The NCAA Athletics Arms Race: Theory and Evidence

Adam Hoffer
University of Wisconsin - La Crosse

Brad R. Humphreys
West Virginia University

Donald J. Lacombe
West Virginia University

Jane E. Ruseski*
West Virginia University

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Abstract

We develop and empirically test a model of intercollegiate athletic department expenditure decisions. The model extends general dynamic models of nonprice competition and includes the idea that nonprofit athletic departments may simply set expenditure equal to revenues. Own and rival prestige is included in the athletic departments' utility function, generating rivalrous interaction. The model predicts that current own and rival investment has multiperiod effects on prestige since investment is durable. We test the model using data from NCAA Division I athletic programs from 2006-2011; the models incorporate spatial autocorrelation that capture dynamic rivalrous interaction. Results support the prediction of both models - NCAA Division I athletic programs appear to engage in dynamic non-price competition in terms of expenditure and spend all revenues generated.

Keywords: NCAA; dynamic nonprice competition; revenue theory of costs; athletic arms race

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*Corresponding author. We thank Dennis Coates for valuable comments on an earlier draft of this paper. Department of Economics, College of Business and Economics, PO Box 6025, Morgantown WV 26506-6025; email: Jane.Ruseski@mail.wvu.edu; phone: 304-293-7835.

Introduction

Substantial resources are invested in paying coaches and maintaining high quality intercollegiate programs at universities throughout the United States. Arguably, the primary purpose of this investment is to attract student athletes to play on the university's football and men's basketball teams, since universities cannot compete for the services of athletes on a price (salary) basis. Universities that are successful on the playing field generate substantial revenues through ticket sales, concessions, parking, television broadcast rights fees, donations, licensed merchandize sales, and bowl appearances (Humphreys and Mondello, 2007). For example, the top five football bowl payouts in the 2011-12 season included $22.3 million to LSU, Ohio State, Oregon, Clemson, West Virginia, and Wisconsin, $6.1 million to Alabama, Stanford, Virginia Tech, and Michigan, $4.55 million to Nebraska and South Carolina, $3.625 million to Arkansas and Kansas State, and $3.5 million to Georgia and Michigan State. Evidence also suggests that success on the playing field results in increased applications for admission to the university (Pope and Pope, 2009, 2014), increased state appropriations (Humphreys, 2006), and other indirect benefits (Getz and Siegfried, 2010).

Intercollegiate athletic expenditure has increased substantially over time in inflation adjusted terms. A number of explanations for this increase in expenditure exist. Bowen (1980) articulated the "revenue theory of costs" in higher education. According to this theory, non-profit colleges and universities collect revenues from students in the form of tuition and fees and set expenditure to always equal this revenue. When revenues rise, expenditures increase in lock-step. Intercollegiate athletics has experienced significant increases in revenues over the past several decades. Applying the revenue theory of costs, the observed increases in intercollegiate athletic expenditure occurs across all big-time athletic departments because they set expenditure equal to revenue and have experienced large revenue increases.

Alternatively, athletic departments may engage in nonprice competition, since NCAA rules explicitly prohibit universities from competing for incoming playing talent on a price basis. Nonprice competition has been called an "arms race", in terms of strategic investment in weapons in the defense industry and the "medical arms race" in the hospital industry. In an intercollegiate sports context, investment in athletic teams, facilities and coaches has been described as the "athletics arms race." This idea extends beyond the athletic department. Winston (2000) describes an analogous "positional arms race" between colleges and universities for students.

A substantial body of research discussed intercollegiate athletics spending in the context of an "arms race" but no previous research has formally modeled this process, and no formal empirical analysis has been performed. Frank (2004) contains an early discussion of the "arms race" in intercollegiate athletics spending: "...any given athletic director knows that his schools odds of having a winning program will go up if it spends a little more than its rivals on coaches and recruiting. But the same calculus is plainly visible to all other schools. ...the gains from bidding higher turn out to be self-canceling when everyone does it. The result is often an expenditure arms race with no apparent limit. (page 10)" Orszag and Orszag (2005), Kahn (2007) and Getz and Siegfried (2010) also discuss the presence of an "arms race" in intercollegiate athletic spending.

We develop an encompassing model to illustrate both of these explanations for increases in intercollegiate athletic expenditure. This model includes a standard approach to athletic department decision making in a nonprofit context based on the model developed by Carroll and Humphreys (2000) that motivates the revenue theory of costs, and a dynamic model of intercollegiate athletic nonprice competition where investment in athletic department staff is the strategic nonprice choice variable. A variable capturing the prestige of the athletic department is included in the athletic director's (AD's) utility function in both models. In the dynamic model, rivals' prestige is also an argument in the AD's utility function which allows for strategic interaction among athletic departments. In this case, the AD takes its rival ADs' behavior into account when making investment decisions. Furthermore, own and rival investment in period t can have multiperiod effects on prestige since investment in athletic department staff and related inputs is durable. The durability of investment yields dynamic conjectural variation terms that describe the competitive interactions between rival athletic departments. If the parameter estimates of the dynamic conjectural variations are nonzero, then we have evidence of strategic nonprice competition or an athletics arms race.

The empirical models are estimated using a panel data set for NCAA member institutions that includes measures of investments by athletic departments on coaches, and total athletic department expenditure based on spatial econometric techniques. The empirical analysis provides strong evidence that athletic departments engage in dynamic nonprice competition: athletic department expenditure varies systematically with expenditure by other conference teams. The results also support the revenue theory of costs in that own revenues also explain expenditure. These results shed light on the nature of competitive interaction embodied by an athletics arms race in intercollegiate athletics.

Athletic Department Spending

Total athletic department expenditure has been increasing over time. Figure 1 shows the average athletic department expenditure at 207 Division 1 public colleges and universities over the period 2006-2011. These data come from the NCAA College Athletics Finances database and have been deflated to real 2011 dollars using the CPI-U for all consumers.[1] The expenditure data have been averaged by conference for the five largest conferences; the "Others" category includes all other Division 1 athletic departments.

