The Analytics of the Pricing of Higher Education and Other Services in Which the Customers Are Inputs

Michael Rothschild

University of California, San Diego, and National Bureau of Economic Research

Lawrence J. White

New York University

Many services provide outputs that depend partially on the customers as inputs; the presence of other customers often contributes to the output experienced by each purchaser. Higher education is the premier example; others are legion. We provide a simple model that addresses the questions of competitive pricing and allocative efficiency for these types of services. Prices that charge customers for what they get on net (output minus input) from the firm both are competitive and support efficient allocations; these prices internalize the apparent external effects of customers on each other. Few examples of such prices exist in the real world.

I. Introduction

Many commercially sold services provide outputs that depend partially on the customers as inputs. The presence of other customers (as inputs) often contributes to the output "experienced" by each purchaser. The prices paid by customers are usually not linked to the true outputs provided. Some examples follow.

A draft of this paper was written while Rothschild was visiting the University of Chicago. We are grateful to Sherwin Rosen, John McMillan, Timothy Brennan, Nicholas Economides, and two anonymous referees for comments on an earlier draft.

[*Journal of Political Economy*, 1995, vol. 103, no. 3]
 0022-3808/95/0303-0006$01.50

1. Colleges and universities provide human capital as outputs, and students—individually and collectively—are clearly inputs into the production process. The presence of some types of students may influence the output received by other students. Universities do not charge explicitly for the human capital that is produced; instead they charge tuition, which is linked to students' enrollments in classes.

2. Spectators at sports events (baseball games, football games, etc.) consume not only the game but also the experience of being part of the crowd. Total output will be determined in part by the characteristics of individual spectators (and their neighbors)—for example, their knowledge of the sport, their enthusiasm, and so forth. However, the Chicago Cubs organization (or the San Diego Chargers or the University of Nebraska) simply sells tickets to games and does not charge for the total experience. At theaters, amusement parks, resort cruises, private clubs, trendy restaurants, and charity balls, the other customers partially determine the quality of what each customer consumes.

3. Health care providers (hospitals, doctors, etc.), in principle, produce health maintenance and improvements. But outcomes depend partially on the characteristics of patients. Health care providers do not charge fees based on successful outcomes (true output) but instead link their fees to the intermediate services supplied.

4. Lawyers, in addition to counseling, provide litigation services. Outcomes depend partially on the quality of the client's case (which may include the quality of the client as a witness). Except for the contingency fee arrangements of some plaintiffs' lawyers, legal fees to clients are not levied according to outcomes but in relation to intermediate services provided.

Other examples can easily be found. In each instance the absence of output-linked pricing is understandable: Outputs are difficult to measure or are subject to moral hazard in reporting by customers.

This pattern—customers as inputs (as well as receiving outputs), charges to customers that are not linked to true outputs, and the presence of other customers often influencing the output received by any given customer—does not conform to the usual microeconomics scenario, in which customers purchase explicitly priced outputs and one customer's presence does not influence what another receives.[1]

[1] Other exceptions to the standard paradigm would include over-the-air commercial radio and television broadcasting and the production and distribution of giveaway neighborhood "shoppers" and other publications that combine editorial content and paid advertising. In both instances, the identities of the advertiser inputs and the viewing (reading) customers are different, so these examples are somewhat different from those mentioned above.

Accordingly, we believe that it is appropriate to ask the generic questions whether there exist pricing schemes that are capable of achieving an efficient allocation of resources and also whether a competitive (zero-profit) industry can achieve these efficient prices. As a subsidiary question, it is worth asking whether the apparent existence of externalities—the presence of some types and numbers of customers influencing the output (or "experiences") received by other customers[2]—interferes with or complicates these pricing problems.[3]

In this paper we develop a simple model that allows us to address and answer these questions. Our model employs standard assumptions concerning the technology of production and the behavior of firms. To provide concreteness, we develop the model in the specific context of universities and higher education. But the model has general applicability to the types of services described above.

