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Abstract

This study theoretically examines whether a uniform relative emission standard improves a professional sports team's competitive balance and social welfare in a professional league. Our study shows that there are cases where tightening (*resp.* relaxing) such standards can improve competitive balance when the differences between the abatement cost conditions of different clubs are sufficiently small (*resp.* large). Social welfare improves when the standard is slightly tougher than an unregulated emission level standard. Furthermore, social welfare also improves when the standard set to a zero-emission level is slightly relaxed.

JEL classification: Q50; Z29
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1 Introduction

Since the late 20th century, there has been a heightened awareness of environmental issues worldwide, and the environmental protection movement has extended into the world of sports. Today, professional sports teams get involved in various environmental protection activities and these are reported and broadcasted in the media: MLB.com has introduced recent environmental protection activities of clubs in Major League Baseball.[1] BBC reported that Liverpool and Tottenham Hotspurs were jointly ranked as first place in the sustainability ranking among the Premier League clubs in 2021.[2]

Soon, leagues, in addition to individual clubs, may be involved in environmental protection activities. For example, on June 28, 2021, the Ministry of the Environment of the Japanese government announced that it will work with the teams in Japan's professional football league to develop initiatives to combat climate change and reduce single-use plastics. At the announcement of this partnership agreement, Chairman Murai said that the idea is to ban the use of single-use plastics in all clubs by 2025.[3]

This study aims to theoretically examine how a league's environmental policy affects competitive balance in a professional team sports league. In the literature, there are several empirical works on the relationship between professional sports clubs and the environment.[4] However, there are few theoretical works about this. This study is the first attempt to reveal theoretical evidence of the effects of a league's environmental policy.

As for environmental policy, this study considers the use of a relative emission standard or an emission intensity regulation.[5] One reason for adopting this type of emission standard is that it is still observed today. For example, the Japanese government is

[1]For details, see the webpage titled "Club Initiatives" on MLB.com. https://www.mlb.com/mlb-community/mlb-green/club-initiatives, (accessed 5 February 2023).

[2]For details, see the webpage titled "How green are Premier League clubs & what are they doing to help?" on BBC.com. https://www.bbc.com/sport/football/60196764, 2022 (accessed 5 February 2023).

[3]KOIZUMI Shinjiro, Minister of Environment, Japan, introduced this initiative at the G20 Environment Ministers' Meeting on July 22, 2021. For details, see the Ministry of the Environment, Government of Japan's webpage. https://www.env.go.jp/en/focus/statement/statement14.html, 2021 (accessed 5 February 2023).

[4]Locke [15] examines the impact of MLB games on local air pollution. Qin et al [18] investigate whether air pollution affects the performances of professional football players.

[5]Helfand [9] states that emission standards can be classified into five categories: a fixed level of emissions, a fixed level of emissions per unit of output, a fixed level of emissions per unit of input, a fixed level of output, and a fixed level of input. The second standard is often called a relative emission standard or an emission intensity regulation.

now aiming to reduce its greenhouse gas emissions to achieve carbon neutrality by 2050, following the Paris Agreement. In response, Keidanren—a comprehensive economic organization in Japan—announced the Keidanren Carbon Neutrality Action Plan, based on which several industry associations adopted a CO_2 emission intensity target on March 22, 2022.[6] One other reason is that research has still been done on such standards even in recent years (e.g. Ino and Matsumura [10], [11]; Lin and Pan [14]) and it is simple to handle for analysis.

In the current study, the model with a Cobb-Douglas functional form by Madden [16] is used. This is a strong assumption, but it allows us to obtain specific equations and numerical values for equilibrium outcomes and social welfare, even for models that incorporate environmental issues, which makes the characteristics of equilibrium outcomes clearer and easier to understand compared to analysis in general functional form.[7] It would be more difficult to derive the equilibrium outcomes and social welfare and to analyze these elements using other models. We return to this in the Conclusion.

We pick up the following two leagues: one is a league where each club's objective is to maximizes its profit and the other is that it is to maximize its win percentage. They are representative leagues in the literature of sports economics.[8]

The remainder of this paper is organized as follows. Section 2 describes our model. Section 3 derives the equilibrium outcomes in a professional team sports leagues with profit maximizers' clubs and win maximizers' clubs. Section 4 examines the effect of a uniform relative emission standard on the equilibrium outcome, competitive balance, and social welfare in each league and compares them between the two types of leagues. Section 5 presents our conclusions. Detailed calculations for the equilibrium outcome in each case and proofs of the propositions are given in the Appendices.

2 Model

We followed the model of Madden [16] except for settings related to the environment. Suppose an economy where there are only two towns (town i, $i = 1, 2$) and a professional

[6] For details of the Keidanren Carbon Neutrality Action Plan, see the Keidanren Japan Business Federation's webpage. https://www.keidanren.or.jp/en/policy/2021/102_report.pdf, (accessed 5 February 2023).

[7] Numerous studies have theoretically analyzed professional sports teams; however, few studies have focused on welfare analyses (e.g. Falconieri et al [6]; Dietl et al [3]; Fort and Quirk [7], [8]; Madden [16]).

[8] There are other leagues in the earlier literature; each club maximizes fan welfare (Madden [16]) and a weighted sum of its profits and wins (Dietl [2]). Dietl [3] considers the league that one club maximizes its profit and the other maximizes its win percentage.

sports club (club i) in each. These teams belong to the same professional league, and they compete against each other. Each club plays the other twice each year, once at home and once away.

In town i, some fans feel an affinity to club i and a representative resident who is not interested in professional sports at all. A representative resident lives near the stadium and fans live some distance from the stadium. Club i's fans are assumed to be the only potential spectators for i's home match. They are heterogeneous in their willingness to pay for tickets, denoted $v_i - x$ where the heterogeneity parameter is $x \geq 0$ and v_i is the common valuation. It is assumed that x is uniformly distributed over $[0, c_i]$ with density μ_i: μ_i can be regarded as the fanbase of club i. We assume $\mu_1 > \mu_2$: club 1 has a larger fanbase than club 2. A fan with heterogeneity parameter x will buy a ticket if $p_i \leq v_i - x$ where p_i denotes the ticket price for club i's home match.

Club i decides the ticket price p_i and obtains all ticket revenue from its home match. We assume that the capacity of club i's stadium is large enough to be never binding on match attendance and that c_i is larger than v_i, and therefore, club i's ticket demand is $\mu_i(v_i - p_i)$. Moreover, we assume that talent is in perfectly elastic supply at a wage normalized to 1 and that stadium costs are 0. From these assumptions, profits of club i without an environmental protection cost are $\Pi_i = p_i\mu_i(v_i - p_i) - Q_i$ where Q_i denotes the quantity of playing talent of club i.

On the day of a match, spectators pollute in or around the stadium in ways such as noise pollution, the littering of single-use plastics, or gas emissions from driving their own vehicles to the stadium. This pollution harms the representative resident. The amount of pollution depends on the number of spectators. We assume that one spectator produces one unit of pollution at the stadium; the gross emission of pollution of the club i is $\mu_i(v_i - p_i)$. For the pollution, club i can reduce its pollution by investing in abatement efforts a_i.[9] We assume that one unit of abatement effort can reduce one unit of emission of pollution; the net emission of pollution of club i is $\mu_i(v_i - p_i) - a_i$.