Real athletic department expenditure grew by between 3% and 6% per year over this period. The growth rate was about 3% per year in the ACC and PAC 10, about 6.2% in the SEC, and about 5.1% in the "Other" group. This is a substantial annual growth in inflation adjusted expenditure, especially given that a significant economic downturn took place from 2008 to 2010 that reduced state government revenues, and state support to public institutions of higher education.

Figure 1 also shows the disparity between the athletic department expenditure at "big-time" athletic departments and smaller athletic departments. Average total athletic department expenditure in the five "big-time" conferences was about 4 times larger than average total athletic department spending at "Other" institutions.

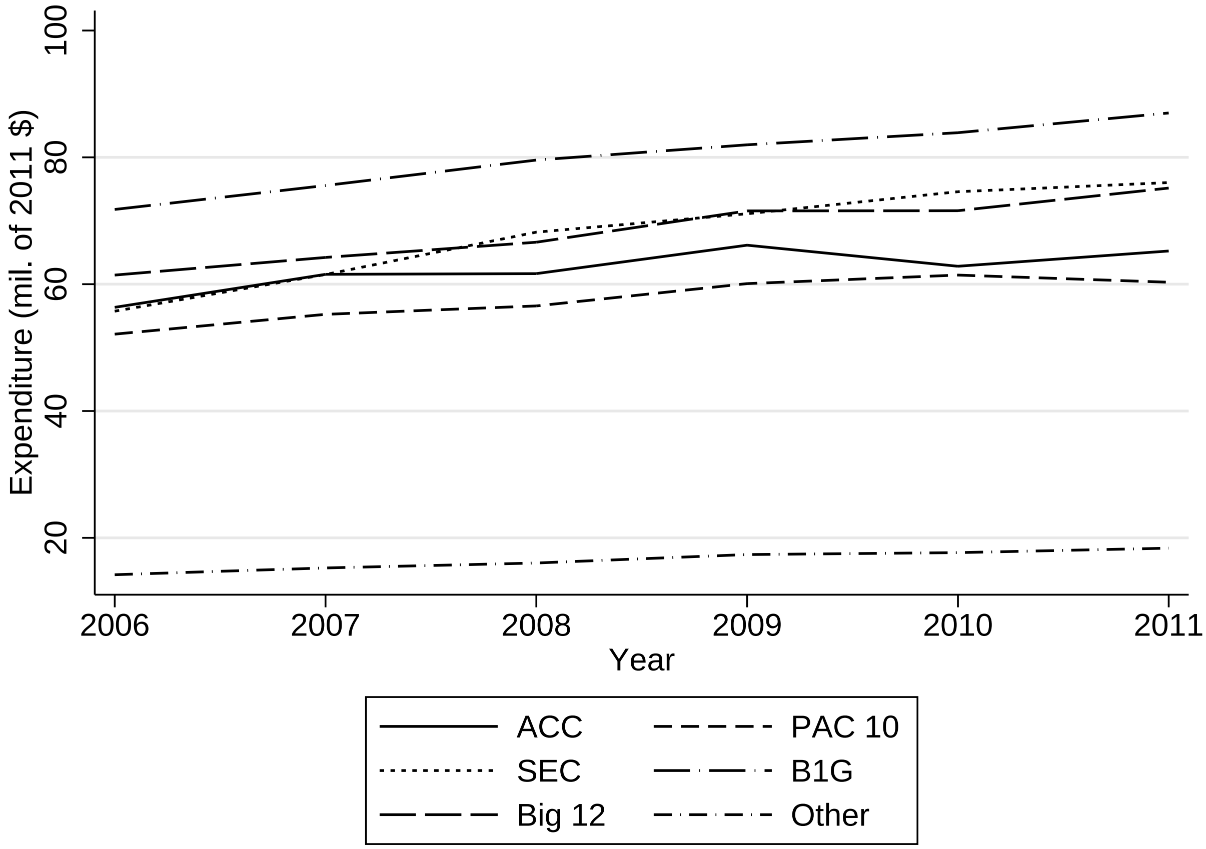
Revenues grew at roughly the same rate over this time period. Among athletic departments in the "Other" category, revenues and expenses grew at almost exactly the same rate. Again, these changes in expenses and revenues can be explained by either the "revenue theory of costs" or by an athletic department "arms race." To provide insight into the determination of athletic department expenditures and decision making, we develop a model of athletic department decisions.

A Basic Model

Our basic model of athletic department decision making is a simplified version of the model developed by Carroll and Humphreys (2000). The model includes a utility-maximizing athletic department decision maker (AD) who obtains utility from income, power or autonomy, and Williamson-type discretionary ability (Williamson, 1964). For convenience, we refer to this decision maker as

[1] `http://www.usatoday.com/sports/college/schools/finances/`. Accessed August 25 2014.

Figure 1: Average Total Athletic Department Expenditure by Conference



the Athletic Director, although most athletic department decisions are made by multiple individuals in the department and represent bargaining and consensus. The factors that generate AD utility depend on the athletic department's total coaching staff (S), prestige (G), and total revenues generated by the athletic department (R). Total athletic department staff includes coaches, assistant coaches, support staff, and all other personnel involved with sports activities. The total quantity of sports activities offered by the athletic department, Q, affects utility indirectly by increasing revenues and includes both men's and women's sports. We assume that S also reflects both the quantity and quality of the coaching staff. The decision maker's utility function is

$$U = U(S, G, R) = U[(S, G(S), R(Q, S)] \tag{1}$$

where $G(S)$ is the prestige function and $R(Q, S)$ the revenue function. Athletic department prestige comes only from the coaching staff. Athletic department revenues are a function of the quality and quantity of teams or programs offered (Q) and investment in athletic department coaching staff (S). We assume diminishing marginal utility from athletic programs ($U'_Q > 0, U''_Q < 0$), staff ($U'_S > 0, U''_S < 0$), and prestige ($U'_G > 0, U''_G < 0$), and require that Q and S are positive.