To anticipate the results, we find that prices exist that support an efficient allocation of resources and that a competitive industry can achieve these efficient prices. The prices have a simple and intuitive interpretation: Customers pay (marginal) net cost; that is, a customer who buys a unit of output pays its marginal cost minus the marginal contribution of his or her input to the firm's output. Further, we show that the apparent externalities are not a problem: Firms are able to internalize these externalities.

The remainder of this paper proceeds as follows: Section II lays out the model. Section III reflects on its implications and also on its limitations and the possible areas of amplification and extension. Section IV offers a brief conclusion.

II. A Model of Higher Education

Universities provide educational services to students and charge prices (tuitions). They compete for students through price and nonprice means.[4] The presence of some students may be especially desir-

[2] Leibenstein (1950) describes similar externality phenomena as "bandwagon," "snob," and "Veblen" effects. However, he focused primarily on the demand curve consequences of these phenomena and did not analytically address the efficiency or optimality of competitive pricing. See also Rohlfs (1974), Economides and Himmelberg (1994), and Economides and White (1994) for discussions of network externalities and pricing.

[3] This question was raised in the discussion surrounding the antitrust controversy involving agreements among Ivy League universities (and Massachusetts Institute of Technology) to limit scholarship amounts to some students. Defenders of the agreements have claimed that they were necessary to prevent "destructive competition" among universities for especially worthwhile students (see Cotter 1989; Putka 1989; Salop and White 1991).

[4] For a more complete discussion of the behavior of universities in the marketplace, see Rothschild and White (1993).

able to a university (e.g., they have positive externalities for other students or the educational process), and those students may thereby be the object of special price discounts (scholarships).

In this section we specify a simple production process for universities' educational services (human capital) and develop a set of prices that would allocate students among universities efficiently. We consider a quite general model that treats students explicitly as inputs into the educational process and also as the recipients of outputs (since the explicit human capital outputs must be attached to specific students). These efficient prices are also zero-profit prices for the universities and thus are consistent with a competitive free-entry equilibrium among the universities.[5]

A. *The Technology*

We assume that society has available to it a number of educational technologies involving multiple inputs and multiple outputs. We represent such technologies in inverse form:

$$Y^t = G^t(s_1^t, \ldots, s_N^t; H_1^t, \ldots, H_N^t), \quad t = 1, \ldots, T, \tag{1}$$

where Y^t is the amount of general resources used in technology (or university) t, s_n^t is the *number* of students of type n attending university t, and H_n^t is the *aggregate amount* of human capital of type n produced by university t. The G^t functions are assumed to be appropriately convex, so that second-order conditions are satisfied. Both Y and H are measured in dollars.

Since human capital is an output,

$$\frac{\partial G^t}{\partial H_n^t} \geq 0. \tag{2}$$

Students are inputs, so

$$\frac{\partial G^t}{\partial s_n^t} \gtrless 0, \tag{3}$$

[5] There is an interesting literature on two-sided "matching"; see, e.g., Roth (1984, 1991), Roth and Sotomayor (1990), Mongell and Roth (1991), and, for a brief summary, Milgrom and Roberts (1992, pp. 43–48). That literature deals with problems of matching the preferences of multiple parties on two sides of a transaction; acceptances to the freshman classes of universities would be an example. While much of that literature deals with such nonprice issues as the existence of efficient allocations and algorithms for reaching an efficient allocation if one exists, the matching literature has discussed prices that support efficient allocation. Our traditional marginal analysis yields a clear and natural interpretation of these prices.