Each club determines the quantity of playing talent Q_i, ticket prices p_i, and abatement effort a_i to maximize their objective functions. The profit of club i, which includes an environmental protection cost, is as follows:

$$\pi_i = \mu_i p_i(v_i - p_i) - Q_i - k_i a_i^2, \tag{1}$$

where the last term is an abatement cost of club i and $k_i > 0$. k_i is the parameter that

[9] The club can adjust its amount of pollution by introducing reusable cups, installing soundproof doors for noise reduction, or issuing tickets for free public transportation to reduce the use of private vehicles.

determines a slope of marginal abatement cost. If k_i is smaller than k_j, it means that club i has better abatement cost conditions than club j.

A uniform relative emission standard is imposed on all clubs by a league. In this study, the standard is made of the ratio of net emissions per spectator:

$$\frac{\mu_i(v_i - p_i) - a_i}{\mu_i(v_i - p_i)} \leq \theta, \tag{2}$$

where $\theta \in [0, 1]$.[10] $\theta = 1$ implies no restriction of its emission and $\theta = 0$ implies zero emission. In this study, we focus only on the case that the standard (2) is binding, and therefore, club i's abatement effort a_i becomes $(1-\theta)\mu_i(v_i - p_i)$.

Social welfare is the sum of the spectators' surplus and the profits of clubs and the environmental damage:[11]

$$S = \sum_{i=1}^{2} \int_0^{v_i - p_i} \mu_i(v_i - p_i - x)dx + \sum_{i=1}^{2} \pi_i - \sum_{i=1}^{2} D_i(E_i), \tag{3}$$

where $D_i(E_i)$ represents the local environmental damage in hometown of club i and E_i denotes the net emission of pollution of club i, $E_i = \theta\mu_i(v_i - p_i)$. We assume that $D_i(E_i) = d_i E_i^2$ and $d_i > 0$. d_i is the parameter that determines a slope of marginal environmental damage. These settings are related to environmental problems and are often used in the literature on environmental economics.[12]

Last, we assume that $v_i = Q_i^\alpha Q_j^\beta$ with $\alpha, \beta > 0$ and $\alpha + \beta < 1/2$ for $i, j = 1, 2, i \neq j$ as Madden [16] assumes. We also assume that $1/(2\mu_i) > d_i$ for assuring the positiveness of social welfare in the equilibrium for this economy.

3 The equilibrium

3.1 Profit maximizers' league

First, we consider the case that both clubs are profit maximizers. We consider the following timing of the game. Each club decides on the quantity of playing talent, and

[10] Concerning a relative emission standard, the denominator is usually the output; Producing the output, the firm emits pollution. In this study, the denominator implies the number of spectators; Increasing the number of spectators causes an increase in gross emissions at the stadium. Therefore, we call this constraint a relative emission standard.

[11] In town i, a representative resident's surplus is $-D_i(E_i)$; It is assumed to be 0 without environmental damage.

[12] For example, see Ulph [22], Bárcena-Ruiz [1], and Pal and Saha [17]. Although they consider pollution by production, we apply these settings because pollution is generated in and around the stadium.

then it decides the ticket price. This two-stage setting is also used by Madden [16] and assures a profit function within each club after monopoly pricing is strictly concave.

The maximization problem in the second stage for club i is as follows:

$$\max_{p_i} \mu_i p_i(v_i - p_i) - Q_i - k_i\{(1-\theta)\mu_i(v_i - p_i)\}^2, \tag{4}$$

for $i = 1, 2$. The first-order condition of the maximization problem of club i is as follows:

$$\frac{\partial \pi_i}{\partial p_i} = \mu_i \left[\left\{1 + 2k_i\mu_i(1-\theta)^2\right\} Q_i^\alpha Q_j^\beta - 2\left\{1 + k_i\mu_i(1-\theta)^2\right\} p_i \right] = 0, \tag{5}$$

for $i, j = 1, 2, i \neq j$. Solving the above equation for p_i, we obtain

$$p_i^{sb} = \frac{\left\{1 + 2k_i\mu_i(1-\theta)^2\right\} Q_i^\alpha Q_j^\beta}{2\left\{1 + k_i\mu_i(1-\theta)^2\right\}}, \tag{6}$$

for $i, j = 1, 2, i \neq j$. p_i^{sb} denotes the equilibrium price when the quantity of playing talent of each club Q_i and Q_j are given in the profit maximizers' league. Substituting the above p_i^{sb} into the profit of club i (called π_i^{sb}) and partially differentiating π_i^{sb} by Q_i, we obtain the following first-order condition for club i in the first stage:

$$\frac{\partial \pi_i^{sb}}{\partial Q_i} = \frac{\alpha\mu_i}{2\{1 + k_1\mu_1(1-\theta)^2\}} Q_i^{2\alpha-1} Q_j^{2\beta} - 1 = 0, \tag{7}$$

for $i, j = 1, 2, i \neq j$. Solving the above two equations for Q_1 and Q_2, and then, we obtain the following equilibrium quantity of playing talent of each club.

$$Q_1^{p*} = \left[\frac{\alpha}{2} \left(\frac{\mu_1}{1 + k_1\mu_1(1-\theta)^2} \right)^{\frac{1-2\alpha}{1-2\alpha+2\beta}} \left(\frac{\mu_2}{1 + k_2\mu_2(1-\theta)^2} \right)^{\frac{2\beta}{1-2\alpha+2\beta}} \right]^{\frac{1}{1-2\alpha-2\beta}}, \tag{8}$$

$$Q_2^{p*} = \left[\frac{\alpha}{2} \left(\frac{\mu_1}{1 + k_1\mu_1(1-\theta)^2} \right)^{\frac{2\beta}{1-2\alpha+2\beta}} \left(\frac{\mu_2}{1 + k_2\mu_2(1-\theta)^2} \right)^{\frac{1-2\alpha}{1-2\alpha+2\beta}} \right]^{\frac{1}{1-2\alpha-2\beta}}. \tag{9}$$

The superscript $p*$ indicates the equilibrium outcome in the case where both clubs are profit maximizers.

