Of Bricks and Bats: New Stadiums, Talent Supply and Team Performance in Major League Baseball

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Abstract

This paper considers whether publicly-financed new facility investments encourage professional sports team owners to increase their investments in costly talent. We develop a model of a sports league that incorporates publicly-financed facility investments, the unique characteristics of the talent market, and revenue sharing to explore the complementarity between new facility amenities, the team budget decision and team performance. Our empirical results suggest that publicly-financed new stadiums do little to improve team performance, not due to restrictions in the talent market, but rather due to a lack of fan response. (JEL: Z21, L88)

Keywords

New stadiums, talent supply, baseball, winning percentage

Introduction

Many professional sports teams in North America have been the recipients of new playing venues in the last 25 years. A total of 21 Major League Baseball (MLB) have moved into new or extensively renovated facilities since 1990; 23 teams in the National Hockey League (NHL), 21 teams in the National Basketball Association (NBA) and 12 teams in the National Football League (NFL) have done the same.[1] These venues were constructed at significant costs, averaging \$533.5 million in MLB in 2011 dollars[2], \$594.4 million in the NFL, \$379.5 million in the NBA and \$358.3 million in the NHL. The majority of these new venues required significant public financing by city and state governments – typically a bond issue that is retired by imposing sales and entertainment taxes. A large literature has developed that assesses the net benefit of new sports venues by estimating increases in employment and income that would not have occurred without the new construction. A sampling of these studies all agree that there are no net benefits, with good surveys in Noll and Zimbalist (1997), Owen (2003), Coates (2007) and Coates and Humphreys (2008). More recent studies reach the same conclusion, including Harger, Humphreys and Ross (2016) and Huang and Humphreys (2014). Humphreys and Zhou (2015) develop a spatial model of urban service consumption and production that suggests that a new sports facility could increase consumption benefits and local property values if the new facility is not too close to an already existing "consumption center" (the so-called agglomeration effect). This could provide a partial justification for a government subsidy for construction. However the concept is not subject to empirical measurement.

Even if the economic benefits strictly calculated are trivial, since we have observed a great deal of new stadium construction, it is reasonable to speculate that a new sports venue may improve team performance and generate psychic benefits that are difficult to measure and are generally excluded from net benefit calculations. These local psychic benefits include the satisfaction of hosting a successful team on the field, even if one never attends a game.[3] The empirical evidence of psychic benefits is mixed and inconclusive and since the studies are highly specific to each stadium project and use different methodologies, the results provide few generalizations. A good survey is Walker and Mondello (2007). It may be the case that the psychic benefits are large and outweigh any economic loss. If so, one has a justification to provide public financing for a new sports venue, although there may be other concerns.[4] Coffin (1996) found that a new stadium significantly increased attendance for several seasons due to its "novelty effect". Clapp and Hakes (2005) used a more extensive dataset covering the 1950 – 2002 seasons in MLB and found a significant novelty effect for only two seasons following new stadium construction for multipurpose stadiums built up to 1974. The novelty effect increased to six to ten seasons for more recent stadiums. Coates and Humphreys (2005) found a significant novelty effect for eight seasons in baseball and nine seasons in basketball over the 1969 – 2001 seasons, but no novelty effect in football. The evidence is mixed across sports and venues, but is suggestive that there are some psychic benefits to new construction and the post construction behavior of the team.

If there are psychic benefits over and above the purported but small economic benefits, then the team's performance should be a driving force in generating these less traditional benefits. Increases in team payrolls should give a clue, however casual observations of changes in team payrolls after moving into a new facility do not show much consistency and offer no clear answers. Team payrolls increased by an average of 16.7% for MLB teams in their first season in the new venue, but did not increase at all in the second season, and in many cases, fell back to their pre-venue values in the third season. Table 1 summarizes the response of team payrolls for

MLB, NBA, NFL and NHL. The empirical puzzle is compounded by the lack of formal models characterizing team owner's optimizing decisions after moving to a new venue.

In this paper, we build a model of a professional sports team's owner decides whether moving to a new facility will improve the team's performance on the field. This leads to two questions: The first is whether a facility investment can increase the profitability of hiring more expensive talent; and the second is whether the owner is able do so. Whether profitability increases can be answered by determining the marginal revenue product schedule and whether it increases with a new facility. Whether the owner is able to acquire additional talent is more subtle. It requires (i) introducing a talent supply schedule into the model and (ii) recognizing that owners have other investment opportunities even if increases in revenue occur.

Our model answers the two questions by incorporating a number of innovations into the standard profit-maximizing model of a professional sports team. First, we assume that the team owner maximizes profit by selecting a talent *budget* rather than an unobservable stock of team talent. As we will show, this is an important feature as it "monetizes" the talent decision and allows for the tightness of the talent market to enter the model. Second, we assume that fans consume amenities that are "produced" by the facility. The decision to invest in a new facility, or significantly renovate an existing facility, affects the consumption of these amenities in a simple way. However other inputs also enter the production of facility amenities that are specific to each market. This new approach permits us to estimate the marginal effect of a new stadium on the winning percentage of the local team. Importantly it also allows us to estimate the elasticity of the supply of league talent even in the absence of a concrete measure of talent itself.