though we expect that universities would normally operate in the region in which

$$\frac{\partial G^t}{\partial s_n^t} < 0. \tag{3a}$$

We assume that all the technologies exhibit constant returns to scale. As an illustration, a specific Cobb-Douglas version of the technology would be[6]

$$Y = s_1^{\beta_1}, \ldots, s_N^{\beta_N} H_1^{\alpha_1}, \ldots, H_N^{\alpha_N}, \tag{4}$$

where

$$\beta_n \leq 0 \tag{5}$$

and

$$\alpha_n \geq 0, \tag{6}$$

and the constant returns condition is satisfied when

$$\sum_n (\alpha_n + \beta_n) = 1. \tag{7}$$

Our technological specification (1) assumes for convenience that the various types of human capital are the only outputs and, aside from the students, production requires only one general input. The model could easily accommodate additional outputs that are sold on competitive markets and also additional inputs, but little extra insight would be gained. We initially assume that the students are the sole beneficiaries of the human capital that they receive; that is, universities do not produce additional outputs that are socially useful but are unmarketable or otherwise incapable of being sold at prices equal to marginal costs. Also, we assume that students care only about their acquisition of human capital and any price (tuition) that they may pay.

We assume constant returns to scale so that we can better explore whether some of the apparent externalities in the educational process

[6] For this Cobb-Douglas illustration we must assume either that all $s_n > 0$ or that alternative Cobb-Douglas technologies can be specified with one or more s_n missing. For the simple case of one type of student and one type of human capital, eq. (4) becomes

$$Y = s^{\beta} H^{\alpha}, \tag{4a}$$

which can be transformed to the more familiar

$$H = Y^{1/\alpha} s^{-\beta/\alpha}, \tag{4b}$$

with the constant returns to scale condition $\alpha + \beta = 1$ implying $\alpha > 1$, $\beta < 0$.

would make competitive pricing incompatible with production efficiency and social optimality.

B. *Optimality*

Assume that there is a limited aggregate number (Q_n) of students of each type. A feasible allocation of students to schools must satisfy

$$\sum_{t=1}^{T} s_n^t = Q_n, \quad n = 1, \ldots, N. \tag{8}$$

The social allocation problem is

$$\text{maximize} \sum_{t=1}^{T} \sum_{n=1}^{N} H_n^t - \sum_{t=1}^{T} Y^t \tag{9}$$

subject to (1), (8), and

$$Y^t \geq 0, \quad t = 1, \ldots, T, \tag{10}$$

$$H_n^t \geq 0, \quad n = 1, \ldots, N; t = 1, \ldots, T, \tag{11}$$

and

$$s_n^t \geq 0, \quad n = 1, \ldots, N; t = 1, \ldots, T. \tag{12}$$

The first-order conditions are

$$-\frac{\partial G^t}{\partial s_n^t} = w_n \quad \text{if } s_n^t > 0, \tag{13}$$

where w_n are Lagrangean multipliers, and

$$\frac{\partial G^t}{\partial H_n^t} = 1 \quad \text{if } H_n^t > 0. \tag{14}$$

These conditions are relatively easy to interpret: Equation (13) states that the optimal allocation of students must be such that the marginal rate of substitution of a student of type n with respect to the general input is the same at all universities that students of type n attend.[7] Equation (14) states that at each university the production of each type of human capital (if it is produced at that university) should be extended to the point at which its marginal cost is equal to unity. Since both human capital and the general input are measured

[7] To ensure that, in the optimal allocation, students do not decrease the output of human capital by attending universities, we could include in the technological specification a "university" that uses no other resources besides students and produces no human capital.

in dollars, equation (14) is simply a statement that the marginal cost of producing an additional unit of human capital should equal its marginal product.

C. *Prices (Tuitions) and Competition*

We assume that if university t admits s_n^t students of type n and produces H_n^t units of human capital of type n, then each student of type n gets H_n^t/s_n^t of human capital from attending that school; that is, the university can neither (*a*) unevenly allocate the human capital of a given type that it produces among the students of type n nor (*b*) reallocate that human capital to other types of students. This is an assumption about the technology of producing human capital.[8]

The university's only expenses are Y^t. By assumption, the university can only sell places to students who wish to attend that university; it cannot sell human capital directly. If the university charges a price (tuition) of p_n^t to students of type n, then its profits will be

$$\pi^t = \sum_n p_n^t s_n^t - Y^t. \tag{15}$$

Will the equilibrium prices charged by a competitive industry of profit-seeking universities also satisfy the conditions for an optimal allocation? We now argue that the answer to this question is "yes," as long as our assumption of constant returns to scale and the usual assumptions of a competitive equilibrium (prices are treated as parameters by all buyers and sellers, entry is easy, and all buyers and sellers are fully knowledgeable about all aspects of the transaction) are maintained.