Other equilibrium outcomes by using the expression of $v_1^{p*} = (Q_1^{p*})^\alpha (Q_2^{p*})^\beta$ and

$v_2^{p*} = (Q_1^{p*})^\beta (Q_2^{p*})^\alpha$ are as follows:

$$p_1^{p*} = \frac{\{1 + 2k_1\mu_1(1-\theta)^2\}v_1^{p*}}{2\{1 + k_1\mu_1(1-\theta)^2\}}, \qquad p_2^{p*} = \frac{\{1 + 2k_2\mu_2(1-\theta)^2\}v_2^{p*}}{2\{1 + k_2\mu_2(1-\theta)^2\}}. \tag{10}$$

$$A_1^{p*} = \frac{\mu_1 v_1^{p*}}{2\{1 + k_1\mu_1(1-\theta)^2\}}, \qquad A_2^{p*} = \frac{\mu_2 v_2^{p*}}{2\{1 + k_2\mu_2(1-\theta)^2\}}. \tag{11}$$

$$a_1^{p*} = \frac{\mu_1(1-\theta) v_1^{p*}}{2\{1 + k_1\mu_1(1-\theta)^2\}}, \qquad a_2^{p*} = \frac{\mu_2(1-\theta) v_2^{p*}}{2\{1 + k_2\mu_2(1-\theta)^2\}}, \tag{12}$$

$$E_1^{p*} = \frac{\mu_1 \theta v_1^{p*}}{2\{1 + k_1\mu_1(1-\theta)^2\}}, \qquad E_2^{p*} = \frac{\mu_2 \theta v_2^{p*}}{2\{1 + k_2\mu_2(1-\theta)^2\}}, \tag{13}$$

where A_i^{p*} denotes the resulting attendance of club i's home match, that is, $\mu_i(v_i^{p*} - p_i^{p*})$.

Social welfare in the profit maximizers' league is as follows:[13]

$$S^{p*} = Q_1^{p*}\Bigg[\frac{3 + 2k_1\mu_1(1-\theta)^2 - 2d_1\mu_1\theta^2}{4\alpha\{1 + k_1\mu_1(1-\theta)^2\}} - 1 + \left(\frac{\mu_2\{1 + k_1\mu_1(1-\theta)^2\}}{\mu_1\{1 + k_2\mu_2(1-\theta)^2\}}\right)^{\frac{1}{1-2\alpha+2\beta}} \left(\frac{3 + 2k_2\mu_2(1-\theta)^2 - 2d_2\mu_2\theta^2}{4\alpha\{1 + k_2\mu_2(1-\theta)^2\}} - 1\right)\Bigg]. \tag{14}$$

3.2 Win maximizers' league

Second, we consider the case that both clubs are win maximizers. Each club maximizes its win percentage by choosing its quantity of playing talent subject to non-negative profits. In a two club model, one of the simplest ways to express a win percentage of club i is $Q_i/(Q_i + Q_j)$ with $i, j = 1, 2, i \neq j$. This setting is used widely in the literature (e.g. El Hodiri and Quirk [5]; Szymanski [19], [20]; Szymanski and Késenne [21]; Vrooman [23]; Dietl et al. [2], [3]; Késenne [12]). The win percentage of club i is the monotonically increasing function for Q_i, and therefore, maximizing win percentage is equal to maximizing Q_i for club i. As a result, the maximization problem of club i in the case where clubs are win maximizers is as follows.

$$\max_{p_i, Q_i} Q_i, \text{ subject to } \pi_i = \ p_i\mu_i(v_i - p_i) - Q_i - k_i\mu_i^2(1-\theta)^2(v_i - p_i)^2 \geq 0, \tag{15}$$

for $i = 1, 2$. We find that the largest value of Q_i can be chosen when $\pi_i = 0$.[14]

From this fact, the following equilibrium quantity of playing talent of each club can

[13] For the calculation of S^{p*}, see Appendix A.

[14] See Appendix B.

be obtained.

$$Q_1^{w*} = \left[\frac{1}{4}\left(\frac{\mu_1}{1+k_1\mu_1(1-\theta)^2}\right)^{\frac{1-2\alpha}{1-2\alpha+2\beta}}\left(\frac{\mu_2}{1+k_2\mu_2(1-\theta)^2}\right)^{\frac{2\beta}{1-2\alpha+2\beta}}\right]^{\frac{1}{1-2\alpha-2\beta}}, \tag{16}$$

$$Q_2^{w*} = \left[\frac{1}{4}\left(\frac{\mu_1}{1+k_1\mu_1(1-\theta)^2}\right)^{\frac{2\beta}{1-2\alpha+2\beta}}\left(\frac{\mu_2}{1+k_2\mu_2(1-\theta)^2}\right)^{\frac{1-2\alpha}{1-2\alpha+2\beta}}\right]^{\frac{1}{1-2\alpha-2\beta}}. \tag{17}$$

The superscript $w*$ indicates the equilibrium outcome in the case where both clubs are win maximizers.

As is a similar manner to the profit maximizers' league, we show other equilibrium outcomes by using the expression of $v_1^{w*} = (Q_1^{w*})^{\alpha}(Q_2^{w*})^{\beta}$ and $v_2^{w*} = (Q_1^{w*})^{\beta}(Q_2^{w*})^{\alpha}$:

$$p_1^{w*} = \frac{\{1+2k_1\mu_1(1-\theta)^2\}v_1^{w*}}{2\{1+k_1\mu_1(1-\theta)^2\}}, \quad p_2^{w*} = \frac{\{1+2k_2\mu_2(1-\theta)^2\}v_2^{w*}}{2\{1+k_2\mu_2(1-\theta)^2\}}. \tag{18}$$

$$A_1^{w*} = \frac{\mu_1 v_1^{w*}}{2\{1+k_1\mu_1(1-\theta)^2\}}, \quad A_2^{w*} = \frac{\mu_2 v_2^{w*}}{2\{1+k_2\mu_2(1-\theta)^2\}}. \tag{19}$$

$$a_1^{w*} = \frac{\mu_1(1-\theta) v_1^{w*}}{2\{1+k_1\mu_1(1-\theta)^2\}}, \quad a_2^{w*} = \frac{\mu_2(1-\theta) v_2^{w*}}{2\{1+k_2\mu_2(1-\theta)^2\}}, \tag{20}$$

$$E_1^{w*} = \frac{\mu_1\theta v_1^{w*}}{2\{1+k_1\mu_1(1-\theta)^2\}}, \quad E_2^{w*} = \frac{\mu_2\theta v_2^{w*}}{2\{1+k_2\mu_2(1-\theta)^2\}}, \tag{21}$$

where A_i^{w*} denotes the resulting attendance of club i's home match, that is, $\mu_i(v_i^{w*} - p_i^{w*})$.

Social welfare in the win maximizer's league is as follows:[15]

$$S^{w*} = \frac{Q_1^{w*}}{2}\left[\frac{1-2d_1\mu_1\theta^2}{1+k_1\mu_1(1-\theta)^2} + \left(\frac{\mu_2\{1+k_1\mu_1(1-\theta)^2\}}{\mu_1\{1+k_2\mu_2(1-\theta)^2\}}\right)^{\frac{1}{1-2\alpha+2\beta}}\left(\frac{1-2d_2\mu_2\theta^2}{1+k_2\mu_2(1-\theta)^2}\right)\right]. \tag{22}$$

4 Analysis

4.1 In each league

We investigate the effect of a uniform relative emission standard on the equilibrium outcome in each league. First, we examine the comparative statics of some equilibrium outcomes of each club in θ. The results are as follows.

Proposition 1. *For $i = 1, 2, l = p, w$,*

$$\frac{\partial Q_i^{l*}}{\partial\theta} \geq 0, \frac{\partial A_i^{l*}}{\partial\theta} \geq 0, \frac{\partial E_i^{l*}}{\partial\theta} > 0,$$

[15] Since the calculation of S^{w*} is the same process as that of S^{p*}, we omit to indicate how to calculate S^{w*}.

where strict inequality holds when $\theta \in [0, 1)$.