Background

Professional sports teams can be thought of as hiring a number of inputs that generate gate revenue. We will restrict our choices of inputs to just two: performance on the field and facility amenities. Amenities might include good sight lines to the field, comfortable seats, high-quality food and drink, large replay and information screens, clean restrooms and all the other features that make attending a game an enjoyable experience beyond the quality of the talent on the team. Each input is a measure of quality that shifts the demand curve for tickets and increases the maximum ticket price that consumers are willing to pay. If team quality and facility amenities are complimentary inputs, an increase in one input will increase the marginal revenue product (MRP) of the other. A new state of the art facility would then increase the MRP of team talent and perhaps encourage an owner to acquire more talent. Complementarity of these inputs is an important policy issue. If spectators and the city's consumers (taxpayers) as a whole receive large psychic benefits from a successful team that wins championships, one could conceivably argue that a public investment in a new or renovated facility is in the public interest

A small literature exists that has addressed the question of complementarity between team performance and a new facility investment. Quinn et al. (2003) developed a theoretical model of a professional sports team that invests in talent and a new facility. Facility investment serves to increase the MRP of team talent and the authors derive a set of necessary conditions for complementarity to hold. The model was tested by employing two time-series regression models that explained how winning percentages changed after the move to a new facility. The sample period included the 1982-96 MBL, NBA, NFL and NHL seasons. The empirical results suggested that MLB clubs displayed a significant improvement in their winning percentages with the opening of a new facility, but this was not the case in the NBA, NFL or NHL. Clapp and Hakes (2005) found that a new facility investment had no significant effect on attendance for MLB clubs for the sample period 1950-2002. This was determined by estimating a log-linear attendance function with team performance, facility investment and an interaction term between team performance and facility investment, as well as other demographic and economic variables.

Our purpose in this paper is to develop a model of complementarity between team talent and facility investment that employs a different approach from Quinn et al. (2003) and Clapp and Hakes (2005). Specifically we consider the extent of the shift in the marginal revenue product of the team budget (that is spent on talent) as the measure of complementarity, not the equilibrium performance of the team which is the outcome of the interaction between talent demand, talent supply and the owner's desire to pursue other investments. Whether winning percentage (Quinn et al. (2003)) or attendance (Clapp and Hakes (2005)) is employed as the measure of complementarity, both are the result of an *equilibrium* outcome in the sports league model rather than suggesting simply a shift in the value of the marginal product of talent. Our approach highlights this distinction both theoretically and empirically. If talent supply is infinitely elastic, winning percentage or attendance could be appropriate measures to indicate *indirectly* a shift in the MRP of the team budget with a new facility investment. However, if talent supply is constrained in any of a number of ways, team performance may show little improvement from a new facility investment even though complementarity exists. Our approach explicitly incorporates the elasticity of the supply of talent and the market rate of return to alternative investments. A team owner, who receives greater revenues after moving into a new facility, may choose to invest the revenue elsewhere if the rate of return is favorable.

A Model of the Club Owner's Decision

Amenities, Budgets and the Market for Talent

Consider a team (indexed by i) that produces two outputs, team performance measured by winning percentage w_i ($0 \leq w_i \leq 1$) and facility amenities measured by $A_i \geq 0$. The team winning percentage is a non-linear function of the team stock of talent t_i given by $w_i = w_i(t_i, t_k)$ where t_k is the talent stock of any one of the other n-1 teams in the league. This function has the properties $\partial w_i / \partial t_i \geq 0$ and $\partial^2 w_i / \partial t_i^2 \leq 0$. An increase in the winning percentage of team i is assumed to reduce the winning percentages of all the other teams equally, so $\partial w_k / \partial t_i \leq 0$. With n teams in the league, we also impose an adding-up constraint that is $\sum_{i=1}^{n} w_i = n/2$ that formally links the winning percentage of each team to all of the other teams winning percentages.[5]

Facility amenities include any facility-specific outputs that increase the utility of a fan in attendance. These could include outputs that are more or less fixed, such as comfortable seats, good sight lines, large video screens, convenient parking and so forth, as well as outputs that are variable, such as food and drink service, clean restrooms, helpful ushers, agreeable music etc..

These amenities are produced according to the production function $A_i = \pi L_i K_i(I_i)$. Periodic investments (I_i) may be necessary to maintain the stock of facility capital (K_i) that could include minor and major renovations or a new facility altogether. The current stock of facility capital is given by $K_{it} = (1 - \tau)K_{i,t-1} + I_{i,t-1}$. The variable inputs that produce facility amenities are captured by L_i since we assume that these are proportional to the stock of labour that is used in the facility. We assume that the wage rate per unit of talent in each local market is exogenous and given by W_i. The quality of the facility is measured by π, a sort of productivity measure that shifts the production function of amenities. Old and new facilities might use the same stock of capital, measured at market prices, but new facilities might be better suited to producing the amenities valued by consumers (HD video screens, luxury suites and so on). For now we assume that π is identical for every facility.

The club owner is assumed to provide a budget of money B_i to purchase the highest amount of talent possible[6]. The best response of the owner of team k to an increase in the owner of team i's budget spending could be interpreted as a strategic rivalry response. If other owners respond, the total league budget B will change by an amount than differs from the increase in the budget spending of team i alone. This is formally captured by the derivative $\partial B/\partial B_i = 1 + \sum_{j \neq i}^{n} \partial B_k/\partial B_i$. We eliminate rivalries by imposing the Cournot-Nash conjecture $\partial B_k/\partial B_i = 0$ for any combination of team's i and k.[7]

We assume that each owner is equally adept at evaluating talent but that each is limited in acquiring talent by its scarcity. The budget for team *i* is transformed into its stock of talent according to the function below.

$$t_i = \frac{B_i}{\left(\sum_{i=1}^{n} B_i\right)^{\omega}} = \frac{B_i}{B^{\omega}} \tag{1}$$