Let $\hat{H}_n^t$, $\hat{s}_n^t$ denote an optimal allocation. We now specify a set of prices that will decentralize this allocation. Let

$$p_n^t = \frac{\hat{H}_n^t}{\hat{s}_n^t} - \hat{w}_n, \tag{16}$$

where $\hat{w}_n$ is given by (13) calculated at the optimal allocation. If universities treat prices as parameters and students are knowledgeable about their alternatives, each university's problem is to choose

[8] An alternative technological assumption would posit university production functions of the form

$$H^t = F^t(s_1^t, \ldots, s_N^t; Y^t), \tag{1a}$$

where H^t is the total amount of undifferentiated human capital produced by university t and available for allocation to its students (and to others?) in an arbitrary fashion. The implications of this specification can be readily developed; it seems less plausible than the technology described in eq. (1).

$H_1^t, \ldots, H_N^t$ so as to minimize $G^t(\hat{s}_1^t, \ldots, \hat{s}_N^t; H_1^t, \ldots, H_N^t)$ subject to[9]

$$H_n^t \geq \hat{H}_n^t, \quad n = 1, \ldots, N. \tag{17}$$

The profit-maximizing choice of levels of human capital is just $\hat{H}_N^t$.

It is easy to show that the prices of (16) are those at which the universities earn zero profits. This follows from Euler's theorem and (13) and (14). Thus these prices are consistent with both a zero-profit competitive equilibrium and the optimal allocation.[10]

Finally, the decisions of knowledgeable students will support this equilibrium. Consider the net gain of a student of type n who attends university t. If she pays tuition of p_n^t (from [16]) and receives human capital of $\hat{H}_n^t/\hat{s}_n^t$, her net gain is $\hat{w}_n$. By assumption, students are indifferent about the specific identities of the universities that they attend. If university t tries to charge her a higher price or tries to provide her with a lower level of human capital, she will instead choose another university that will satisfy these conditions. Thus the optimal allocation will be supported.[11]

This optimality of competitive processes may seem strange at first glance, and our model may seem a bit unfamiliar in structure. But the strangeness is largely due to the peculiar role of tuition. Universities cannot sell or charge for human capital directly. Instead they must earn their revenues by *levying* a *positive* price on one set of inputs (students) into the production process. As we discussed in the Introduction, this practice applies more widely to a number of service industries.[12]

If universities could sell human capital directly, the workings of the model would be more familiar: Universities would hire students $s_1^t, \ldots, s_N^t$ as inputs. If the student input market is competitive, the universities would have to pay students of type n a wage of w_n, their

[9] If H_n^t were less than $\hat{H}_n^t$, knowledgeable students would shun this university in favor of others at which they could receive at least $\hat{H}_n^t/\hat{s}_n^t$.

[10] With convexity of G^t, these prices are both necessary and sufficient.

[11] It is worth noting that, in the presence of knowledgeable students, these competitive equilibrium prices are stable and sustainable. A university could not benefit (increase its profits) by trying to shade its prices slightly to attract more students. Unless it spent appropriately more on the general input Y^t (in which case its unit costs would remain above its prices), its output of human capital would not rise proportionately with the increase in students, so the human capital per student (H_n^t/s_n^t) would fall. This fall would always be greater than the price decrease, so the quantity-and-price package presented would be inferior, and knowledgeable students would apply elsewhere.