As the manager of a nonprofit organization, the AD is subject to a breakeven constraint, where revenues, R, must at least cover total cost, C. Total cost encompasses the cost of providing athletic programs, including staff and facilities for these programs

$$C = C(Q, S). \tag{2}$$

We assume that the marginal returns to staff and athletic programs are diminishing, so marginal costs are increasing ($C'_Q > 0, C''_Q > 0, C'_S > 0, C''_S > 0$). The AD's nonprofit breakeven constraint is

$$[R(Q, S) - C(Q, S)] \geq 0. \tag{3}$$

Maximizing (1) subject to (3) generates a Lagrangian, Λ

$$\max\ \Lambda = U[S, G(S), R(Q, S)] + \lambda[R(Q, S) - C(Q, S)] \tag{4}$$

Differentiating Equation (4) with respect to the choice variables Q and S, yields a number of predictions about AD behavior. The first order condition for the utility maximizing quantity and quality of athletic program offerings is

$$\frac{\partial \Lambda}{\partial Q} = \frac{\partial U \partial R}{\partial R \partial Q} + \lambda \left(\frac{\partial R}{\partial Q} - \frac{\partial C}{\partial Q} \right) \leq 0 \tag{5}$$

This can be rearranged to show

$$R'_Q = \frac{\lambda}{(U'_R + \lambda)} C'_Q.$$

When the breakeven constraint is not binding ($\lambda = 0$) the AD can increase expenditures on athletic programs above revenues. In this case, $R'_Q = 0$ implying that the AD overinvests in athletic programs and program quality. When the breakeven constraint is binding ($\lambda > 0$), and the AD must keep total expenditures equal to total costs, and the AD's investment in athletic programs, and program quality, is reduced. Exogenous factors that increase the marginal revenue of athletic programs, like larger television broadcast contracts or additional media revenues from sports activities, will increase expenditure (over-investment) on the quantity and quality of sports activities. This is the standard prediction from the revenue theory of costs (Bowen, 1980).

The first order condition for the utility maximizing size of the athletic department staff is

$$\frac{\partial \Lambda}{\partial S} = \frac{\partial U}{\partial S} + \frac{\partial U \partial G}{\partial G \partial S} + \frac{\partial U \partial R}{\partial R \partial S} + \lambda \left(\frac{\partial R}{\partial S} - \frac{\partial C}{\partial S} \right) \leq 0 \tag{6}$$

This expression can be rearranged to show

$$R'_S = \frac{\lambda}{(U'_R + \lambda)} C'_S - \frac{U'_S + U'_G G'_S}{(U'_R + \lambda)}$$

Again, when the breakeven constraint is not binding ($\lambda = 0$) the AD can increase expenditures on coaching staff and staff quality above revenues. In this case, $R'_S = \frac{U'_S + U'_G G'_S}{U'_R}$. It is unlikely that the marginal revenue generated by additional coaching staff investment would be negative. Marginal revenue from broadcast rights fees, licensed merchandize sales, and other non-ticket related revenues could be zero, but any non-ticket related marginal revenues should not be less than zero.[2] In this case, the first order condition implies even more over-investment in coaching staff. Exogenous factors that increase the marginal revenue of coaching staff will also increase expenditure on the quantity and quality of coaching staff. Again, this prediction illustrates Bowen's (1980) revenue theory of costs.

[2] Clearly, marginal revenue from ticket sales could be negative, since most teams are monopolists in their local market and the AD could increase ticket prices high enough to generate negative marginal revenues.

Dynamic Non-price Competition

We next extend this model of athletic department decision making to include dynamic nonprice competition in the form of investment in coaches.[3] The key assumption in these models is that investment, either in fixed assets like capital, or in an intercollegiate athletics context, in coaches and program quantity/quality, increases the prestige of the athletic department and has a predatory effect in the industry. If a rival athletic department increases its prestige in any time period when athletic department i's prestige remains constant, then athletic department i is perceived as less prestigious because it does not have "star" coaches or "state of the art" facilities. Conversely, if athletic department i increases its prestige in any time period when rival athletic departments' prestige remains constant, then athletic department i is perceived as more prestigious. Furthermore, own and rival investment in period t can have multiperiod effects on prestige since it is durable. Durability of investment in coaches and teams yields dynamic conjectural variations terms that describe the competitive interactions between rival athletic departments.

Optimization Problem and Solution Concept

Athletic departments pursue investment strategies in coaches and programs to maintain or upgrade their athletic prestige. For simplicity in demonstrating the rivalrous interactions that arise from this model, we consider athletic department investment in coaches and other athletic department staff only. The model generalizes to other types of investments such as facilities and program quality. Investment is durable implying that investment in coaches today has effects in current and future periods. The durability of investment is important since it creates intertemporal links between athletic departments' investment choices and other economic outcomes. Athletic department i is characterized by a stock of "prestige" at time t denoted G_{it}:

$$G_{it} = \delta G_{it-1} + A_{it} \tag{7}$$

where δ is the retention rate of athletic department prestige and Ait is athletic department i's investment in coaching staff in period t. This is analogous to the prestige variable that appears in the utility function above, Equation (1), with the added assumption that prestige depreciates by $(1-\delta)$ each period and is increased by Ait each period. Given this definition of prestige and explicitly considering rivals' actions, Equation (1) becomes:

$$U_{it} = U_{it}(S_{it}, G_t, R_{it}) = U_{it}[(S_{it}, G_t(S_t), R_{it}(Q_{it}, S_{it})] \tag{8}$$

where $G_t(S_t) = (G_{1t}(S_{1t}), \ldots, G_{it}(S_{it}), \ldots, G_{nt}(S_{nt}))$ is the vector of prestige stocks for *all* athletic departments in period t. Own and rival prestige stocks enter the athletic department's utility function formalizing the notion that athletes consider the reputation of an athletic department prior to signing a letter of intent to commit to the program. The presence of rival athletic departments' prestige stock in the utility function also captures rivalrous interaction among athletic departments in terms of nonprice competition for athletes.