The league supply of talent is 'closed' when $\omega = 1$. This is shown by aggregating to find the total league stock of talent. $T = \sum_{i=1}^{n} t_i = \sum_{i=1}^{n} B_i / B^{\omega} = B/B^{\omega} = B^{1-\omega}$. The average wage per unit of talent, Z, is related to both the league budget and the structure of the industry through ω: $Z = B/T = B/B^{1-\omega} = B^{\omega}$. Substituting $B = ZT$ into $T = B^{1-\omega}$ and taking logs, allows us to define the elasticity of talent supply as

$$\varepsilon_Z^T = \frac{dlnT}{dlnZ} = \frac{1-\omega}{\omega} \tag{2}$$

In the closed talent case, each team can only bid away talent from another team by increasing its budget as a share of the total league budget. In this case in which T is the total stock of league talent, $\partial T/\partial t_i = 0$ as $T = 1$, a constant and $\varepsilon_Z^T = 0$. In contrast, if the league supply of talent is 'open' (competitive), then $\omega = 0$, $T = B$ and $\varepsilon_Z^T = \infty$. In this case, the league stock of talent can increase as much as team budgets will allow since talent is available in infinitely elastic supply and $\partial T/\partial t_i = 1$.[8]

An individual owner's ability to acquire talent, ∂t_i for a given budget increase, ∂B_i, is greater in the case of a open talent market than an closed one. It is not difficult to show that $\partial t_i/\partial B_i = (1-\omega\sigma_i)/B^{\omega}$ where σ_i is the share of team i's budget in the league budget: $\sigma_i = B_i/B$. A team owner can purchase more talent from an increase in the budget with an open talent market since $\partial t_i/\partial B_i = 1$ but is $\partial t_i/\partial B_i = (1-\sigma_i)/B < 1$ in the closed talent market since we assume that B is scaled to a number at least as large as unity.

The responsiveness of the league stock of talent to an increase in team i's budget is measured by the elasticity $\varepsilon_{B_i}^{T}$ and is a function of ω and the share of team i's budget in the total league budget (σ_i).

$$\varepsilon_{B_i}^{T} = \frac{B_i}{T}\frac{\partial T}{\partial B_i} = \frac{B_i}{T}(1-\omega)B^{-\omega}\frac{\partial B}{\partial B_i} = \frac{B_i}{B^{1-\omega}}(1-\omega)B^{-\omega} = (1-\omega)\sigma_i \quad (3)$$

In the closed talent case ($\omega = 1$), $\varepsilon_{B_i}^{T} = 0$ while in the open market case ($\omega = 0$), $\varepsilon_{B_i}^{T} = \sigma_i$ and is higher for teams that compose a larger share of the total league budget. We discuss intermediate values of ω below.

The market wage rate per unit of talent is given by Z and is identical for each unit of talent acquired. A player's salary is then just his own inherent stock of talent multiplied by *Z*. The average market wage rate is determined by $Z = B/T$. In the open talent market, we have shown that $T = B$ so $Z = 1$ and is constant regardless of the size of the league stock of talent. In the closed talent market, we have shown that $T = 1$ so $Z = B$. Any increase in the league budget simply drives up the market wage in the aggregate. The resulting increase in talent from a one dollar increase in the budget is smaller for team *i* in a closed market than in the open market in which the market wage is left unaffected by the efforts of team *i* to acquire talent. What will be the resulting increase in the market wage in the general case? We can find the elasticity of the market wage with respect to the budget of team *i* by utilizing the conditions that $Z = B/T$ and $T = B^{1-\omega}$.

$$\varepsilon_{B_i}^{Z} = \frac{\partial Z}{\partial B_i}\frac{B_i}{Z} = \frac{T - B(1-\omega)B^{-\omega}}{T^2}\frac{B_i}{Z} = \frac{T-(1-\omega)B^{1-\omega}}{T^2}\frac{B_i}{Z} = \frac{\omega B^{1-\omega}}{B^{2(1-\omega)}}\frac{B_i}{Z} = \frac{\omega\sigma_i}{B^{-\omega}Z} = \omega\sigma_i \qquad (4)$$

The elasticities in (3) and (4) give us a good picture of the talent market in our model. In the closed talent market, any attempt to acquire talent by increasing the team budget has no effect on the total stock of talent and the higher market wage rate increases the share of the team budget in the total league budget. Large market teams drive up the wage rate by more than small market teams in a closed talent market. In the open talent market, the stock of talent of the team increases by the budget share and the market wage rate does not increase at all. The novelty of (3) and (4) is that talent markets that fall between these two extremes are possible and even probable. The model allows for intermediate talent market constraints.[9]

Profit-Maximization with a Budget

The local revenue for team *i* includes gate revenue from ticket sales, concession and parking revenue, local media revenue (radio and TV) and other sources of revenue. We choose to focus exclusively on gate revenue so that we can specify an inverse demand function that determines a unique ticket price. Including all sources of local revenue makes it difficult to specify a demand function for a unique product. Local revenue, R_i, is the product of the average ticket price and the quantity of tickets sold for the regular season and is given by

$$R_i = P_i Q_i = P_i\left(\delta w_i^{\gamma} A_i^{\theta} P_i^{-\rho}\right) = \delta w_i^{\gamma} A_i^{\theta} P_i^{1-\rho} \tag{5}$$

The team winning percentage w_i and arena amenities A_i serve to shift the demand function for tickets according to their elasticities γ and θ. For simplicity, we assume for now that all teams share the same values of γ and θ. The price elasticity of demand is given by ρ while the term δ captures demographic characteristics. We model demographic characteristics in this way for simplicity rather than include a variety of demographic variables in (5). We also assume that all ticket costs are fixed and known at the start of a season and are equal to F_i. In the long run, investment affects the number of tickets too, as per the size of the stadium.

To motivate the public policy discussion, we assume that the team owner receives an amount of facility investment exogenously from a government. The amount of facility investment is not a choice variable for the team owner, although the owner may expend resources in lobbying for it.