Proof. See Appendix C. □

These results imply that the equilibrium quantity of playing talent, attendance, and emissions of each club are smaller if the uniform emission standard tightens more regardless of whether it is in the profit maximizers' league or win maximizers' league. This is because each club must decrease its emissions more than they already do. Since emissions are related to attendance, each club decreases its quantity of playing talent. Similar results are obtained by Ebert [4], who shows that tightening standards leads to a decrease in the firm's output in several types of market competition in the framework of industrial organization. Unfortunately, the comparative statistics of the equilibrium ticket price and abatement effort in θ are ambiguous. This is due to the possibility that the abatement effort might increase by relaxing the standard. If relaxing the standard causes the gross amount of emissions to increase, it might also cause the abatement effort to increase since only the ratio of gross and net emissions of pollution is regulated. Further, the equilibrium ticket price depends on the magnitude of marginal abatement costs, and therefore, the sign of the comparative statics in θ is ambiguous.

[Incert Figures 1, 2, and 3]

Figures 1, 2, and 3 show the relationship between the equilibirum abatement effort and ticket price of each club and θ for some cases of parameter; $\alpha = 1/8$, $\beta = 1/16$, $\mu_1 = 3/4$, $\mu_2 = 1/2$. In Figure 1, where both clubs has the symmetric abatement cost function ($k_1 = k_2 = 1$), the equilibrium ticket price decreases in θ. However, in Figure 2 and 3, where the difference of k_i between the two clubs are large ($|k_1 - k_2| = 3$), the equilibrium ticket price of the club with a larger k_i does not always monotonically decreases in θ; it may increase in the range of θ that the equilibrium abatement effort increases.

Second, we derive the ratio of the equilibrium outcome between the two clubs. In particular, we use the ratio of the quantity of playing talent between two clubs Q_1/Q_2 as a measure of competitive balance and call it a win ratio because it is derived by the ratio of the win percentage between two clubs, $\{Q_1/(Q_1+Q_2)\}/\{Q_2/(Q_1+Q_2)\}$. This is one common way of measuring competitive balance (e.g. Szymanski [19]; Szymanski and Késenne [21]; Vrooman [23]; Dietl et al. [2]; Késenne [12]); the league is fully balanced when the win ratio is equal to 1 and less balanced when it is lower or higher than 1. We show the results in Proposition 2. We note that we exclude the following two cases, $\theta = 1$ concerning a_1^{l*}/a_2^{l*} and $\theta = 0$ concerning E_1^{l*}/E_2^{l*}, in Proposition 2 because $a_1^{l*} = a_2^{l*} = 0$ when $\theta = 1$ and $E_1^{l*} = E_2^{l*} = 0$ when $\theta = 0$ for $l = p, w$.

Proposition 2. *The ratio between the equilibrium quantity of playing talent, attendance, abatement efforts, and the emissions levels of the clubs in each league are as follows. Suppose $\theta = 1$. Then, for $l = p, w$, Q_1^{l*}/Q_2^{l*}, A_1^{l*}/A_2^{l*}, and $E_1^{l*}/E_2^{l*} > 1$. Suppose $\theta \in [0, 1)$. Then, for $l = p, w$,*

$$\frac{Q_1^{l*}}{Q_2^{l*}}, \frac{A_1^{l*}}{A_2^{l*}}, \frac{a_1^{l*}}{a_2^{l*}}, \frac{E_1^{l*}}{E_2^{l*}} > 1 \quad \textit{if and only if} \quad 0 < k_1 < k_2 + \frac{\mu_1 - \mu_2}{\mu_1 \mu_2 (1-\theta)^2}.$$

Proof. See Appendix D. □

As is shown by Madden [16], club 1, which has a larger fanbase, hires a larger quantity of playing talent than club 2 when there is no emission restriction. The win ratio is always larger than 1; therefore, club 1 will have a better chance of winning the league. However, under a uniform relative emission standard, club 1 does not always hire more playing talent than club 2 because each club must abate its emissions and its cost can be different between the two clubs: club 2 will have a better chance of winning the league despite $\mu_1 > \mu_2$ if its abatement cost condition is much better than that of club 1. The club with the advantage in terms of environmental measures will win the league. Concerning p_1^{l*}/p_2^{l*}, it is too difficult to show the condition of its magnitude relation.

Below, we focus on the effects of the uniform relative emission standard on competitive balance and social welfare. The following proposition shows whether the shift of θ improves the competitive balance in each league or not.[16]

Proposition 3. *Suppose $\theta = 1$. Then, $\partial(Q_1^{l*}/Q_2^{l*})/\partial\theta = 0$, for $l = p, w$. Suppose $\theta \in [0, 1)$. Then, for $l = p, w$,*

$$\begin{aligned}
&\frac{Q_1^{l*}}{Q_2^{l*}} \leq 1, \frac{\partial(Q_1^{l*}/Q_2^{l*})}{\partial\theta} > 0, \ \textit{when} \ k_1 \geq k_2 + \frac{\mu_1 - \mu_2}{\mu_1 \mu_2 (1-\theta)^2}, \\
&\frac{Q_1^{l*}}{Q_2^{l*}} > 1, \frac{\partial(Q_1^{l*}/Q_2^{l*})}{\partial\theta} \geq 0, \ \textit{when} \ \frac{\mu_2}{\mu_1} k_2 \leq k_1 < k_2 + \frac{\mu_1 - \mu_2}{\mu_1 \mu_2 (1-\theta)^2}, \\
&\frac{Q_1^{l*}}{Q_2^{l*}} > 1, \frac{\partial(Q_1^{l*}/Q_2^{l*})}{\partial\theta} < 0, \ \textit{when} \ 0 < k_1 < \frac{\mu_2}{\mu_1} k_2.
\end{aligned}$$

Proof. See the appendix E. □

[16] We use the word "improve" which means that the strength of the two teams is moving toward equalization.

The second case of Proposition 3 implies that the competitive balance improves when there is a tightened uniform relative emission standard if the abatement cost conditions of both clubs, k_1 and k_2, are almost the same. This is because the quantity of playing talent and emissions of club 1 are larger than those of club 2; therefore, tightening the standard leads club 1 to reduce emissions more. The first and third cases of Proposition 3 imply that the competitive balance improves when the standard is relaxed if there is a sufficiently large difference between k_1 and k_2. Relaxing the standard enables the club with inferior abatement cost conditions, that is, a larger k_i, to increase the quantity of playing talent more than the club with better abatement conditions: this reduces the influence of the marginal abatement cost on the decision of the quantity of playing talent in the club with a larger k_i more. If both clubs have the same magnitude of their fanbases $\mu_1 = \mu_2$, $(\mu_1 - \mu_2)/\{\mu_1\mu_2(1-\theta)^2\}$ becomes zero, and then, whether k_1 is larger than k_2 only matters.

Now, we examine the effect of the uniform relative emission standard on social welfare. Unfortunately, it is too difficult to derive the behavior of S^{l*} on $\theta \in [0, 1]$.

