} = X\beta + (\rho_{NN}W_{NN} + \rho_{NC}W_{NC} + \rho_{CN}W_{CN} + \rho_{CC}W_{CC})\begin{pmatrix} Y_N \\ Y_C \end{pmatrix} + u,$$

or, more generally,

$$(9)\quad Y = \sum_j \sum_k \rho_{jk} W_{jk} Y + X\beta + u.$$

The corresponding log-likelihood function is therefore

$$(10)\quad \log L = -(n/2)\log(2\pi) - (1/2\sigma^2)\sum_{i=1}^{n} u_i^2 - (n/2)\log\sigma^2 + \log\left|I - \sum_j \sum_k \rho_{jk} W_{jk}.\right|$$

As before, if $Z_{jk} = W_{jk}Y$, the first-order conditions imply that

$$(11)\quad \hat{\sigma}^2 = n^{-1}\sum_{i=1}^{n}(Y_i - \sum_j \sum_k \rho_{jk} Z_{jki} - X_i\beta)^2,$$

which in turn implies the following concentrated log-likelihood function:

$$(12)\quad \log L_c = -(n/2)\log(2\pi + 1) - (n/2)\log\hat{\sigma}^2 + \log|I - \sum_j \sum_k \rho_{jk} W_{jk}|.$$

In general, the Jacobian term does not simplify any further.[11] Defining $A = (I - \sum_j \sum_k \rho_{jk} W_{jk})^{-1}$ and $\theta = (\beta, \rho_{11}, \rho_{12}, \ldots, \rho_{JJ})$, the score vector continues to have a simple structure

$$(13)\quad \partial L_c/\partial\theta = (1/\sigma^2)\begin{pmatrix} X'u \\ Z'_{jk}u - \sigma^2 tr(AW_{jk}) \end{pmatrix},$$

with $tr(AW_{jk}) = 0$, unless $j = k$. However, the information matrix is more complicated than before because it includes the cross-partial derivatives for ρ_{jk} and ρ_{mn}. Note that $-E(\partial^2 L_c/\partial\rho_{jk}\partial\rho_{mn}) = Z'_{jk}Z_{mn} + \sigma^2 tr(AW_{jk}AW_{mn})$. The information matrix is therefore

$$(14)\quad -E(\partial^2 L_c/\partial\theta\partial\theta') = (1/\sigma^2)\begin{pmatrix} X'X & X'Z_{jk} & X'Z_{mn} \\ Z'_{jk}X & Z'_{jk}Z_{jk} + \sigma^2 tr(AW_{jk}AW_{jk}) & Z'_{jk}Z_{mn} + \sigma^2 tr(AW_{jk}AW_{mn}) \\ Z'_{mn}X & Z'_{mn}Z_{mn} + \sigma^2 tr(AW_{mn}AW_{jk}) & Z'_{mn}Z_{mn} + \sigma^2 tr(AW_{mn}AW_{mn}) \end{pmatrix}.$$

As in the previous section, an iterative, nonlinear ML estimation procedure is used to calculate the change in θ across iterations.[12]

11. However, in the special case where all cross-effects are zero (i.e., $\rho_{jk} = 0$ for all $j \neq k$), the Jacobian term simplifies to $\sum_j \sum_i \ln(1 - \rho_{jk}\omega_{jki})$, where ω_{jki} is an eigenvalue for the submatrix W_{jk}.

12. Results are qualitatively robust to a GMM estimator of the model, $Y = \rho_{NN}W_{NN}Y + \rho_{NC}W_{NC}Y + \rho_{CN}W_{CN}Y + \rho_{CC}W_{CC}Y + XB + u$, using $W_{ij}X$ as instruments for $W_{ij}Y$, as the division between the two categories (i and j) is exogenous.

B. Results: List and Net Tuition

Recall that introducing a spatial-autoregressive component to the baseline specification of Section II left OLS point estimates unchanged, in general, having significant effects only on location-based attributes. Although the results reported in Table 3 remain qualitatively similar when one incorporates the potential for asymmetry in the spatial component, there are often sizable differences in the magnitude of coefficients, mainly with regard to institutional attributes. In particular, this is true for those attributes that are correlated with an institution's classification as either national or regional versus comprehensive. Thus, for brevity, the discussion of the empirical results focuses on the institutional factors along with those for spatial dependence.