We do not explicitly model the lobbying decision. Bodvarsson and Humphreys (2013) point out that facility investments are almost always financed by some level of government with little team participation. They then go on to model the level of facility investment by government as a positive function of team performance (winning percentage) on the argument that local governments are more willing to finance new constructions for winning teams. This is an intriguing and novel idea in a sports model, however we can cite many counterexamples of teams that have performed poorly for many seasons and still were rewarded with new facilities.[10]

We adopt the pooled revenue sharing system used in the NFL and MLB where each club contributes a share 1-α of their local revenue to a central league pool that is split evenly among all clubs at the end of the season.[11] Under the pooled revenue sharing system, revenue after revenue sharing, R_i^A for team i is given by

$$R_i^A = \alpha R_i + \frac{(1-\alpha)\left(\sum_{i=1}^{n} R_i\right)}{n} = \frac{\left((n-1)\alpha+1\right)}{n} R_i + \frac{(1-\alpha)\sum_{k\neq i}^{n} R_k}{n} \qquad (6)$$

where the first term reflects the revenue share received by the team directly, and the second, the return from the central pool.

The owner maximizes team profit by choosing the team budget B_i and stadium labour input L_i subject to equations (1) and (5). The amounts spent on team talent and facility labour are assumed to be independent. While not borrowing the funds needed for the team budget, the owner faces the opportunity cost of using the budget to purchase talent rather than some other investment that pays a market rate of return equal to *r*.

$$MAX\ \pi_i = R_i - B_i = \frac{((n-1)\alpha+1)}{n} R_i + \frac{(1-\alpha)\sum_{k\neq i}^{n} R_k}{n} - W_i L_i - (1+r)B_i - F_i \tag{7}$$

The Case of No Revenue Sharing

Revenue sharing is an important feature of our model as it will impact the owner's talent decision when facility investment is increased. For now we proceed without revenue sharing to more easily characterize and highlight some of the fundamental results generated by our model. . Setting $\alpha = 1$ and maximizing (6) with respect to L_i gives the first-order condition below.

$$\frac{\partial R_i}{\partial L_i} = \delta w_i^{\gamma} P_i^{1-\rho} \theta (\pi L_i K_i)^{\theta-1} \pi K_i - W_i = 0 \tag{8}$$

To insure a diminishing marginal revenue product of labour, we impose $\theta < 1$. The solution for L_i can be found easily.

$$L_i^* = (\pi K_i)^{-1} \left(\frac{W}{\delta\theta w_i^{\gamma} P_i^{1-\rho} \pi K_i}\right)^{\frac{1}{\theta-1}} = (\pi K_i)^{-1} \left(\frac{\delta\theta w_i^{\gamma} P_i^{1-\rho} \pi K_i}{W}\right)^{1-\theta} \tag{9}$$

All of the variables that contribute positively to the value of the marginal product of labour increase the optimal amount of labour to hire (w_i, P_i, π, K_i). The local wage rate reduces the optimal amount to hire. Substituting (9) into the function for facility amenities results in the optimized amenity function.

$$A_i^* = \left(\frac{\delta\theta w_i^{\gamma} P_i^{1-\rho} \pi K_i}{W}\right)^{1-\theta} \tag{10}$$

The team owner also maximizes (7) with respect to the team budget, giving the first-order condition below.

$$\frac{\partial R_i}{\partial B_i} = \delta\theta\gamma {w_i}^{\gamma-1} \left(\frac{\partial w_i}{\partial t_i}\frac{\partial t_i}{\partial B_i}\right) A_i^{\theta} P_i^{1-\rho} - (1+r) = 0$$

$$= \delta\theta\gamma w_i^{\gamma-1} \left(\frac{\partial w_i}{\partial t_i}\frac{1-\omega\sigma_i}{Z}\right) A_i^{*\theta} P_i^{1-\rho} - (1+r) = 0 \tag{11}$$

The first term in (11) is the marginal revenue product (MRP) of the team budget. We assume diminishing returns in revenue with the winning percentage so that < 1 . A larger market size (δ), ticket price (P), flow of facility amenities (A*), and a larger revenue elasticity with respect to the production of facility amenities (θ) shifts the MRP schedule to the right.

The owner maximizes profit according to (7) when an additional dollar spent on talent (the team budget) that foregoes an investment yielding the market rate of return just equals the increase in revenue generated by the additional wins from that talent increase. This yields the optimal budget is B_i*. An increase in the real market rate of return to *r'* reduces the optimal budget. The resulting stock of talent is determined by (1) that then determines an optimal winning percentage through an unspecified contest success function. Revenue and profit is then found through (5) and (7).[12] The tighter the talent market, the smaller the optimal budget since the budget will just drive up the market wage *Z* with little result on team performance and profit.

Complementarity Between Stadium Investment and Talent

Solving for the optimal team budget from (11) is difficult and not necessary for our purposes. The important point is that (11) determines an optimal B_i^* that can then be used to determine an optimal t_i^* and w_i^* using (1). These reduced form solutions incorporate the tightness of the talent market through the value of ω which is our (exogenous) characterization of the labor market. When a team owner receives a large new facility investment from a local government, his or her behavior regarding the team budget for talent is constrained by the tightness of the talent market. If ω is close or equal to one, and/or the team accounts for a significant share of the total league budget, then $\varepsilon_{B_i}^Z$ from (4) is large it could be optimal for the team owner to forego attempting to acquire expensive talent so as to avoid simply driving up the market wage W.