[3]The model extension here is based on two models of dynamic nonprice competition developed by Friedman (1983) and Roberts and Samuelson (1988). Roberts and Samuelson (1988) extended the model developed by Friedman (1983) to produce a model of competition in the cigarette industry where advertising is the strategic nonprice variable. Advertising is the strategic variable in the cigarette industry and is treated as an investment that produces a stock of goodwill. The durability of advertising gives links to terms that are similar to conjectural variations. Ruseski (1998) adapted this model to the hospital industry where capital investment is the strategic nonprice variable. Consistent with Roberts and Samuelson (1988), the durability of investment generates terms that are similar to conjectural variations.

Given this set-up, the athletic department's strategy, denoted σ_i, is a sequence of coaching staff investments for each time period: $\sigma_i = (S_{i1}, S_{i2}, S_{i3}, ...)$ which contribute to the stock of prestige in each period. The athletic department's objective is to choose a sequence to maximize the present discounted value of its net utility stream, defined by a payoff function, $V_i(\sigma)$

$$V_i(\sigma) = \sum_{t=0}^{\infty} \beta_{it}(\Lambda_{it}) \tag{9}$$

where and β_{it} is the factor that athletic department i uses to discount period t net utility back to the present and (Λ_{it}) is the Lagrangian:

$$\Lambda_{it} = U_{it}[(S_{it}, G_t(S_t), R_{it}(Q_{it}, S_{it})] + \lambda[R_{it}(Q_{it}, S_{it}) - C(Q_{it}, S_{it})] \tag{10}$$

where the cost function, Equation (2) is now written as $C(Q_{it}, S_{it})$ and represents the period t costs associated with maintaining or increasing prestige. Choices about investment in coaches in each period must be optimal given the choices of other athletic departments.

Two types of Nash equilibria can exist in such models: an open-loop (or "naive") and a closed-loop (or "sophisticated") equilibrium. The "naive" equilibrium requires that a strategy consist of a sequence of actions that are optimal given the actions of other firms. This equilibrium is "naive" in that athletic department j's actions are taken as fixed in equilibrium; hence, athletic department i does not recognize any dependence among its current actions and rival athletic departments' future actions. In contrast, the "sophisticated" equilibrium requires that athletic department i recognizes that its period t actions affect athletic department j's period $t+1$ actions (because of the durability in investment in athletic department staff), and takes that dependence into account when choosing its strategy. An increase in investment today adds to the current prestige stock and the initial stock of prestige tomorrow. Therefore, an increase in the prestige stock in period t alters the initial conditions in period $t+1$ which, in turn, alters the equilibrium in period $t+1$.

The first order condition that must be satisfied in the open-loop (or "naive") equilibrium is:

$$\frac{\partial \Lambda_{it}}{\partial S_{it}} \equiv \frac{\partial U_{it}}{\partial S_{it}} + \frac{\partial U_{it}}{\partial G_{it}}\frac{\partial G_{it}}{\partial S_{it}} + \frac{\partial U_{it} \partial R_{it}}{\partial R_{it} \partial S_{it}} + \lambda\left(\frac{\partial R_{it}}{\partial S_{it}} - \frac{\partial C_{it}}{\partial S_{it}}\right) \leq 0 \tag{11}$$

Note that optimal investment choices do not depend on rivals' choices in this case. This equilibrium is a dynamic version of equilibrium in the "basic" model developed in the previous section. In the "sophisticated" equilibrium, athletic departments recognize that period t athletic staff investment choices may alter rivals' choices in period $t+1$. The choice rule adopted by each athletic department must be optimal given the choice rules of rival athletic departments, yielding the first-order condition:

$$\frac{\partial \Lambda_{it}}{\partial S_{it}} + \beta_{t+1} \sum_{j \neq i} \left[\left[\frac{\partial U_{it+1}}{\partial G_{jt+1}}\frac{\partial G_{jt+1}}{\partial S_{jt+1}}\right]\frac{\partial S_{jt+1}}{\partial S_{it}}\right] + R_i \leq 0 \tag{12}$$

where R_i collectively denotes the effects for periods after $t+1$ and $\frac{\partial S_{jt+1}}{\partial S_{it}}$ represents the "dynamic conjectural variation." If athletic department i is sophisticated, this dynamic conjectural variation represents its understanding that a change in its period t investment in staff will affect its rivals' optimal choices about staff in period $t+1$ and all future periods. If the athletic department is naive, it does not take these potential future rival responses into account.

Empirical Analysis

The theoretical model makes predictions about competitive behavior among intercollegiate athletic departments. It identifies two types of competitive behavior: in the “naive” equilibrium, the athletic department ignores the effects of its current actions on rivals’ optimal future actions, while in the “sophisticated” equilibrium, the athletic department recognizes and optimizes its choices against these responses. In the empirical analysis we hypothesize that athletic departments behave in a manner representative of the “sophisticated” equilibrium. To do this, we exploit the prediction from the theoretical model that the presence of nonzero dynamic conjectural variations identifies “sophisticated” behavior to investigate the basic question of interest: do athletic departments take rivals’ decisions into account when choosing a nonprice variable, in this context, investment in athletic department staff? In other words, do athletic departments make expenditure choices based on the choices of their rivals?

To test this hypothesis, we estimate a reduced form spatial econometric model using total athletic department expenditures, and expenditures on coaches salaries, as the dependent variables. We use a spatial econometric model because a spatial model with an autoregressive term can account for the endogenous expenditure decision of each athletic department, and the “sophisticated” equilibrium predicts that athletic department expenditure decisions are partially determined by the expenditure decisions of other athletic departments. Also, a spatial econometric model is general enough to capture forward-looking and backward-looking dynamic interaction that takes place over the sample period. It permits tests for dynamic strategic interaction without specifying a lag or lead structure in the empirical model.

Further, a single cross-sectional spatial autoregressive model can also be used to explore time-dependent decisions. LeSage and Pace (2010) observe “We can interpret the observed cross-sectional relation as the outcome or expectation of a long-run equilibrium or steady state . . . this provides a dynamic motivation for the data generating process of the cross-sectional [spatial autoregressive] model that serves as a workhorse of spatial regression modeling. That is, a cross-sectional [spatial autoregressive] model relation can arise from time-dependence of decisions by economic agents located at various points in space when decisions depend on those of neighbors.”