[12] For the two examples mentioned in n. 1 (over-the-air broadcasting and giveaway publications), the production technology represented in eq. (1a) (n. 8) seems appropriate, since the recipients of the output are different from the fee-paying input providers.

opportunity costs (from [13]). The students and the general input Y^t would be combined by university t to produce the array of human capital outputs $H_1^t, \ldots, H_N^t$, according to production function (1). The human capital would be sold back to the students at market prices. If the price of all types of human capital were standardized to \$1.00 per unit, then the net price paid by students of type n at university t would be $p_n^t = (H_n^t/s_n^t) - w_n$. With this recasting, it is easier to see how the competitive equilibrium (zero-profit) prices would be consistent with the optimal allocation.[13]

This recasting also makes clearer why the apparent externality[14] embodied by the more desirable students does not cause a conflict between the competitive equilibrium and the optimal allocation. Since students are inputs, the more desirable students can simply be considered to be more productive inputs.[15] In our alternative wage-paying scenario, these more productive inputs would receive higher wages, so that their net costs of receiving human capital would be less. In the more traditional framework, they receive (larger) scholarships. The effect and outcome are the same. As in most production relationships, the firm (university) is able to internalize the apparent exter-

[13] It has been suggested to us that apprenticeship systems may approach the reconfigured pricing scheme suggested above. On reflection, we do not believe that this is the case. Apprenticeship schemes (including those of doctoral students) basically involve learning by doing. In a competitive market, an apprentice's wages should be equal to her marginal productivity. These wages will be below her opportunity costs in other occupations, with the differential representing her investment in human capital. The human capital produced is, in an important sense, a by-product of the main production process. Contrary to our reconfigured pricing scheme, the human capital is not sold to the apprentice for an explicit price.

[14] The apparent externality could operate to favor diversity (if students of other types benefit from the presence of students of type n) or to favor uniformity (since uniformity of student type might make instruction more efficient). In the former case we would expect to see universities with diverse student bodies; in the latter, specialized institutions. Our technology (1) allows for both, and they could coexist among different universities.

[15] If the desirable students enhance the educational experience of other students, the university should be able to charge higher tuitions to the latter; if the desirable students make the educational process more efficient, competitive universities either will be able to provide more human capital per student (and thereby collect more tuition) or will be able to reduce their use of the general input. In either case, the university internalizes the externality and recoups the extra expenditure on (or larger scholarships for) the more desirable students. Note that we have assumed that there are limited quantities of all types of students, so the more desirable (not surprisingly) will earn rents on their desirable attributes.

In another context, the season ticket holders for football or baseball games may well be the most knowledgeable and enthusiastic and thus have substantial positive "crowd" externalities for other spectators. In addition to reductions in transactions costs, this could be a reason for giving these season ticket holders favorable prices, desirable locations, etc., and also for giving them favorable access to postseason championship events.

nality of the more productive inputs, and competitive markets ensure that the more productive inputs are rewarded appropriately.[16]

III. Implications, Limitations, and Extensions

A. *Implications*

Our model of optimal-cum-competitive pricing for higher education yields a number of direct implications: (1) Students of different types may be charged different tuitions at the same university. (2) Students of different types may receive different amounts of human capital at the same university. (3) The net gain of students of different types may be different and will depend on their marginal productivities (proxied by the marginal rates of substitution in [13]). (4) Students of the same type may receive different amounts of human capital from different universities; but they will pay appropriately different tuitions at those universities, so their net gain will be uniform across all the universities at which they are enrolled. (5) Universities may employ different technologies, admit different mixes of students, provide them with different levels of human capital, and charge them different tuitions. But the tuition and human capital package that a university offers to a given student type will have to satisfy the condition of the uniform net gain across all students of that type.

How well do these predictions hold up? Scholarships are a common form of price discrimination. In 1986–87, scholarship aid (including Pell grants) amounted to 24 percent of aggregate tuition receipts by private universities and 35 percent by public universities (U.S. Department of Education 1991, pp. 291–92). Unfortunately, we do not know whether these scholarships represented different net tuition levels for students of differing types (productivity) or a more conventional form of price discrimination by universities among students of the same type.