Differentiating the MRP with respect to $I_{i,t-1}$ provides the complementarity effect (if positive) of a new facility investment on the team budget.

$$\frac{\partial MRP}{\partial I_{i,t-1}} = \frac{P_i^{1-\rho}\delta\theta^2(1-\theta)\gamma w_i^{\gamma-1}}{K_i}\left(\frac{\partial w_i}{\partial t_i}\frac{1-\omega\sigma_i}{Z}\right)A_i^{*\frac{\theta}{1-\theta}} > 0 \qquad (12)$$

The interesting feature for our purposes is the scalar effect of the tightness of the talent market on the extent of complementarity. This is captured by the term $(1-\omega\sigma_i)/Z$. The complementarity effect is the largest when $\omega = 0$, an open talent market, since all of the increased budget spending is used to acquire physical talent with no increase in the market wage Z. As the talent market tightens, the complementarity effect is reduced. This can lead to the perverse case of a completely closed talent market ($\omega = 1$) and a very large budget team (σ_i approaches one). The derivative in (12) approaches zero and the team owner will not be able to acquire any new talent, since he or she already owns all of it. The upshot is that any model that involves the marginal revenue product requires a characterization of labor market tightness and the team's share of the league budget. This has clear implications for any econometric specification.

Other scalar effects in (12) are worth noting. If a team is already a very good team on the field, then $\partial w_i/\partial t_i$ will be small, reducing complementarity. Perennial powerhouse teams might have little incentive to invest in new talent when a large new facility investment is provided. This suggests that an interaction term that includes the past winning percentage and a new facility investment should be part of a regression model. Complementarity is smaller when K_i is large. This can be interpreted to be the new facility investment relative to the stock of capital that already exists. Moving from a relatively new stadium to a brand new stadium will have little effect on the team owner's decision to increase the team budget. A regression model could include the increase in the market value of significant renovations or when moving from one stadium to another, instead of just using a dummy variable for a new stadium. A dummy variable reveals nothing about the magnitude of the flow of new facility investment.

The More Complex Environment of Revenue Sharing

All four major North American professional sports leagues utilize revenue sharing. The revenue sharing systems vary markedly, but they all require revenue contributions to a central fund.[13] With revenue sharing ($0 < \alpha < 1$), the optimal team stock of facility labor is given by

$$L_i^* = (\pi_i K_i)^{-1} \left(\frac{\left(\frac{((n-1)\alpha+1)}{n}\right) \delta\theta w_i^{\gamma} P_i^{1-\rho} \pi K_i}{W} \right)^{1-\theta} \tag{13}$$

The optimal stock of labour used to produce facility amenities decreases with revenue sharing and the number of teams in the league. The optimized flow of facility amenities is given by

$$A_i^* = \left(\frac{\left(\frac{((n-1)\alpha+1)}{n}\right) \delta\theta w_i^{\gamma} P_i^{1-\rho} \pi K_i}{W} \right)^{1-\theta} \tag{14}$$

The production of facility amenities is reduced because the revenue generated must be shared with all of the other teams in the league.

Maximizing (7) with respect to the team budget results in the first-order condition below.

$$\frac{\partial \pi_i}{\partial B_i} = \frac{\partial t_i}{\partial B_i}\left[\left(\frac{((n-1)\alpha+1)}{n}\right)\frac{\partial R_i}{\partial w_i}\frac{\partial w_i}{\partial t_i} + (1-\alpha)\sum_{k\neq i}^{n}\frac{\partial R_k}{\partial w_k}\left(\frac{\partial w_k}{\partial t_i} + \frac{\partial w_k}{\partial t_k}\frac{\partial t_k}{\partial t_i}\right)\right] - (1+r) = 0 \qquad (15)$$

The large bracketed term in (15) is the MRP of the team budget and can be divided into the direct and indirect effects noted by Fort and Quirk (2007), but in this case it is in the context of the team budget. The first term inside the bracket is the direct effect on the revenue of team *i* when it increases its budget by one dollar and is dependent on the talent market openness according to the value of the first term $\partial t_i/\partial B_i$: the change in the budget affects the quantity of talent, talent changes wins, and wins change revenue. The summation term is the indirect effect that is itself the sum of two effects. First, the acquisition of talent by team *i* will have a negative effect on the winning percentage and revenue of team *k* holding constant the talent stock of team *k*. Added to that is a second potential negative effect if team *i* can only acquire its talent by poaching talent from team *k* depending on the talent market condition $\partial t_k/\partial t_i$. The $\partial t_k/\partial t_i$term is determined by how constrained the talent market is although its value is not obvious if $0 < \omega < 1$. At $\omega = 0$ then, $\partial t_k/\partial t_i = 0$, and when $\omega = 0$, $\partial t_k/\partial t_i = -1$.

Substituting the necessary derivatives into (15) gives the MRP of the budget as a function of the underlying market for talent.

$$MRP_i = \frac{1-\sigma_i\omega}{Z}\left[\left(\frac{((n-1)\alpha+1)}{n}\right)\frac{\gamma R_i}{w_i}\frac{\partial w_i}{\partial t_i} - (1-\alpha)\sum_{k\neq i}^{n}\frac{\gamma R_k}{w_k}\left(\left|\frac{\partial w_k}{\partial t_i}\right| + \frac{\partial w_k}{\partial t_k}\left|\frac{\partial t_k}{\partial t_i}\right|\right)\right] \tag{16}$$

Complementarity Between Stadium Investment and Talent

With revenue sharing the equivalent first order condition in (12) is given by

$$\frac{\partial MRP}{\partial I_{i,t-1}} = \left(\frac{((n-1)\alpha+1)}{n}\right)\frac{P_i^{1-\rho}\delta\theta^2(1-\theta)\gamma w_i^{\gamma-1}}{K_i}\left(\frac{\partial w_i}{\partial t_i}\frac{1-\omega\sigma_i}{Z}\right)A_i^{*\frac{\theta}{1-\theta}} > 0 \tag{17}$$

The effects of revenue sharing and labour market tightness on the extent of complementarity can be deduced from (17). More extensive revenue sharing reduces α, thereby reducing φ and the return to the team budget from a higher A_i. The increased revenues from investing in more talent and improving the team must be shared to a greater extent with the rest of the league, reducing the incentive to acquire talent and to improve the teams winning percentage. If the team is required to contribute a significant proportion of the new facility financing, insofar as it is sharing with the rest of the league, it may decide not to invest (although self-finance is not a feature of our model in (7)) and continue to operate in an aging facility with a losing team.