Data

Our data consist of a panel of athletic department revenue and expenditure data for 207 NCAA Division I public colleges and universities from 2006 to 2011. The data come from the USA TODAY College Athletics Finances website. Private schools, for example the University of Notre Dame, are not required to release revenue and expenditure reports publicly so they are excluded from the sample. Some states, notably Pennsylvania, also shield public schools from fully disclosing their athletic revenue and expenditure data so they are also excluded (e.g. Temple University). We also balance the panel by dropping all schools that did not participate in each year of the survey. Revenue and expenditure data are in constant 2011 dollars deflated by the CPI.

Revenue data are available for six categories: ticket sales, student fees, direct and indirect support from the university, contributions to the athletic department, broadcast rights and licensing, and other revenues. Direct and indirect institutional support includes state funds, tuition and tuition waivers, federal work study money paid to athletes, as well as university-provided support for activities like administrative costs, facilities and grounds maintenance, security, risk management, utilities, depreciation and service on debt. Contributions to the athletic department include money received directly from individuals, corporations, associations, foundations, clubs or other organizations earmarked for the operation of the athletic department. Contributions can include cash, marketable securities and in-kind contributions like dealer-provided cars, apparel and drink products for team and staff use and revenue from preferential seating at games. Total Revenue is the sum total of these six categories.

Expenditure data are available for four different categories of spending: scholarships, coaching staff salaries, building and grounds expenses, and other expenditures. Total expenditures are the sum total of these four expense types.

Table 1: Summary Statistics

	Mean	Std Dev
Total annual athletic department expenditure	27,854,934	25,530,202
Total annual expenditure on coaching salaries	9,400,233	8,679,285
Annual total revenues	28,826,909	27,405,051
Total annual contributions	5,277,483	8,336,436
Annual institutional support	4,881,249	4,533,105
Annual broadcast rights and licensing	5,804,822	9479,266
Observations	1242	

We utilize two different dependent variables in the empirical analysis: total athletic department expenditure and athletic department expenditure on coaching salaries. Non-price competition for athletes can take the form of hiring better coaches, which would increase total salary expenses, constructing and maintaining more lavish facilities, or possibly just spending more on the athletic department. These two outcome variables should reflect non-price competition, if it exists.

Summary statistics are shown on Table 1. Total annual expenditures are about \$27.8 million, and average revenues exceed this by a small amount. Coaching salaries make up about a third of total athletic department expenses. Contributions, institutional support, and broadcast rights fees make up roughly equal fractions of total revenues. The sample includes six years of data for 207 Division I public institutions. We report summary statistics for levels of all variables on Table 1, but in the empirical analysis below, we use logs of all variables so that the parameter estimates can be interpreted as elasticities.

Spatial Model Selection

We employ the testing procedure in Elhorst (2010) to determine whether spatial dependence is present in our data and which spatial econometric model is most appropriate for our analysis. The testing procedure developed in Elhorst (2010) evaluates model fit for five alternative econometric models: (1) OLS; (2) the spatial autoregressive model (SAR); (3) the spatial error model (SEM); (4) the spatial lag of X model (SLX); and (5) the spatial Durbin model (SDM). Note that models (2)-(5) are spatial models. A general form that nests each of these alternative models is

$$\begin{aligned} y &= \alpha + \rho W Y + X\beta + W X \Theta + \varepsilon \\ \varepsilon &= \lambda W \varepsilon + \mu \end{aligned} \tag{13}$$

where y is an $n \times 1$ vector of cross-sectional observations on the dependent variable; X is an $n \times m$ matrix of control variables weighted by the $m \times 1$ vector of coefficients, β, and ε is an $n \times 1$ vector of unobservable equation errors. W is an $n \times n$ spatial weight matrix that defines neighbor relationships in the data, ρ and λ are spatial scalar parameters, and Θ is a $k \times 1$ vector of coefficients on the spatially–weighted X variables (where k is the number of X variables).

In this empirical approach W, X, and y are specified exogenously and $\alpha, \beta, \rho, \Theta, \lambda$ and μ are determined endogenously. In the simplest case, if ρ, Θ, and λ are all zero, no significant spatial correlation is present and the best model fit would be OLS. Alternatively, the Elhorst procedure tests whether spatial dependence exists in the dependent variable (ρ), the independent variables (Θ), the error term (ε), or any combination of the three. Each of the following specific models (14) - (18) can be expressed through parameter restrictions on the general model in Equation (13):

$$\text{OLS} \qquad 0 = \rho = \Theta = \lambda \tag{14}$$

$$\text{SEM} \qquad 0 = \rho = \Theta \tag{15}$$

$$\text{SLX} \qquad 0 = \rho = \lambda \tag{16}$$

$$\text{SAR} \qquad 0 = \Theta = \lambda \tag{17}$$

$$\text{SDM} \qquad 0 = \lambda \tag{18}$$

Traditionally in spatial econometrics, a "neighbor" in the spatial weight matrix, W, is determined by a geographic proximity (i.e. border contiguity, distance between capitals, distance from population centers, etc.). In this context, we identify 'neighbors' by athletic conference membership (Big Ten Conference, Southeastern Conference, etc.). Every athletic department is considered a neighbor to every other athletic department in its own athletic conference.

We define neighbors in this manner because we hypothesize that athletic department expenditures are influenced by other conference members' athletic department expenditures, not expenditures of schools closest in proximity. Ohio State University's athletic department expenditures are influenced by the expenditures by the University of Michigan and Penn State University, not nearby Capital University or Columbus State Community College or the University of Pittsburgh.

In the 207×207 weight matrix W, conference members for each school receive a 1 and the remaining schools receive a zero. W is then "row-normalized" (LeSage and Pace, 2010) such that the sum of each row sums to one and all non-zero values within each row are equal. The row–normalizing of the spatial weight matrix also ensures that the bounds of the ρ parameter ensure that the variance–covariance matrix for the error term is positive–definite.