Relaxing the constraint in the standard spatial model that any spatial dependence is common across all institutions reveals three distinct and important differences in point estimates relating to institutional attributes. First, variation in institution size, as measured by discrete enrollment categories, correlates less with variation in list and net tuition once the spatial distribution of competitor institutions is explicitly taken into account. That is, differences in point estimates between Tables 2 and 3 suggest that the empirical regularity of larger institutions offering lower tuition is explained by differences in the proximity and pricing behavior of other institutions as they relate to institutional classifications as national or regional and comprehensive. Likewise, while still significant, the proportion of out-of-state students at an institution is of less importance in explaining tuition in the model with asymmetries. Last, the range of tuition levels across the distribution of institution quality is lower in the model with asymmetries.[13] In particular, the average institution with most difficult or very difficult admissions criteria is less differentiated from other lower quality institutions in the asymmetric spatial specifications of both list and net tuitions. Overall, comparing the results across both specifications implies that tuition levels correlate across both institutional attributes and spatial dimensions and that properly accounting for both dimensions is important in determining patterns of university pricing behavior.

As anticipated, spatial dependence is very different across classifications of institutions as either national or regional, or as comprehensive. In fact, in considering the results in Table 3, we find that national and regional tuition levels are not significantly correlated with the proximity of other national and regional tuitions (i.e., $\hat{\rho}_{NN} = 0$), while tuitions observed at comprehensive universities do exhibit a statistically significant pattern of positive spatial dependence (i.e., $\hat{\rho}_{CC} > 0$). That tuition levels at national and regional universities within 400 miles do not significantly contribute to explaining tuitions at a given national and regional university is consistent with these institutions competing over (geographically) larger markets than comprehensive universities which may be expected to have much more active local competition.[14] In particular, point estimates suggest that where the weighted average of tuition levels at proximate comprehensive institutions is 10% higher, list and net tuitions at comprehensive institutions are 2.2% and 3.6% higher, respectively. For the average comprehensive institution, this estimate translates into a \$246 and \$281 increase in 2006 CPI-adjusted list and net tuitions, respectively. Again, we see that the spatial-autoregressive relationship is larger in percentage and absolute terms for net tuition than for list tuition, which suggests that price competition among comprehensive institutions is greater when institutional aid is taken into account. In general, the cross-lag spatial model may suggest that comprehensive institutions are more likely to use financial aid to manage enrollments.

While our analysis suggests that comprehensive institutions are sensitive to their direct competitors and that national and regional institutions are not, results also point to significant cross-classification tuition sensitivity for both classes of institution. More interesting, however, is that spatial dependence is found to be not only asymmetric but of opposite sign.

13. Estimates from Column 1 of Table 3 suggest that list tuition is 72%, 99%, 62%, and 27% higher at most, very, moderately, and minimally difficult institutions relative to the noncompetitive institutions, respectively (compared to 89%, 117%, 64%, and 27% in the standard spatial model). From Column 2, differences in net tuition across the same qualitative measures are 48%, 67%, 43%, and 22% (compared to 57%, 75%, 43%, and 22%).

14. Recalling our earlier discussion of the potential for omitted variables (e.g., neighboring institutions facing similar cost pressures) driving the baseline spatial relationship of Table 2, we view the strong asymmetries in Table 3 as suggestive that fears of such omissions being behind the results may be unwarranted.

TABLE 3
Spatial Models of List and Net Tuition with Differential Responses[a]