Talent market tightness is reflected in a value for ω that is closer to one and reduces the complementarity between the facility amenities and the team budget in (17). The magnitude of the disincentive effect depends upon the share of the team budget in the total league budget given by σ_i. High budget teams that face a tighter labour market will experience smaller positive complementarity. This is due to the increase in the market wage Z that results from an increase in the team talent stock. For large spenders, Z will increase quickly in (17). Complementarity cannot exist when $\varepsilon_{B_i}^{Z} = \sigma_i \omega = 1$, however we can safely exclude that possibility by recognizing that the largest share of any single team in the league budget over the 1991 – 2013 period in MLB was the New York Yankees in 2005 at 9.9%. Setting $\omega = 1$, the largest possible value for $\varepsilon_{B_i}^{Z}$ was 0.099 for any of the 30 teams in MLB, not close at all to eliminating complementarity in (17), given that $Z > 0$.

The scant empirical literature, represented by Clapp and Hakes (2005) and Quinn et al (2003), finds only weak to zero complementarity between new facilities and attendance, or new facility investments and team performance. Weak or zero complementarity is possible in (17) in the simplest case if revenue does not respond to amenities, $\theta = 0$. However even if $\theta > 0$ when $\gamma = 0$ (attendance is completely unresponsive to an increase in the team winning percentage) or $\partial w_i / \partial t_i = 0$ (a team with a very large stock of talent), complementarity is zero. A team with a large budget operating in a tight labour market could make $\varepsilon_{B_i}^{Z} = \sigma_i \omega$ close to one and reduce complementarity to insignificance. Finally, a high market wage per unit of talent, Z, reduces complementarity.

Empirical Evidence

The question is simple: does the provision of a new facility encourage team owners to invest in talent and improve the performance of the team? The answer is complex. As we have shown in the model, the ultimate effect on producing a winning team is dependent upon tightness in the talent market, the economic size of the local market, how much is already being spent on payroll, the fans response to winning and the extent of revenue sharing. Since a higher winning percentage is the variable in question, it makes sense to solve for it in the model so that an econometric specification is suggested. This can be accomplished by solving for the optimal MRP in (11) (or (16) with revenue sharing), then solving for the optimal stock of talent (t_i^*) and finally substituting into a contest success function to arrive at an optimal winning percentage (w_i^*). This would, of course, include all of the exogenous parameters in the model in a highly non-linear form. Even with the most basic functional forms, this task has proven difficult.

We have chosen to use a much simpler empirical model that captures the important features. Our sample period will include all MLB teams from 1991 to 2013. We exclude NFL, NBA and NHL teams from consideration. The NFL and NBA used some form of salary cap during the entire sample period, while the NHL adopted a salary cap in the 2005-06 season. The presence of a salary cap makes it very difficult to measure the extent of talent market tightness if many teams are at or near the salary cap.

In our approach, a team owner can respond to a new facility that promises greater amenities by investing in team talent. We use the team payroll (in 1991 dollars) to measure the owner's effort to do this. His or her efforts might have the effect of driving up the wage rate per unit of talent in the league, with little effect on the team stock of talent. We include the median salary (in 1991 dollars) to attempt to control for this type of talent market tightness. Payroll might also increase if the league receives higher national television revenue so we include this (in 1991 dollars). The revenue garnered from local television contracts has been much higher than the national revenue recently, but unfortunately accurate data on local television revenue is not available from a convenient source.[14]

Revenue sharing was utilized in different forms in MLB throughout the sample period. Over the 1991 through 1997 seasons, a gate sharing system was used that required American League teams to give 20% of their ticket revenue to the visiting club. National League visiting teams received 50 cents per ticket sold which worked out to approximately 5% of the ticket revenue using average ticket prices in the league. A transition period to more extensive revenue sharing began in the 1998 season that culminated with a central pool revenue sharing system for the 2003 season. Each MLB club contributed one-third of their local revenue to a central fund to be divided evenly among all MLB clubs. We construct a dummy variable that takes on the value one for the 2003-13 seasons to account for the potential negative effect of more extensive revenue sharing on MLB payrolls, as predicted by theory.

A simple way to capture a new facility is to use a dummy variable, however our model suggests that the ability to produce valued amenities is greater the more that is invested in facility capital. We construct a measure of the real value of the facility capital by inflating (or deflating) the construction costs of every stadium in MLB to 1991 dollars (construction costs obtained from http://www.ballparks.com) using a construction cost index (http://enr.construction.com/economics/historical_indices/). In most cases, a new stadium (or a major renovation of an existing stadium) generated a large increase in the real value of the facility capital. We also include team fixed effects to account for differences in local market sizes on payrolls.

Our payroll regression specification is:

$$ln(payroll_{it}) = \beta_0 + \beta_1 ln(K_{it}) + \beta_2 ln(medwage_t) + \beta_3 ln(NatTV_t) + \beta_4 D2003_t \qquad (18)$$

where $payroll_{it}$ = real team payroll (1991 = 100)
K_{it} = real value of the facility capital (1991 = 100)
$medwage_t$ = real median league salary (1991 = 100)
$NatTV_t$ = real national television revenue per team (1991 = 100)
$D2003_t$ = dummy variable (D2003 = 1 for 2003-13 seasons)

In our theoretical model, the team winning percentage is determined by an unspecified contest success function that includes the team stock of talent and the total stock of talent in the rest of the league. We have no measure of a stock of talent and use the team payroll in 1991 dollars as a proxy and the total payroll in 1991 dollars for the other MLB teams (rol_payroll).