Given this definition of the spatial weights matrix W, we conduct Elhorst specification tests. Table 2 presents the LM model specification tests and the likelihood-ratio (LR) tests for various panel model specifications when the dependent variable is total athletic department expenditure. The first two tests, LM Lag and LM Error, test for the existence of spatial correlation in the dependent variable (H_0: the dependent variable does not exhibit spatial correlation) and the residual estimate of the error term (H_0: ε does not exhibit spatial correlation), respectively. If both null hypotheses are rejected, the second set of LM tests, LM Lag Robust and LM Error Robust, test for the existence of spatial correlation, similar to first stage tests, but account for the existence of spatial correlation in the alternative location (error term or dependent variable).

The LM Lag and LM Error tests suggest the existence of spatial correlation in the dependent variable and error term, respectively. Using the robust LM tests, a statistically significant coefficient on the LM Lag test indicates that a model incorporating a spatial autoregressive term is most appropriate.

LeSage and Pace (2010) explain that the SDM model, Equation (18), is the most likely model to produce unbiased estimates since it is actually a generalization of models Equation (14) through (17). The SAR model is nested within the SDM and the SDM includes spatially weighted independent variables which absorb much of spatial variation that may otherwise appear in the error term if using the SAR or SEM model. Additionally, LeSage and Pace (2010) note that the spatial Durbin model is preferred if: 1) there are omitted variables that are spatially correlated; and 2)

Table 2: Elhorst Spatial Panel Diagnostic Tests

	Total Expenditure		Coaching Expenditure	
Pooled OLS	Test Statistic	p-value	Test Statistic	p-value
LM Lag	525.7	< 0.001	470.9	< 0.001
LM Error	187.6	< 0.001	193.9	< 0.001
LM Lag Robust	349.2	< 0.001	288.2	< 0.001
LM Error Robust	6.7	0.0095	6.19	0.0128
Spatial FE	Test Statistic	p-value	Test Statistic	p-value
LM Lag	1643.7	< 0.001	1322.56	< 0.001
LM Error	1356.4	< 0.001	1070.20	< 0.001
LM Lag Robust	287.4	< 0.001	263.04	< 0.001
LM Error Robust	0.003	0.960	0.184	0.668
Time-Period FE	Test Statistic	p-value	Test Stat.	p-value
LM Lag	483.9	< 0.001	421.30	< 0.001
LM Error	120.5	< 0.001	120.84	< 0.001
LM Lag Robust	364.4	< 0.001	301.23	< 0.001
LM Error Robust	0.58	0.446	0.434	0.510
Space + Time FE	Test Statistic	p-value	Test Stat.	p-value
LM Lag	92.7	< 0.001	31.02	< 0.001
LM Error	100.3	< 0.001	30.71	< 0.001
LM Lag Robust	0.017	0.896	0.455	0.500
LM Error Robust	0.036	0.850	0.002	0.989
LR Test stat H_o: Spatial FE Jointly Insignificant: 3508 (P-value < 0.001)				
LR Test stat H_o: Time FE Jointly Insignificant: 1149 (P-value < 0.001)				

these omitted spatially correlated variables are correlated with an already included X. If these two conditions hold, then the spatial Durbin model is the most appropriate model. Therefore, based on the Elhorst specification test results, we selected the spatial Durban model (SDM) as the appropriate empirical model in this setting.

Two LR tests reject the joint insignificance of time fixed effects and spatial fixed effects, respectively. We include time fixed effects in our panel fixed effects model, but we do not include spatial fixed effects because, as discussed by Anselin and Arribas-Bel (2013), inclusion of spatial fixed effects in spatial panel models may spuriously remove spatial autocorrelation even if the true data generating process includes spatial autocorrelation. The panel fixed effects model estimated is

$$\begin{aligned} &Y_{it} = \rho W Y_{it} + \beta X_{it} + W X_{it}\Theta + \varepsilon_{it} \\ &\varepsilon \sim (0, \sigma^2). \end{aligned} \tag{19}$$

Again, we use two different dependent variables, Y_{it}, for each athletic department, i, in year, t, to explore various aspects of the arms race: total athletic department expenditures and athletic department expenditures on coaching and staff. We use three athletic department revenue sources as independent variables, comprising elements of the X_{it} matrix: contributions, institutional subsidies, and broadcast rights and licensing revenues. We assume that these revenue sources are exogenous, in that they cannot be directly determined by the athletic department. Contributions come from alumni and athletic department boosters, and depend on decisions made by these individuals and broader economic conditions. Institutional support comes from the central university campus and state government. While the athletic department may try to influence these revenue streams, individuals outside the athletic department determine their size. Most broadcast revenues come from the television rights deals negotiated by conferences for members of the conference. Licensing revenues depend on the decisions of consumers to purchase merchandize bearing the logo of the athletic department. Only local broadcast rights fees depend directly on the athletic department, and even these revenues reflect the size of the local media market and the existence of competing sports events in the local market.

We also include a time fixed effect, α_t, in the regression model to capture factors affecting all athletic departments in each year of the sample and an error term, ε_{it} to capture unobservable random factors affecting athletic department spending.

Spatial Regression Model and Results

The spatial econometric model addresses the endogeneity of Y_{it} by solving Equation (19) to generate a regression model

$$Y_{it} = A\left[\beta X_{it} + \Theta W X_{it} + \alpha_t + \varepsilon_{it}\right] \tag{20}$$

where

$$A = (I_n - \rho W)^{-1} \tag{21}$$

and n is the number of observations.

The regression results from a SDM can be decomposed and analyzed in terms of direct effects, indirect effects, and total effects. Direct effects represent the effect that a change in an explanatory variable has on its own school's athletic department expenditures; indirect effects represent the average "spillover" effects resulting from the spatial interconnectedness of athletic department expenditures, and total effects are the sum of the direct and indirect effects.

To obtain estimated direct, indirect, and total effects, $(I_n - \rho W)^{-1}$ is multiplied by $(I_n\beta + W\Theta)$ producing an $n \times n$ matrix of impacts for each independent variable. LeSage and Pace (2010) define the average of the sum of the diagonal elements of this matrix as the direct effect and the average of the sum of off-diagonal elements in each row as the indirect effect.