Independent Variable	Log[List Tuition] 1	Log[Net Tuition] 2
Institution offers advanced degree	0.027 (0.018)	0.002 (0.026)
Undergraduate enrollment <2,000	0.013 (0.024)	−0.075 (0.034)**
Undergraduate enrollment >10,000	−0.178 (0.096)*	−0.309 (0.136)**
Proportion of undergraduate enrollment receiving Pell	−0.222 (0.044)***	−0.230 (0.062)***
Log[institutional endowment]	0.029 (0.004)***	0.022 (0.006)***
Proportion of undergraduate enrollment out of state	0.078 (0.041)*	0.079 (0.058)
Log[state disposable income]	0.031 (0.124)	0.021 (0.175)
State unemployment rate	0.011 (0.009)	−0.001 (0.012)
State population: proportion between 18 and 24	−3.503 (1.982)*	−5.403 (2.816)*
State population	0.000 (0.000)	0.000 (0.000)
Verbal SAT: state mean	−0.005 (0.002)**	−0.004 (0.003)
Math SAT: state mean	0.006 (0.002)**	0.005 (0.003)
Small city	−0.011 (0.022)	−0.017 (0.031)
Medium city	−0.013 (0.030)	0.047 (0.042)
Large city	−0.023 (0.024)	0.010 (0.034)
City offers good arts environment	0.008 (0.021)	−0.012 (0.030)
City offers good recreational activities	−0.013 (0.021)	−0.010 (0.030)
City offers good climate	−0.034 (0.024)	−0.002 (0.034)
South	−0.029 (0.038)	−0.043 (0.053)
Midwest	−0.036 (0.038)	−0.080 (0.055)
West	−0.059 (0.040)	−0.046 (0.056)
Log[mean public in-state tuition in region]	0.268 (0.064)***	0.369 (0.091)***
Log[mean public out-of-state tuition in region]	0.246 (0.105)**	0.111 (0.150)
Ranking: most difficult	0.542 (0.062)***	0.390 (0.088)***
Ranking: very difficult	0.688 (0.047)***	0.512 (0.066)***
Ranking: moderately difficult	0.484 (0.034)***	0.359 (0.048)***
Ranking: minimally difficult	0.240 (0.035)***	0.200 (0.050)***
Spatial-lag coefficients[b]		
ρ_{NN} ρ_{NC}	−0.340 (0.269) 0.557 (0.294)*	−0.019 (0.260) 0.408 (0.308)
ρ_{CN} ρ_{CC}	−0.034 (0.016)** 0.225 (0.106)**	−0.045 (0.024)* 0.358 (0.129)***
National or regional institution (i.e., N in the above)	0.051 (1.084)	−0.571 (1.274)
Constant	1.512 (1.472)	1.013 (2.056)
	$F(32,896) = 60.50$	$F(32,896) = 26.00$
Observations (national or regional/ comprehensive)	929 (237/692)	929 (237/692)

[a]All estimates are derived by ML. Standard errors are in parentheses.

[b]Estimated spatial-lag coefficients measure the degree to which tuition at a national and regional institution depends on the average tuition of proximate national and regional institutions (ρ_{NN}) and proximate comprehensive regional institutions (ρ_{NC}), and the degree to which tuition at a comprehensive institution depends on the average tuition of proximate national and regional institutions (ρ_{CN}) and proximate comprehensive regional institutions (ρ_{CC}).

*Significant at 10%; **Significant at 5%; ***Significant at 1%.

Specifically, point estimates suggest that list tuition at comprehensive institutions is negatively correlated with that of proximate national and regional institutions: where a weighted average of list tuitions at proximate national and regional institutions is 10% higher, list tuition at a given comprehensive institution is 0.3% *lower* (i.e., a $33 price reduction for the average comprehensive institution in 2006). On the other hand, list tuition at national and regional universities is positively correlated with that of proximate comprehensives: where a weighted average of list tuitions at proximate comprehensive institutions is 10% higher, list tuition at a given national or regional institution is 5.6% *higher* (i.e., $959 for the average national and regional institutions).

In interpreting the cross-lag estimates of $\hat{\rho}_{NC} > 0$ and $\hat{\rho}_{CN} < 0$, recall the identification strategy used in Equation (7). First, the positive spatial dependence implied by $\hat{\rho}_{NC} > 0$ is identified through variation across national and regional universities in the tuition levels of their proximate comprehensive universities. What the reported results reveal is that national and regional universities relate positively to the tuition levels at comprehensive universities within 400 miles, setting higher tuition where neighboring comprehensives are expensive, and lower tuition where neighboring comprehensives are inexpensive. This result is certainly suggestive that national and regional institutions are aware of competing forces from less-selective institutions and are not insulated from price competition with comprehensive universities.

Second, and in similar fashion, the negative spatial dependence implied by $\hat{\rho}_{CN} < 0$ is identified through variation across comprehensive universities in the tuition levels of their proximate national and regional universities. As such, there appears to be statistically significant power in the average level of tuition at proximate national and regional universities in explaining variation in tuition levels at comprehensive institutions, consistent with comprehensive institutions competing more aggressively on price where their national and regional competitors are more expensive. This result is not entirely surprising as tuition levels surely correlate cross-sectionally with institution quality, even holding constant an extensive list of other covariates. In fact, one may expect that the presence of higher priced national and regional universities, all else being equal, may make comprehensive institutions less competitive on other nonprice attributes and thereby increase the importance of pricing competitively as discussed in Epple et al. (2002). This is consistent with the empirical regularities we identify in Table 3.