Students from higher-quality universities (graduates or dropouts) appear to earn higher incomes than similar students from lower-quality universities, even after personal attributes are held constant (Taubman and Wales 1974, pp. 13–15). These higher incomes may well be a reflection of the greater quantities of human capital provided by the higher-quality institutions (though it might instead be an indication of the universities' screening on a different set of personal

[16] Accordingly, the "destructive competition" argument, mentioned in n. 3, is not supported by this model. Also, for the larger set of demand externalities explored by Leibenstein (1950), the logic developed by this paper indicates that, as long as the externalities are confined to a firm's own products, the firm should be able to internalize the externality in its pricing, and no obvious market imperfections arise.

attributes than those for which Taubman and Wales controlled). But higher-quality universities do not appear to charge appropriately higher tuitions that would be commensurate with the higher levels of human capital that they provide (see below).

Contrary to the model's predictions, universities seem firmly wedded to the principle of charging uniform tuitions across a broad array of different disciplines within their schools of arts and sciences. Casual empiricism leads us to suspect that the marginal costs (and, quite likely, the human capital provided) per student differ substantially across these disciplines; student types may well differ across them as well. Universities do, however, seem more inclined to charge different tuitions across different schools or programs within the same university (e.g., an engineering school vs. arts and sciences).

Further, the tuitions charged across the range of private universities show a surprisingly small amount of variation, considering the wide variety of university technologies (e.g., small liberal arts colleges, large research universities, and many variants in between) and of student types (indexed, say, by average scores on the Scholastic Aptitude Test). The evidence is clearest for tuitions at graduate professional schools. Rothschild and White (1993) found that tuitions at private law schools and private business schools vary only moderately despite substantial differences in student types or human capital provided (as indicated by the differences in expected first-year salaries of their graduates). The annual tuition differences among schools captured only 10 percent of the differences in *starting annual* salaries.

In sum, though there are a few resemblances between universities' pricing behaviors and the predictions of our model, much of universities' behavior is at odds with our predictions of a competitive equilibrium by profit-seeking institutions. It seems worthwhile, therefore, to examine some of the possible limitations of our model.

B. Limitations

Profit maximization and resource constraints.—We assumed that universities were profit maximizers and (implicitly) that they were subject to the usual forms of resource constraints. But universities do not typically cover all their costs through tuitions and other fees, and it is difficult to state what universities are trying to maximize or even who is doing the maximizing. Deans, faculty, trustees, alumni, and students are the relevant parties for private universities; state (or local) governments add an extra element to public universities.

Capital market imperfections.—We implicitly assumed that students would have no difficulty in paying for the acquisition of their (valuable) human capital. Because of a well-known set of asymmetric information problems with respect to individuals' borrowing to finance their own education, students of various types may not be able to purchase human capital in the optimal quantities or qualities.

Informational asymmetries in the education market.—We explicitly assumed that universities were fully knowledgeable about student types and that students were fully knowledgeable about their own types and about the human capital that would be provided by various universities. In the absence of that complete information, various types of asymmetric information problems—for example, lemons, adverse selection, moral hazard, or agent-principal—may arise.

Technology.—We explicitly assumed a technology of constant returns to scale and the absence of meaningful product differentiation among universities (i.e., a student of type n would be indifferent among universities that charged the same price and provided the same amount of human capital per student). We believe that the properties of the model would hold for a technology that was similar to the standard microeconomics parable of the U-shaped cost curve. With uniformly increasing returns to scale, however, a standard set of pricing problems could arise. Further, if increasing returns to scale are combined with unique attributes of individual universities, the standard problems of Chamberlinian monopolistic competition—with the possibility of either too much or too little variety provided[17]—can arise.

Other outputs.—If universities produce additional outputs that cannot be sold at prices equal to marginal costs, standard externality problems arise.

C. *Extensions*

Obvious extensions to the model would be to incorporate one or more of the imperfections described above and examine their implications for competitive stability and optimality.