[Incert Figure 4]

Figure 4 shows the relationship between social welfare and θ for some cases of parameter; $\alpha = 1/8$, $\beta = 1/16$, $\mu_1 = 3/4$, $\mu_2 = 1/2$. In Figure 4 (a), where both clubs has the symmetric abatement cost function ($k_1 = k_2 = 1$), social welfare seems to be concave in θ. However, in Figures 4 (b) and 4 (c), where the difference of k_i between the two clubs are large ($|k_1 - k_2| = 3$), social welfare is not concave in θ.

Therefore, we focus on the following two representative cases. One is that the standard is made slightly tougher than in the absence of the standard, $\theta = 1$. The other is that the standard is slightly relaxed to a zero-emission standard, $\theta = 0$. Regarding the former case, we obtain the following proposition.

Proposition 4. *For $l = p, w$,*

$$\left.\frac{\partial S^{l*}}{\partial \theta}\right|_{\theta=1} < 0.$$

Proof. See Appendix F. □

Proposition 4 implies that social welfare improves by tightening the standard marginally when the standard is set to an unrestricted emissions level, $\theta = 1$. The intuition behind Proposition 4 is as follows. Suppose $\theta = 1$. When the league decides to decrease θ from 1, it directly causes the marginal abatement costs of each club to increase, whereas it also directly causes marginal environmental damage in each town to decrease. In this case, the latter effect is larger than the former. The increase of the marginal abatement costs of each club is 0 as the abatement cost function of club i is $k_i a_i^2$ and a_i is $(1-\theta)\mu_i(v_i - p_i)$. However, a decrease of marginal environmental damage in each town is positive since the environmental damage function in town i is $d_i E_i^2$ and E_i is $\theta\mu_i(v_i - p_i)$.

Regarding the latter case, we obtain the following proposition.

Proposition 5. *For $l = p, w$,*

$$\left.\frac{\partial S^{l*}}{\partial \theta}\right|_{\theta=0} > 0.$$

Proof. See Appendix G. □

Proposition 5 implies that social welfare improves when the standard is marginally relaxed in the case that a zero-emission standard is imposed, $\theta = 0$: a zero-emission standard is not good in terms of social welfare. The intuition behind the proposition is as follows. Suppose $\theta = 0$. When the league decides to increase θ from 0, a decrease in marginal abatement costs of each club is larger than an increase in marginal environmental damages in each town. We find that the latter is zero, whereas the former is positive. This is due to the functional forms of abatement cost and environmental damage as is a similar explanation of Proposition 4.

We summarize propositions 3, 4, and 5. A few regulations could improve social welfare without changing the competitive balance compared to no regulations since $\partial(Q_1^*/Q_2^*)/\partial\theta = 0$ and $\partial S^{l*}/\partial\theta < 0$ when $\theta = 1$ from Propositions 3 and 4. However, the standard set to a zero-emission level is not desirable for social welfare since $\partial S^{l*}/\partial\theta > 0$ when $\theta = 0$ from Porposition 5. The competitive balance can vary with θ; therefore, it can also be improved if the league can choose θ well, paying attention to the magnitude relations of k_1 and k_2.

4.2 Between the two leagues

We compare the equilibrium quantity of playing talent, attendance, abatement effort, emission, and ticket price of each club between the two leagues. We note that $a_i^{p*} = a_i^{w*} = 0$ when $\theta = 1$ and $E_i^{p*} = E_i^{w*} = 0$ when $\theta = 0$ $(i = 1, 2)$. Concerning the results of other comparisons for $\theta \in [0, 1]$, the following proposition shows the results.

Proposition 6. *For $i = 1, 2$,*

$$\frac{Q_i^{p*}}{Q_i^{w*}}, \frac{A_i^{p*}}{A_i^{w*}}, \frac{a_i^{p*}}{a_i^{w*}}, \frac{E_i^{p*}}{E_i^{w*}}, \frac{p_i^{p*}}{p_i^{w*}} < 1.$$

Proof. See Appendix H. □

The equilibrium quantity of playing talent, attendance, abatement effort, emission, and ticket price are larger in a win maximizers' league than in a profit maximizers' league. These results are consistent with those of Madden [16] when there is no restriction of emissions, $\theta = 1$.

When we compare social welfare between the two leagues, we do not obtain a clear result due to the formulas being disorganized. We focus on a very specific case: $k_1\mu_1 = k_2\mu_2$ and $d_1\mu_1 = d_2\mu_2$ holds. As is seen in Appendix D, the differences in the equilibrium outcome between the two clubs depend only on the difference between μ_1 and μ_2 under the condition $k_1\mu_1 = k_2\mu_2$; These results are identical to those of Madden [16] in a case that does not deal with environmental problems. This is because the condition $k_1\mu_1 = k_2\mu_2$ creates an influence of marginal abatement costs of club i on its decision of quantity of playing talent to be identical to that of club j. Under the condition $k_1\mu_1 = k_2\mu_2$ and $d_1\mu_1 = d_2\mu_2$, the differences of environmental damages between towns i and j depends only on the difference between μ_1 and μ_2.[17] Under this specific case, the result of welfare comparison between the two leagues are summed up in the following proposition.

Proposition 7. *Suppose that $k_1\mu_1 = k_2\mu_2$ and $d_1\mu_1 = d_2\mu_2$. Then, the condition that social welfare is larger in the win maximizers' league than that in the profit maximizers' league is narrower in the model of this study than the model that does not include any environmental problem.*

Proof. See Appendix I. □

The intuition behind Proposition 7 is as follows. In the model of this study, an increase in the quantity of playing talent increases the common value of the match for spectators, thereby increasing attendance, which in turn causes an increase in gross emissions as well as environmental damage. Under a restriction of emissions, each club must abate its emissions and its costs for each club. It costs more in a win maximizers' league than in a profit maximizers' league since the gross emission is larger in a win maximizers' league than in a profit maximizers' league. Therefore, the condition $S^{w*} > S^{p*}$ is narrower in this study's model than in a model that does not address environmental problems.

[17] Under the conditions, $Q_1^{l*}/Q_2^{l*} = D_1(E_1^{l*})/D_2(E_2^{l*}) = (\mu_1/\mu_2)^{1/(1-2\alpha+2\beta)}$.

5 Concluding remarks

This study theoretically examines the effects of a uniform relative emission standard on the equilibrium outcome of a professional sports league. We also investigate whether it improves the competitive balance and social welfare in the league.

Our main findings are as follows. Under a uniform relative emission standard, a club with even a smaller fanbase will have a better chance of winning the league if its abatement cost condition is much better than that of a club with larger fanbase. A few regulations could improve social welfare without changing the competitive balance compared to no regulations. However, a standard set to a zero-emission level is not desirable for social welfare. The competitive balance can vary with the degree of the regulation; therefore, it could also be improved if the league chooses the right degree, paying attention to the abatement cost conditions of both clubs.