The general patterns revealed in the estimation of list tuition models that allow for the estimation of spatial-lag parameters by classification are also evident in models of net tuition. In both models, the results are statistically consistent with no spatial price competition between national and regional universities. However, although the point estimate is quite large, $\hat{\rho}_{NC}$ is insignificant in the model of net tuition, suggesting that while some positive spatial dependence exists between national and regional list tuitions and proximate comprehensive list tuitions, there is no similarly observed pattern in net tuition, at least statistically speaking. At the same time, looking across our models of list and net tuition provides strong evidence that national and regional universities are sensitive to comprehensive institutions in setting list tuition at the application stage but not in setting net tuition at the subsequent enrollment stage. This result is potentially important from a policy perspective as it suggests that market segmentation and the sequence of application and enrollment processes may insulate national and regional universities from needing to use financial aid to manage enrollments.

Point estimates of $\hat{\rho}_{CN}$ and $\hat{\rho}_{CC}$ are both larger in magnitude in the model of net tuition, suggesting that comprehensive institutions are generally more spatially interdependent in setting net tuition, both in terms of proximate comprehensive and proximate national and regional institutions. This finding is consistent with comprehensive institutions using net tuition to compete more aggressively for students at the enrollment stage (through financial aid) than at the application stage with listed tuition. It also follows that comprehensive universities are not insulated from competition with proximate national and regional universities insofar as the stronger relationship in net tuition with neighboring institutions suggests that they use financial aid to manage enrollments. Broadly speaking, the results suggest that once students have sorted into applicant pools, it is the comprehensive institutions (i.e., the less selective) that are more apt to compete on price in order to enroll students.

Finally, the cross-lag estimates measuring the national or regional institutions' responses to tuitions at their proximate comprehensive institutions appear quite large relative to comprehensive institutions' responses to proximate national institutions. In terms of interpretation, however, note that these cross-effects are not "scale neutral." Specifically, by following the standard practice of row-standardizing weighting matrices, we have held constant the sum of weights within each of the four distinct classification pairings. The point estimates, therefore, fail to adjust for potential scale effects related to the number of institutions contributing to mean tuition levels. Given that there are three comprehensive institutions for every national or regional institution, an individual national or regional institution will tend to contribute more to the arithmetic mean than will an individual comprehensive institution. In other words, a 10% increase in the *mean* tuition at national and regional institutions (the thought experiment one would be inclined to run) may be less economically significant than a 10% increase in the *mean* tuition at comprehensive institutions.

Table 4 reports "scale-neutral" spatial lags that deflate the Table 3 estimates using the average number of institutions in the related classification (i.e., N or C).[15] These rescaled coefficients indicate the effect of a change in a *single* institution's tuition on neighboring tuition levels. For example, these scaled coefficients suggest that when list tuition at a single national and regional institution is 10% higher, list tuition at a given comprehensive university is predicted to be 0.006% lower. Similarly, when list tuition at a single comprehensive institution is 10% higher, list tuition at a given national institution is 0.031% higher and list tuition at a given comprehensive university is 0.015% higher. The net tuition results presented in Table 4 also exhibit similarly scaled effects. In summary, even apart from high standard errors associated with the statistically significant terms, the differences in cross-lag effects are not as large as they appear after netting out the effects of scale.[16]

IV. CONCLUDING REMARKS

This study contributes to our understanding of university and college tuition determination by introducing spatial proximity into empirical models of list and net tuition. In particular, we adopt both a standard spatial-autoregression model and a new, more flexible ML specification of the spatial patterns that relaxes the implicit constraint that the strength of any spatial relationship be common across all observations. We are the first to investigate the potential spatial dependence of tuition and, then, the potential for asymmetric spatial dependencies. The application of this more flexible specification, here explaining variation in tuition levels, demonstrates that spatial dependence can, in fact, be asymmetric and that models that are restricted to estimating a single spatial-lag coefficient are potentially misleading.