IV. Conclusion

For some services, customers clearly are *inputs* into the production process, as well as receiving outputs. Rather than being charged for outputs, customers are charged fees that are, in essence, related to their role as inputs. Further, the presence of some types of customers often influences the outputs received by other customers. All these features are at variance with the standard microeconomics scenario

[17] These "it all depends" results are found in Spence (1976) and Dixit and Stiglitz (1977).

that describes customers as purchasing explicitly priced outputs and one customer's presence not influencing the output received by others.

Using a simple model that captures the essential features just described, we have shown that competitive firms are capable of charging zero-profit prices that efficiently allocate resources, including the internalization of the apparent externality. The model was developed in the specific context of higher education (i.e., universities' practice of charging tuition to students for attendance rather than charging explicitly for human capital received), but the model is generally applicable to the wider class of services that are characterized by these features.

The introduction of various forms of market imperfections would likely cast doubt on the conclusions of our model; but the same would be true for almost any market that would be subject to the same imperfections. As is true generally in microeconomics, a competitive model of these services is a good place to start.

References

Cotter, William R. "Colleges' Efforts to Rationalize the Financial-Aid System Should Not Be Treated as Violations of Antitrust Laws." *Chronicle Higher Education* (October 4, 1989).

Dixit, Avinash K., and Stiglitz, Joseph E. "Monopolistic Competition and Optimum Product Diversity." *A.E.R.* 67 (June 1977): 297–308.

Economides, Nicholas, and Himmelberg, Charles. "Critical Mass and Network Size." Manuscript. New York: New York Univ., Stern School Bus., 1994.

Economides, Nicholas, and White, Lawrence J. "Networks and Compatibility: Implications for Antitrust." *European Econ. Rev.* 38 (April 1994): 651–62.

Leibenstein, Harvey. "Bandwagon, Snob, and Veblen Effects in the Theory of Consumers' Demand." *Q.J.E.* 64 (May 1950): 183–207.

Milgrom, Paul, and Roberts, John. *Economics, Organization, and Management.* Englewood Cliffs, N.J.: Prentice-Hall, 1992.

Mongell, Susan, and Roth, Alvin E. "Sorority Rush as a Two-Sided Matching Mechanism." *A.E.R.* 81 (June 1991): 441–64.

Putka, Gary. "Do Colleges Collude on Financial Aid?" *Wall Street J.* (May 2, 1989).

Rohlfs, Jeffrey. "A Theory of Interdependent Demand for a Communications Service." *Bell J. Econ. and Management Sci.* 5 (Spring 1974): 16–37.

Roth, Alvin E. "The Evolution of the Labor Market for Medical Interns and Residents: A Case Study in Game Theory." *J.P.E.* 92 (December 1984): 991–1016.

———. "A National Experiment in the Organization of Entry-Level Labor Markets: Regional Markets for New Physicians and Surgeons in the United Kingdom." *A.E.R.* 81 (June 1991): 415–40.

Roth, Alvin E., and Sotomayor, Marilda A. Oliveira. *Two-Sided Matching: A Study in Game-Theoretic Modeling and Analysis.* Cambridge: Cambridge Univ. Press, 1990.

Rothschild, Michael, and White, Lawrence J. "The University in the Marketplace: Some Insights and Some Puzzles." In *Studies of Supply and Demand in Higher Education,* edited by Charles T. Clotfelter and Michael Rothschild. Chicago: Univ. Chicago Press (for NBER), 1993.

Salop, Steven C., and White, Lawrence J. "Policy Watch: Antitrust Goes to College." *J. Econ. Perspectives* 5 (Summer 1991): 193–202.

Spence, A. Michael. "Product Selection, Fixed Costs, and Monopolistic Competition." *Rev. Econ. Studies* 43 (June 1976): 217–35.

Taubman, Paul, and Wales, Terence. *Higher Education and Earnings: College as an Investment and a Screening Device.* New York: McGraw-Hill, 1974.

U.S. Department of Education. Office of Educational Research and Improvement. National Center for Education Statistics. *Digest of Education Statistics, 1990.* Washington: Nat. Center Education Statis., 1991.