The spatial autoregressive coefficient, ρ captures arms race effects in this setting.[4] ρ is endogenously determined and bound such that $-1/\lambda_{\min} \leq \hat{\rho} \leq 1$, where λ_{min} is the smallest eigenvalue of the spatial weight matrix. A positive $\hat{\rho}$ indicates a positive relationship between athletic department expenditures among conference members. So, if the University of Tennessee (Southeastern Conference) increases their athletic department expenditures, we would expect an increase in athletic department expenditures by the University of Alabama, Louisiana State University, the University of Florida, and the other Southeastern Conference institutions. This is consistent with the "sophisticated" equilibrium in the dynamic non-price competition model.

In spatial econometric models, the reduced form of models like Equation (20) is $Y = (I_n - \rho W)^{-1}(X\beta + WX\Theta) + (I_n - \rho W)^{-1}\varepsilon$, and the partial derivatives are $(I_n - \rho W)^{-1}(I_n\beta + W\Theta)$ which is an $N \times N$ matrix of effects. The diagonal elements of this matrix are the direct effects which show how a change in a variable in X at location i affects the dependent variable at location i. The indirect effects, which are the off-diagonal elements of this matrix, show how a change in an explanatory variable at location j affects the dependent variable at location i. The total effects are the sum of the two. The indirect or "spillover" effects are cumulated over all neighbors (conference members) in the estimates.

Table 3 contains estimates of the direct, indirect, and total effects of changes in the explanatory variables on total athletic department expenditures and salary expenditures using a spatial Durbin model (SDM). All variables have been log transposed, so the direct and decomposed parameter estimates can be interpreted as elasticities. Again, these decomposed estimates have been averaged over all schools in all conferences in the sample. We do not report the direct results from estimation of Equation (20), with one exception. The parameter estimates from this equation are simply the values that maximize the likelihood function.

The only important parameter estimate from Equation (20) is the estimate of ρ, which captures spatial dependence in conference-wide athletic department spending. $\hat{\rho}$ is positive and statistically significant in both models. When the dependent variable is total athletic department expenditure, $\hat{\rho}$, which again captures the spatial (conference-wide) dispersion rate, was 0.311 and statistically significant. This estimate supports the "sophisticated equilibrium" and our hypothesis that athletic department expenditures are significantly influenced by the expenditure decisions made by other conference members. Increases in athletic department expenditures by one team in an athletic conference result in increases in athletic department expenditures by all other conference teams, holding factors like own revenues constant.

The estimated indirect ("spillover") elasticity on both contributions, 0.056, and broadcast rights revenues, 0.322, are positive and significant when the dependent variable is total expenditure. A 1% increase in contributions at a conference rival leads to a 0.056% increase in total athletic department expenditures at other universities in the conference. Since athletic department expenditures at a given university depends on expenditures by other conference members, donations at the University of Oregon athletic department, for example, will increase total athletic department expenditures at the University of Washington, the University of Arizona, and the other PAC-12 conference schools. Phil Knight's donations to the Oregon athletic department increases total athletic department expenditure at all other PAC-12 universities. The total effects - the sum of the direct and indirect

[4] In essence, ρ represents the parameterization of the dynamic conjectural variations term, $\frac{\partial S_{jt+1}}{\partial S_{it}}$, in Equation (12).

Table 3: Pooled SDM results

Variable	Direct Effect	t-stat	Indirect Effect	t-stat	Total Effect	t-stat
	Dependent Variable: Total Athletic Department Expenditure					
Contributions	0.056	10.64	0.009	0.805	0.066	5.42
Institutional support	-0.007	-2.89	-0.018	-2.94	-0.025	-3.99
Broadcast rights & licensing	0.322	28.81	0.117	7.01	0.440	28.19
$\hat{\rho}$					0.311	8.54
	Dependent Variable: Salary Expenditure					
Contributions	0.039	6.29	0.016	1.25	0.055	4.08
Institutional support	-0.009	-2.89	-0.017	-2.34	-0.026	-3.46
Broadcast rights & licensing	0.341	26.48	0.110	5.65	0.451	25.29
$\hat{\rho}$					0.289	7.72

effects - are also positive and significant.

Interestingly, Institutional Support, had a negative and significant athletic department direct expenditure elasticity of -0.007. Thus, the less financially sustainable or financially independent an athletic department, the smaller its expenditures. As athletic department expenditures grow, presumably from revenue sources such as broadcast rights, schools scale back their institutional support of intercollegiate athletics, suggesting that the central administration views revenues generated within the athletic department by athletic programs and support from central campus as substitutes.

Within a spatial framework, because of the positive relationship in within conference expenditures, it is not surprising that institutional support also has a negative and statistically significant spillover effect on both total expenditures, -0.035 estimated total elasticity, and on salary expenditures, -0.026 estimated total elasticity. An increase in an athletic department subsidy (presumably occurring due to a decrease in an alternative revenue source) at the University of North Carolina (UNC), for example, would result in fewer athletic department expenditures at UNC (direct effect) and fewer athletic department expenditures at other ACC schools competing with UNC (indirect effect). Thus, the total effect of athletic department subsidies is negative.

The estimates of the direct effect of broadcast rights fees and licensing revenues, contributions, and institutional support on total athletic department expenditure capture the "revenue theory of costs" explanation. The estimated direct elasticity of increases in both contributions and broadcast rights revenues are positive and statistically significant. The estimated direct elasticity of broadcast rights revenues is much larger than the other estimated elasticities. This strongly supports the "revenue theory of costs" in that athletic department expenditures increase when the universities' broadcast rights fee revenues increase.

We find very similar results when coaching staff expenditures is used as the dependent variable. Again, the results when the dependent variable is coaching expenditure support both the "revenue theory of costs" and the arms race explanations for observed athletic department expenditure. Total expenditure includes coaching salaries, recruiting expenditure, expenditure on teams that reflect the number and quantity of programs offered, and a number of other types of expenditure.