Using a sample of private universities in the United States, reduced-form models of tuition indicate that list and net tuitions are both positively correlated, in general, across all classifications of institution. In contrast to the standard spatial model, however, relaxing the constraint that the strength of the spatial relationship be common across all observations, in particular, across institutions classified as national or regional versus comprehensive (i.e., serving relatively local market), we find no statistically robust evidence of spatially dependent correlation among list or net tuitions at national and regional universities. List tuition at national and regional universities is positively correlated to list tuition at proximate comprehensive institutions, however, which suggests that they are potentially responsive

15. The calculations assume that the spatial-lag coefficients do not vary within classification (e.g., the influence of a national or regional institution on other national and regional or comprehensive institutions does not vary across institutions). The average national or regional institution is within 400 miles of 74.7 other national or regional institutions and 177.3 comprehensive institutions. The average comprehensive institution is within 400 miles of 60.7 national or regional institutions and 156.2 other comprehensive institutions.

16. We consider scaling issues relating to the number of institutions that enter into the empirical model through the contiguity matrix, but issues of scale that are outside of the model could also be of interest. For example, the average national-regional institution has full-time student enrollment that is 834 larger than the average comprehensive institution, which implies that a national-regional tuition response has the potential to affect more students (and therefore be thought of as more economically significant) than a comprehensive tuition response. As student-specific scale issues are not well addressed by our institution-level model of tuition responses, we leave this for future consideration.

TABLE 4
Scale-Neutral Interpretation of Estimated Spatial Relationships[a]

Independent Variable	Log[List Tuition] 1		Log[Net Tuition] 2	
Scale-neutral spatial-lag coefficients[b]				
ρ_{NN} ρ_{NC}	−0.0046 (0.0036)	0.0031 (0.0017)*	−0.0003 (0.0035)	0.0023 (0.0017)
ρ_{CN} ρ_{CC}	−0.0006 (0.0003)**	0.0015 (0.0007)**	−0.0007 (0.0004)*	0.0024 (0.0009)***

[a]All specifications include the covariates detailed in Table 3. The average national or regional institution is within 400 miles of 74.667 other national or regional institutions and 177.266 comprehensive institutions. The average comprehensive institution is within 400 miles of 60.711 national or regional institutions and 156.243 other comprehensive institutions. As such, while all estimates are derived by ML, as in Table 3, they are rescaled here to represent the per-institution effects. In particular, reported coefficients (and standard errors) are derived from those of Table 3, divided by the appropriate number of institutions within each cell (e.g., −0.0046 = −0.340/74.667, 0.0031 = 0.557/177.266).

[b]Estimated spatial-lag coefficients measure the degree to which tuition at a national and regional institution depends on the tuition of a single proximate national and regional institution (ρ_{NN}) and a proximate comprehensive regional institution (ρ_{NC}), and the degree to which tuition at a comprehensive institution depends on the tuition of a single proximate national and regional institution (ρ_{CN}) and a proximate comprehensive regional institution (ρ_{CC}).

*Significant at 10%; **Significant at 5%; ***Significant at 1%.

to competing forces from proximate comprehensive (i.e., less selective) institutions.

Furthermore, comprehensive institutions are sensitive both to the tuitions of other proximate comprehensive institutions and to the tuitions of proximate national and regional institutions. In particular, while tuitions at comprehensive institutions in close proximity are positively correlated, the presence of relatively higher priced national and regional universities correlates with lower prices at proximate comprehensive institutions. To the extent tuition proxies for otherwise unobserved heterogeneity in institution quality, this regularity in the data suggests that being relatively less competitive on other nonprice attributes may increase the importance for comprehensive institutions to price competitively.

Overall, our results suggest that national and regional universities do not compete on net price (i.e., tuition less financial aid) with either their fellow national and regional universities or with local comprehensive institutions. Thus, market segmentation and the sequential application and enrollment process may well insulate national and regional universities with regard to the need to use financial aid to manage enrollments. On the other hand, the spatial-autoregressive relationship for comprehensive institutions is larger in percentage and absolute terms for net versus list tuition. In other words, price competition among comprehensive institutions appears to be greater when financial aid is taken into account, suggesting these institutions may use institutional aid to manage enrollments. Asymmetric price competition is important from a policy perspective within postsecondary education markets, as it suggests that rules directed at curbing the possible ill effects of rising tuition by limiting price competition may yield unintended consequences if applied commonly across institutions' markets. Moreover, our evidence of asymmetric spatial dependence in university tuitions suggests that taking account of potential asymmetry in spatial dependence in other markets would be fruitful.

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