A higher payroll could translate to a higher winning percentage. We can use the function in (1) and the definition of the wage rate ($Z = B/T$) to derive an expression for the winning percentage, $w_{it} = t_{it}/T_t = (B_{it}/B^{\omega})/(B/Z)$. Taking logs of both sides results in our winning percentage regression specification.

$$ln(w_{it}) = \varphi_1 ln(payroll_{it}) + \varphi_2 ln(rol\_payroll_t + payroll_{it}) + \varphi_3 ln(mwage_t) \qquad (19)$$

where w_{it} = team winning percentage

$payroll_{it}$ = real team payroll (1991 = 100)

$rol\_payroll_t$ = real total payroll for rest of league (1991 = 100)

$mwage_t$ = real median league salary (1991 = 100)

The median wage is a proxy for the wage rate per unit of talent (*Z*). The regression coefficients in (18) and (19) were estimated using cross-section fixed effects and White's heteroskedasticity consistent covariance matrix estimator in each case. The estimates of the payroll function in (18) and the winning percentage function in (19) are given in Table 1.

A 100% increase in the capital value of the facility (not unreasonable given the construction costs of new facilities) increases the payroll by just 7.7% holding the median wage constant. This is quite inelastic, suggesting that the shift in the MRP from a new facility is small. A 10% increase in the median wage increases the club payroll by 9.85%, suggesting that clubs do not react by releasing talent.[15] Neither national TV revenue nor the change to the pooled revenue sharing system in 2003 had a significant effect on club payrolls.

All three independent variables in the estimate of equation (18) were statistically significant at a high level of confidence. Summary statistics are not reported in Table 1 since the winning percentage function was estimated without an intercept resulting in a negative R-squared. It is easy to show that $\omega = 1 - \varphi_2$ so that we have an estimate of the tightness in the talent market equal to 0.234 and the point elasticity estimate of the talent supply function of 3.3 – highly elastic over the twenty-four year sample period. Recall that $\omega = 0$ is the open talent market case in our model, so we can say that the talent market in MLB is reasonably open. Acquiring more talent bids up the market wage rate per unit of talent somewhat.

Using the coefficients from Table 1, we can estimate the effect of a one dollar increase in stadium investment on the club winning percentage for an average club in MLB. This is given by the derivative

$$\frac{\partial w_{it}}{\partial K_{it}} = \frac{\partial w_{it}}{\partial B_{it}} \frac{\partial B_{it}}{\partial K_{it}} = \hat{\beta}_1 (\hat{\varphi}_1 + \hat{\varphi}_2 \overline{\sigma_\iota}) \frac{\overline{w_{\iota t}}}{\overline{K_{\iota t}}} \quad (20)$$

By definition, the average winning percentage is 0.5 (or 500 in the units used in the estimation of (19)) and the average share of total league payroll is 1/30. The average capital value is $204 million (1991 dollars) in the sample. Inserting the coefficients estimates, using these average values and multiplying by the average increase in asset value with a new facility over the sample of $102.5 million (1991 dollars), results in an estimated increase in club winning percentage of just 3.38 percentage points. While statistically significant, this result is not economically significant.

We do not have a sufficient number of observations to estimate (18) and (19) for each team, however we can estimate the specific team effect by using the league average coefficient estimates in Table 1 and the average team values for σ_i, w_i and K_i. These estimates appear in Table 2. Teams with higher average winning percentages experience a larger stadium effect, *ceteris paribus*, due to the upward shift in the MRP of the investment, while teams with higher capital values experience a smaller stadium effect due to a lower MRP. Teams whose payroll accounts for a larger share of total league payroll experience a larger stadium effect due to the greater effect on the market wage of bidding for more talent.

Conclusions

We construct a model of a profit-maximizing sports team owner who chooses an optimal talent budget and stadium labor. This permits us to measure the degree of complementarity between the budget and improved facility amenities that are typical of a new stadium or a stadium that undergoes a major renovation. The novelty of our approach is the incorporation of the state of the talent market. We show that estimating the effect of stadium amenities on team performance requires modelling the supply of talent. If it is scarce as in the case of a closed talent market, the owner will simply drive up the market wage with no improvement in the team winning percentage, and a smaller increase in attendance than would have been the case had the team been improved. Further, our approach allows us to estimate the elasticity of talent supply which has a long run value of 3.3. In our model, a new stadium shifts fan demand for tickets by only 7.7 percent in the first year, resulting in more slightly more revenue for the owner which can be spent on acquiring talent even though the winning percentage rose only by 3.8 percentage points. The model permits complementarity between the stadium investment and talent although without an explicit measure of talent, we are unable to calculate a numerical estimate of the elasticity. Our model also suggests additional variables and interactions that should enhance empirical investigation of the relationship between facilities' improvements and team performance.

Notes

[11] http://www.ballparks.com/

[2] Deflated using a construction cost index obtained from http://enr.construction.com/economics/historical_indices/

[3] Psychic benefits may accrue all over the world from a particular stadium, and in principle the beneficiaries should be taxed. We restrict our discussion to local benefits since this is where the lion's share of the costs accrue.

[4] There may be other reasons for building a stadium. Increased local employment, increased local income, drawing contingent funding from other public or even private sources, revitalization of urban areas are only some of the rationales.

[5] We do not specify a specific form for this contest success function as doing so would unnecessarily complicate the development of the model. We could find no generally agreed upon function for the case of $n > 2$.