We finally discuss three points. First, in this study, we assume that talent is in perfectly elastic supply. If we analyze the case that talent is in perfectly inelastic supply, we can use other theoretical models, a closed case in the model of Vrooman [23], for example. Unfortunately, simply applying a uniform emissions standard to the model in Vrooman [23] does not enable us to derive the equilibrium outcome explicitly because the best response function becomes more dimensional. To solve this problem, the ingenuity of the analysis or model is needed. Second, we can consider other environmental policies: emission tax, quotas, and tradable emission permits. A welfare superiority among environmental policies is also a major interest in environmental economics.[18] It is important to note that the equilibrium results in this study are explicitly derived successfully because a uniform relative emission standard is treated in Madden [16]'s model, and could not be derived successfully for other environmental policies. Finally, we assume the case that pollution relates to the number of spectators. However, we can consider the case wherein pollution does not relate to the number of spectators: the light pollution of the stadium. These are issues for future research.

[18] Lahiri and Ono [13] compares a relative emission standard and an emission tax in terms of social welfare by focusing on the effects of equivalent changes between the two regulations.

Appendix A

How to derive social welfare in profit maximizers' league

Social welfare is defined in (3). We divide social welfare into two categories S_1 and S_2. S_1 represents social welfare in club 1's hometown and S_2 does that in club 2's. First, we derive S_1 by using (6).

$$
\begin{aligned}
S_1 &= \int_0^{v_1 - p_1^{sb}} \mu_1 (v_1 - p_1^{sb} - x) dx + \pi_1 - D_1(E_1), \\
&= \frac{\mu_1 Q_1^{2\alpha} Q_2^{2\beta}}{8\{1 + k_1\mu_1(1-\theta)^2\}^2} + \frac{\{1 + 2k_1\mu_1(1-\theta)^2\}\mu_1 Q_1^{2\alpha} Q_2^{2\beta}}{4\{1 + k_1\mu_1(1-\theta)^2\}^2} - Q_1 - \frac{\{k_1(1-\theta)^2 + d_1\theta^2\}\mu_1^2 Q_1^{2\alpha} Q_2^{2\beta}}{4\{1 + k_1\mu_1(1-\theta)^2\}^2},
\end{aligned}
$$

The first term represents club 1's spectators' surplus, the second term the revenue of club 1, the third the expenditure on playing talent of club 1, and the last term the sum of the abatement cost of club 1 and the environmental damage in club 1's hometown.

Summing up the above expression in the equilibrium and then, we find

$$
S_1^{p*} = Q_1^{p*} \left[\frac{\mu_1 (Q_1^{p*})^{2\alpha - 1} (Q_2^{p*})^{2\beta}}{8\{1 + k_1\mu_1(1-\theta)^2\}^2} \{3 + 2k_1\mu_1(1-\theta)^2 - 2d_1\mu_1\theta^2\} - 1 \right]. \tag{23}
$$

By using the result of Appendix D, Q_2^{p*} becomes

$$
Q_2^{p*} = \left[\frac{\mu_1\{1 + k_2\mu_2(1-\theta)^2\}}{\mu_2\{1 + k_1\mu_1(1-\theta)^2\}} \right]^{\frac{-1}{1-2\alpha+2\beta}} Q_1^{p*}. \tag{24}
$$

Substituting Q_2^{p*} in (24) for Q_2^{p*} in (23) and summing up the expression in square brackets by using (8), we obtain the former parts in (14). The same process for S_2 as for S_1 yields the latter parts in (14).

Appendix B

How to derive the equilibrium quantity of playing talent of each club in the case that clubs are win maximizers

Given $Q_j > 0$, we derive such prices that the budget constraint of club i is the following case: $\pi_i \geq \bar{\pi}$ where $\bar{\pi}$ is non-negative constant ($\bar{\pi} \geq 0$). Solving $\pi_i - \bar{\pi} = 0$ for p_i, we obtain the following prices:

$$p_i^L = \frac{\{1+2k_i\mu_i(1-\theta)^2\}\mu_i Q_i^\alpha Q_j^\beta - \sqrt{\mu_i^2 Q_i^{2\alpha} Q_j^{2\beta} - 4\mu_i(Q_i+\bar{\pi})\{1+k_i\mu_i(1-\theta)^2\}}}{2\{1+k_i\mu_i(1-\theta)^2\}\mu_i},$$

$$p_i^H = \frac{\{1+2k_i\mu_i(1-\theta)^2\}\mu_i Q_i^\alpha Q_j^\beta + \sqrt{\mu_i^2 Q_i^{2\alpha} Q_j^{2\beta} - 4\mu_i(Q_i+\bar{\pi})\{1+k_i\mu_i(1-\theta)^2\}}}{2\{1+k_i\mu_i(1-\theta)^2\}\mu_i},$$

where $\mu_i^2 Q_i^{2\alpha} Q_j^{2\beta} - 4\mu_i(Q_i+\bar{\pi})\{1+k_i\mu_i(1-\theta)^2\} \geq 0$.[19] Subsequently, we derive the range of Q_i where $\mu_i^2 Q_i^{2\alpha} Q_j^{2\beta} - 4\mu_i(Q_i+\bar{\pi})\{1+k_i\mu_i(1-\theta)^2\} \geq 0$ and show that the upper limit of Q_i in the range is maximized at the case that $\bar{\pi} = 0$. The previous equation is transformed into the following expression:

$$\mu_i^2 Q_j^{2\beta} Q_i^{2\alpha} - 4\mu_i\{1+k_i\mu_i(1-\theta)^2\}Q_i \geq 4\mu_i\{1+k_i\mu_i(1-\theta)^2\}\bar{\pi}. \tag{25}$$

The first term of the left-hand side of (25) is the monotonically increasing function in Q_i that satisfies the Inada condition and the second term of that is the linear function in Q_i that passes through the origin. Therefore, we find that the left-hand side of (25) is non-negative in the range that $Q_i \in \left[0, \bar{Q}\right]$, where

$$\bar{Q} = \left(\frac{\mu_i Q_j^{2\beta}}{4\{1+k_i\mu_i(1-\theta)^2\}}\right)^{\frac{1}{1-2\alpha}}. \tag{26}$$

The right-hand side of (25) is a non-negative constant, and therefore, the range of Q_i that satisfies (25) is included in the range that $Q_i \in \left[0, \bar{Q}\right]$ if the right-hand side is not so large. A decrease of $\bar{\pi}$ makes the range wider. Q_i is the largest when $\bar{\pi} = 0$, that is, $Q_i = \bar{Q}$. This is the best response function for club i. We note that $p_i^L = p_i^H$ in this case. By solving the two best response functions of both clubs concerning Q_1 and Q_2, we obtain the equilibrium quantity of playing talent for each club.