Table 4: Pooled SDM results - Random Conference Assignment

Variable	Direct Effect	t-stat	Indirect Effect	t-stat	Total Effect	t-stat
	Dependent Variable: Total Athletic Department Expenditure					
Contributions	0.042	10.39	0.013	1.43	0.055	5.88
Institutional support	-0.011	-5.44	0.022	4.50	0.011	2.11
Broadcast rights & licensing	0.430	61.47	-0.0002	-0.013	0.430	22.46
$\hat{\rho}$					-0.067	-1.28
	Dependent Variable: Salary Expenditure					
Contributions	0.031	6.77	0.007	0.651	0.038	3.36
Institutional support	-0.011	-4.91	0.025	4.24	0.013	2.18
Broadcast rights & licensing	0.444	53.20	0.023	1.11	0.467	20.87
$\hat{\rho}$					-0.038	-0.739

Falsification Test

The evidence supporting an athletic department arms race discussed above comes from the spatial structure of the spatial Durbin model, Equation (20). We impose spatial structure on the model by defining neighbors as other conference members. However, the strong positive direct effect of own broadcast rights revenues and own contributions, and other conference member revenues, on athletic department spending suggests that, to the extent that revenues have increased across all big-time athletic departments over time, the estimated spatial interaction simply reflects the effect of a "rising tide" on all boats.

To investigate the extent to which this "rising tide" effect drives the spatial dependence indicated by the positive and significant $\hat{\rho}$ reported above, we conducted a falsification test. We created an artificial spatial weights matrix based on random assignment of athletic departments into synthetic "conferences" containing 12 teams. By randomly assigning athletic departments to these conferences, we create a situation where, if the "rising tide" explanation is correct, we should still find evidence of spatial dependence in the expenditure data, simply because the direct effect of increasing revenues on own expenditures dwarfs any strategic interaction.

Table 4 shows the results of this falsification test. $\hat{\rho}$ is not statistically different from zero in either model specification, suggesting that there is no evidence of spatial dependence in athletic department expenditure when athletic departments are randomly assigned as neighbors. The direct effects of increases in revenues on athletic department expenditure are unchanged from those on Table 3, which again supports the "revenue theory of costs." The estimated indirect effect of contributions and broadcast rights revenues are also statistically insignificant, indicating that no detectable strategic interaction takes place in these randomly created conferences. The only significant indirect effect is on institutional support. This parameter estimate supports the idea that the central administration at all universities in the sample view athletic department generated revenue and institutional subsidies as substitutes. The estimated indirect elasticity is positive, so when other universities reduce institutional subsidies because of growing broadcast revenues, the central administration at the current university takes the same action.

The falsification test supports the idea that both the "revenue theory of costs" and the athletic arms race model explain observed increases in athletic department expenditures over this period. Increases in own revenues increase expenditures, but the lack of spatial dependence and "spillover" effects in the randomly assigned synthetic conferences suggests that the spatial dependence in actual conferences represents dynamic strategic nonprice competition among conference members, an athletic arms race.

Conclusions

We perform a theoretical and empirical analysis of athletic department expenditure at big-time college athletic programs in terms of two competing theories: the "arms race" model and the "revenue theory of cost" model. The "arms race" model of nonprice competition emphasizes that investment, in the form of athletic department expenditures on coaches' salaries and total expenditures generates prestige and also leads to strategic interaction that can be interpreted as an "arms race" in which the spending by one athletic department influences decisions made by other rival athletic departments in the conference. The "revenue theory of costs" emphasizes the non-profit nature of athletic departments and reflects the notion that decision makers in athletic departments set spending to equal revenues, which have risen significantly over the last three decades. The empirical analysis accounts for spatial autocorrelation, where neighbors are defined as institutions in the same conference. The results support the idea that universities take their conference rivals' behavior into account suggesting that the competitive behavior among rival institutions is sophisticated and evidence of an athletics arms race exists. We also find evidence of "spillover" effects that suggest increases in contributions and broadcast rights revenues at one school in a conference are associated with higher total athletic department expenditure and salaries by conference members. The results are also consistent with the "revenue theory of costs" in that own revenue increases are strongly associated with increases in total expenditure and investment in coach salaries.

In general, the results suggest inter-related expenditure decisions among conference members in Division I sports. The competition among Division I conference members extends beyond the playing field. Expenditure by athletic departments does not depend solely on factors in that department or at each university. Instead, athletic department expenditure at individual universities depends on decisions made by other athletic departments in the conference. If athletic department expenditure on salaries did not affect decisions made at other universities, then Alabama's decision to pay head football coach Nick Saban $7 million per year could be viewed as a (possibly poor) choice that affects only the University of Alabama, its students, employees and fans. But the evidence generated here suggests that Alabama's decision to pay Saban this salary will ultimately increase spending on salaries and total athletic spending at all other universities in the SEC. Decisions about athletic spending at one university can lead to changes at other universities, providing evidence that an "arms race" takes place in intercollegiate athletics. The "revenue theory of costs" cannot explain all of the observed athletic department expenditure at big-time athletic programs.

The results have important implications for NCAA-related economic policy. The NCAA currently faces legal challenges to its cartel behavior in terms of permitting athletes to receive only tuition, room, and board (a "grant-in-aid") as compensation for providing athletic services to athletic departments. The basic model predicts that NCAA overinvests in both program quality/quantity and coaching staff, even when the breakeven constraint is binding. The model of dynamic nonprice competition predicts that expenditure on programs and coaching staff could increase even more because of this dynamic strategic interaction. The empirical analysis supports both of these predictions. The NCAA has argued that athletic departments cannot compensate athletes beyond the standard grant-in-aid because it would be prohibitively expensive. However, if athletic departments overinvest in coaching staff and program quality/quantity, then resources for compensating athletes could be freed up if athletic departments only invested in coaching salaries and program quality/quantity up to the efficient level, where marginal cost equals marginal revenue.

Finally, the paper makes an important methodological contribution. We analyze the dynamic strategic interaction among teams in intercollegiate athletic conferences using a spatial econometric model, and our results support the presence of dynamic strategic interaction in this setting. To our knowledge, this is the first research to use spatial econometric models to analyze competition among sports teams or athletic programs. Strategic interaction takes place in a wide variety of settings in sport, including in professional sports leagues around the world. This spatial econometric approach could be clearly applied in a number of other settings in sport.

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