[6] Madden (2011) also develops a model of a professional sports league in which team owners invest in talent by choosing a budget. Our approach is a somewhat simplified version of his model.

[7] Working with a team budget, rather than a stock of talent, allows for both a Cournot-Nash conjecture regarding budgets and a different derivative regarding talent stocks, $\partial t_k/\partial t_i$, that could be equal to zero in an open talent

market or something else in a restricted talent market. Easton and Rockerbie (2005) considered the best responses of teams to changes in each other's stock of talent in the face of pooled revenue sharing. The extension to team budgets is straightforward and will not change the results found there either. This follows Winfree and Fort (2012) and Madden (2011) who recommend this approach to make the sports league model logically consistent. In the traditional sports league model, $\partial t_k/\partial t_i$ served the dual purpose of a behavioral conjecture and a talent supply constraint, something it cannot do. The upshot is that in the Winfree and Fort (2012) approach, $\partial t_k/\partial t_i$ is not a behavioral conjecture at all, rather it is just a physical constraint imposed by the talent market supply assumption. However in a static one-shot game (Lindh (1992)), $\partial B_k/\partial B_i = 0$ is a consistent budget conjecture. The Winfree and Fort (2012) and Madden (2011) approaches allow for this.

[8] The elasticity of league talent is linked to budgets as: $(B/T)(dT/dB) = (1-\omega)$.
[9] Vrooman (2015) utilizes an elasticity of talent supply by specifying an ad hoc talent supply function that is not linked to budgets. His approach focuses on parity issues that we do not address in this paper.
[10] Some examples are the MLB Miami Marlins, Pittsburgh Pirates, Cincinnati Reds, Milwaukee Brewers, New York Mets and Houston Astros, among others. All of these clubs had losing records for at least five years prior to agreeing on a new stadium deal.
[11] The NBA and NHL also use revenue sharing systems, however they are too complex to model easily.
[12] It is important to note that requiring the team owner to pay for a portion of the new facility investment will not affect the results we derive concerning complementarity of the team budget (that is spent on acquiring talent) and the facility investment for two reasons. First, if the team budget is set independently of the owner share of the facility investment, and in no way constrains the team budget, we can treat the owner share as a fixed cost in the algebra. Second, even if the owner share comes out of the team budget, it would simply increase the marginal cost of the budget in Figure 1 and reduce the optimal team budget spent on talent. This would be equivalent to an increase in r.
[13] The most extensive revenue sharing agreements are MLB and the NFL where each team contributes roughly one-third of its local revenue to a central fund that is then divided evenly among all teams. NBA teams each contribute 50% of their local revenue, less allowable expenses, to a central fund and receive back an amount equal to the average team payroll. The top ten revenue teams in the NHL contribute decreasing amounts based on their revenue rank. Playoff teams ten contribute 35% of their home gate revenue so that the total revenue raised is equal to approximately 6% of total anticipated hockey related revenues for the league. Monies are then redistributed disproportionately to the lowest payroll clubs.
[14] National TV revenue has caught up to local TV revenue very recently. National TV revenue for the 2014-15 season amounted to approximately $50 million per team in MLB. Prior to this season, the amount was approximately $13.3 million per team. Local TV revenue varied considerably for the 2013-14 season. The Los Angeles Dodgers are estimated to have received $123 million while the Cincinnati Reds received only $20 million. Most teams earned less than $40 million. All TV revenue data were taken from Rod Fort's sports business data website on 22/06/2015 (https://umich.app.box.com/s/41707f0b2619c0107b8b/1/32002264).
[15] We also estimated (18) with a smaller sample that excluded new expansion clubs and clubs that did not move into new facilities or have major renovations during the sample period. The capital value effect on the club payroll was estimated to be 8.8% and the effect of the median wage was 9.11%, both statistically significant at 95% confidence. These values did not differ enough from the full sample to change any of the results that follow.

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Table 1. Estimates of equations (18) and (19), 1991-2013, full sample.

Coefficient	Estimate	T statistic	Estimate	T statistic
β_0	1.683	1.927**		

β_1	0.077	2.545*		
β_2	0.985	15.477*		
β_3	0.010	0.299		
β_4	0.048	1.603		
φ_1			0.149	9.696*
φ_2			0.766	9.507*
φ_3			-0.867	-7.451*
Adjusted R^2	0.704			
Std. Error	0.288			
F	47.885*			
N	670		672	

** indicates statistical significance at 90% confidence. * indicates statistical significance at 95% confidence.

Table 2. Team-specific stadium effects on winning percentage

	$\bar{\sigma}_i$	$\bar{w}_i$	K_i [1]	dK_i	dw_i
Atlanta	0.116	581	195	110	6.00
Cincinnati	0.087	500	158	95	4.98
Miami	0.062	469	325	199	4.34
Milwaukee	0.077	475	305	265	6.61
New York (NL)	0.129	490	337	205	5.70
Philadelphia	0.118	507	235	82	3.26
Pittsburgh	0.057	454	200	0	0.00
San Diego	0.071	481	354	244	5.18
San Francisco	0.110	521	277	189	6.38
St. Louis	0.108	535	248	153	5.90
Baltimore	0.100	474	97	47	3.98
Cleveland	0.087	513	156	33	1.80
Detroit	0.106	469	233	138	4.92
Houston	0.089	495	188	-46	-2.03
Kansas City	0.069	444	314	135	2.96
Los Angeles (AL)	0.118	515	208	94	4.29
Minnesota	0.076	490	295	265	7.02
New York (AL)	0.205	580	742	587	10.80
Oakland	0.105	519	177	70	3.63
Seattle	0.106	491	330	204	5.37
Texas	0.105	510	171	119	6.27

[1]Stadium construction cost of new facility or renovations in 1991 dollars (using construction cost index) excluding land value.