Appendix C

Proof of Proposition 1

Proof. Partially differentiating Q_1^{l*} and Q_2^{l*} by θ, we obtain

$$\frac{\partial Q_1^{l*}}{\partial \theta} = \frac{2(1-\theta)Q_1^{l*}\{(1-2\alpha)k_1\mu_1 + 2\beta k_2\mu_2 + (1-2\alpha+2\beta)(1-\theta)^2 k_1k_2\mu_1\mu_2\}}{(1-2\alpha+2\beta)(1-2\alpha-2\beta)\{1+k_1\mu_1(1-\theta)^2\}\{1+k_2\mu_2(1-\theta)^2\}} \geq 0,$$

$$\frac{\partial Q_2^{l*}}{\partial \theta} = \frac{2(1-\theta)Q_2^{l*}\{2\beta k_1\mu_1 + (1-2\alpha)k_2\mu_2 + (1-2\alpha+2\beta)(1-\theta)^2 k_1k_2\mu_1\mu_2\}}{(1-2\alpha+2\beta)(1-2\alpha-2\beta)\{1+k_1\mu_1(1-\theta)^2\}\{1+k_2\mu_2(1-\theta)^2\}} \geq 0,$$

[19]When $\mu_i^2 Q_i^{2\alpha} Q_j^{2\beta} - 4\mu_i(Q_i+\bar{\pi})\{1+k_i\mu_i(1-\theta)^2\} < 0$, there are no positive prices that satisfy the budget constraint.

for $l = p, w$. The strict inequality holds when $\theta \neq 1$.

Partially differentiating A_i^{l*} by θ, we obtain the following result.

$$\frac{\partial A_i^{l*}}{\partial \theta} = \left(\frac{\mu_i}{2}\right)\left[\frac{\left(\frac{\partial v_i^{l*}}{\partial \theta}\right)\{1 + k_i\mu_i(1-\theta)^2\} + 2v_i^{l*}k_i\mu_i(1-\theta)}{\{1 + k_i\mu_i(1-\theta)^2\}^2}\right] \geq 0, \tag{27}$$

where $\partial v_i^{l*}/\partial\theta = \alpha(Q_i^{l*})^{\alpha-1}(Q_j^{l*})^{\beta}(\partial Q_i^{l*}/\partial\theta) + \beta(Q_i^{l*})^{\alpha}(Q_j^{l*})^{\beta-1}(\partial Q_j^{l*}/\partial\theta) \geq 0$ from $\partial Q_i^{l*}/\partial\theta \geq 0$ for $i, j = 1, 2, i \neq j$, $l = p, w$. The strict inequality holds when $\theta \neq 1$.

We easily find $\partial E_i^{l*}/\partial\theta > 0$ since $\partial E_i^{l*}/\partial\theta = A_i^{l*} + \theta\partial A_i^{l*}/\partial\theta$ with (11), (19), and (27). □

Appendix D

Proof of Proposition 2

Proof. Calculating the ratio of the equilibrium outcomes between the two clubs, we obtain the following results: for $l = p, w$,

$$\frac{Q_1^{l*}}{Q_2^{l*}} = \left[\frac{\mu_1\{1 + k_2\mu_2(1-\theta)^2\}}{\mu_2\{1 + k_1\mu_1(1-\theta)^2\}}\right]^{\frac{1}{1-2\alpha+2\beta}}, \quad \frac{A_1^{l*}}{A_2^{l*}}, \frac{a_1^{l*}}{a_2^{l*}}, \frac{E_1^{l*}}{E_2^{l*}} = \left[\frac{\mu_1\{1 + k_2\mu_2(1-\theta)^2\}}{\mu_2\{1 + k_1\mu_1(1-\theta)^2\}}\right]^{\frac{1-\alpha+\beta}{1-2\alpha+2\beta}},$$

$$\frac{p_1^{l*}}{p_2^{l*}} = \left[\left\{\frac{1 + 2k_1\mu_1(1-\theta)^2}{1 + 2k_2\mu_2(1-\theta)^2}\right\}^{1-2\alpha+2\beta}\left\{\frac{1 + k_2\mu_2(1-\theta)^2}{1 + k_1\mu_1(1-\theta)^2}\right\}^{1-\alpha+\beta}\left(\frac{\mu_1}{\mu_2}\right)^{\alpha-\beta}\right]^{\frac{1}{1-2\alpha+2\beta}}.$$

For Q_1^{l*}/Q_2^{l*}, we find the following relation.

$$\frac{Q_1^{l*}}{Q_2^{l*}} > 1 \text{ if and only if } \frac{\mu_1\{1 + k_2\mu_2(1-\theta)^2\}}{\mu_2\{1 + k_1\mu_1(1-\theta)^2\}} > 1,$$

for $l = p, w$. Solving the necessary and sufficient condition for k_1, we obtain the magnitude relation of Q_1^{l*}/Q_2^{l*} in Proposition 2. With respect to other ratio A_1^{l*}/A_2^{l*}, a_1^{l*}/a_2^{l*}, and E_1^{l*}/E_2^{l*}, the same proof can be applied. Summarizing the above results yields Proposition 2. □

Appendix E

Proof of Proposition 3

Proof. Partially differentiating Q_1^{l*}/Q_2^{l*} by θ, we obtain

$$\frac{\partial(Q_1^{l*}/Q_2^{l*})}{\partial\theta} = \frac{2(1-\theta)(k_1\mu_1 - k_2\mu_2)}{(1-2\alpha+2\beta)\{1 + k_1\mu_1(1-\theta)^2\}\{1 + k_2\mu_2(1-\theta)^2\}}\left(\frac{Q_1^{l*}}{Q_2^{l*}}\right), \tag{28}$$

for $l = p, w$. When $\theta = 1$, (28) becomes 0. When $\theta \in [0, 1)$, its sign coincides with the sign of $k_1\mu_1 - k_2\mu_2$, that is,

$$\frac{\partial(Q_1^{l*}/Q_2^{l*})}{\partial\theta} > 0, \text{ if and only if } k_1 > \frac{\mu_2}{\mu_1}k_2, \tag{29}$$

for $l = p, w$. Summing up Proposition 2 and (29), we obtain proposition 3. □

Appendix F

Proof of proposition 4

Proof. Partially differentiating S^{p*} and S^{w*} by θ and substituting 1 for θ, we find

$$\left.\frac{\partial S^{p*}}{\partial\theta}\right|_{\theta=1} = -\frac{1}{\alpha}Q_1^{p*}\left\{d_1\mu_1 + d_2\mu_2\left(\frac{\mu_2}{\mu_1}\right)^{\frac{1}{1-2\alpha+2\beta}}\right\} < 0,$$
$$\left.\frac{\partial S^{w*}}{\partial\theta}\right|_{\theta=1} = -2Q_1^{w*}\left\{d_1\mu_1 + d_2\mu_2\left(\frac{\mu_2}{\mu_1}\right)^{\frac{1}{1-2\alpha+2\beta}}\right\} < 0.$$

□

Appendix G

Proof of proposition 5

Proof. Partially differentiating S^{p*} and S^{w*} by θ and substituting 0 for θ, and then, we obtain the following calculation results:

$$\left.\frac{\partial S^{p*}}{\partial\theta}\right|_{\theta=0} = \frac{Q_1^{p*}(F^p + G^p)}{\alpha(1-2\alpha+2\beta)(1-2\alpha-2\beta)(1+k_1\mu_1)^2(1+k_2\mu_2)^2}, \tag{30}$$
$$\left.\frac{\partial S^{w*}}{\partial\theta}\right|_{\theta=0} = \frac{2Q_1^{w*}(F^w + G^w)}{(1-2\alpha+2\beta)(1-2\alpha-2\beta)(1+k_1\mu_1)^2(1+k_2\mu_2)^2}, \tag{31}$$

where

$$F^p = (1+k_2\mu_2)\left\{(2-7\alpha+6\alpha^2-2\beta^2)k_1\mu_1 + (1-2\alpha)^2k_1^2\mu_1^2 + (3-4\alpha)\beta k_2\mu_2 \right.$$
$$\left. +(2-7\alpha+6\alpha^2+5\beta-8\alpha\beta-2\beta^2)k_1k_2\mu_1\mu_2 + (1-2\alpha)(1-2\alpha+2\beta)k_1^2k_2\mu_1^2\mu_2\right\},$$

$$G^p = (1+k_1\mu_1)\left\{\frac{\mu_2(1+k_1\mu_1)}{\mu_1(1+k_2\mu_2)}\right\}^{\frac{1}{1-2\alpha+2\beta}}\left\{(3-4\alpha)\beta k_1\mu_1 + (2-7\alpha+6\alpha^2-2\beta^2)k_2\mu_2\right.$$
$$\left.+(2-7\alpha+6\alpha^2+5\beta-8\alpha\beta-2\beta^2)k_1k_2\mu_1\mu_2 + (1-2\alpha)^2k_2^2\mu_2^2 + (1-2\alpha)(1-2\alpha+2\beta)k_1k_2^2\mu_1\mu_2^2\right\},$$

$$F^w = (1 + k_2\mu_2)\left\{(1-3\alpha+2\alpha^2-2\beta^2)k_1\mu_1 + \beta k_2\mu_2 + (1-2\alpha+2\beta)(1-\alpha-\beta)k_1k_2\mu_1\mu_2\right\},$$

$$G^w = (1+k_1\mu_1)\left\{\frac{\mu_2(1+k_1\mu_1)}{\mu_1(1+k_2\mu_2)}\right\}^{\frac{1}{1-2\alpha+2\beta}} \{\beta k_1\mu_1 + (1-3\alpha+2\alpha^2-2\beta^2)k_2\mu_2 \\ +(1-2\alpha+2\beta)(1-\alpha-\beta)k_1k_2\mu_1\mu_2\}.$$

The denominators of (30) and (31), Q_1^{p*}, and Q_1^{w*} are positive, and therefore, we check the signs of F^p, G^p, F^w, and G^w. First, we check the signs of F^p and G^p. From the assumption that $1/2 > \alpha + \beta$, we easily find that $3 - 4\alpha > 0$ and $1 - 2\alpha > 0$. Rearranging this assumption, we obtain $1 > 2\alpha + 2\beta$ and $2 > 4\alpha + 4\beta$. Using this inequality, we find the following relation.

$$\begin{aligned} 2-7\alpha+6\alpha^2-2\beta^2 &= (2-3\alpha)(1-2\alpha)-2\beta^2, \\ &> (4\alpha+4\beta-3\alpha)(2\alpha+2\beta-2\alpha)-2\beta^2, \\ &= 2\alpha\beta+6\beta^2 > 0. \end{aligned}$$

Concerning $2-7\alpha+6\alpha^2+5\beta-8\alpha\beta-2\beta^2$, $2-7\alpha+6\alpha^2-2\beta^2$ is positive from the above calculation. With respect to $5\beta-8\alpha\beta$, this is also positive because $\beta+4\beta(1-2\alpha) > 0$. The signs of F^p and G^p are positive respectively, and therefore, the sign of (30) is positive.

Second, we check the signs of F^w and G^w. Concerning $1-3\alpha+2\alpha^2-2\beta^2$, we show that its sign is positive by using the condition that $1 > 2\alpha + 2\beta$:

$$\begin{aligned} 1-3\alpha+2\alpha^2-2\beta^2 &= (1-\alpha)(1-2\alpha)-2\beta^2, \\ &> (2\alpha+2\beta-\alpha)(2\alpha+2\beta-2\alpha)-2\beta^2, \\ &= 2\alpha\beta+2\beta^2 > 0. \end{aligned}$$

From the above results, we find that signs of F^w and G^w are positive respectively, and therefore, the sign of (31) is positive. □

Appendix H

Proof of Proposition 6

Proof. First, we compare the equilibrium quantity of playing talent of each club between the two leagues. From (8) and (16), (9) and (17), we find

$$\frac{Q_i^{p*}}{Q_i^{w*}} = (2\alpha)^{\frac{1}{1-2\alpha-2\beta}}, \tag{32}$$

for $i = 1, 2$. Since $2\alpha < 1$, $Q_i^{p*} < Q_i^{w*}$.

Second, we compare the equilibrium emissions of club i. By using (13), (21), and (32), we find

$$\begin{aligned}\frac{E_i^{p*}}{E_i^{w*}} &= \frac{v_i^{p*}}{v_i^{w*}}, \\ &= \left(\frac{Q_i^{p*}}{Q_i^{w*}}\right)^{\alpha}\left(\frac{Q_j^{p*}}{Q_j^{w*}}\right)^{\beta}, \\ &= (2\alpha)^{\frac{\alpha+\beta}{1-2\alpha-2\beta}} < 1,\end{aligned}$$

for $i, j = 1, 2, i \neq j$. Concerning other ratios A_i^{p*}/A_i^{w*}, a_i^{p*}/a_i^{w*}, and p_i^{p*}/p_i^{w*}, the same calculation results as the above can be obtained. Summarizing the above results yields Proposition 6. □

Appendix I

Proof of Proposition 7

Proof. Suppose that $k_1\mu_1 = k_2\mu_2$ and $d_1\mu_1 = d_2\mu_2$. Then, S^p and S^w is

$$\begin{aligned}S^{p*} &= Q_1^{p*}\left\{1 + \left(\frac{\mu_2}{\mu_1}\right)^{\frac{1}{1-2\alpha+2\beta}}\right\}\left[\frac{3 - 4\alpha + 2(1-2\alpha)k_1\mu_1(1-\theta)^2 - 2d_1\mu_1\theta^2}{4\alpha\{1 + k_1\mu_1(1-\theta)^2\}}\right], \\ S^{w*} &= Q_1^{w*}\left\{1 + \left(\frac{\mu_2}{\mu_1}\right)^{\frac{1}{1-2\alpha+2\beta}}\right\}\left[\frac{1 - 2d_1\mu_1\theta^2}{2\{1 + k_1\mu_1(1-\theta)^2\}}\right].\end{aligned}$$

The ratio of them is as follows.

$$\frac{S^{p*}}{S^{w*}} = (2\alpha)^{\frac{2\alpha+2\beta}{1-2\alpha-2\beta}}\left[\frac{3 - 4\alpha + 2(1-2\alpha)k_1\mu_1(1-\theta)^2 - 2d_1\mu_1\theta^2}{1 - 2d_1\mu_1\theta^2}\right],$$

If there are no environmental problems, that is, $k_i = d_i = 0$, the above equation becomes

$$\frac{S^{p*}}{S^{w*}} = (2\alpha)^{\frac{2\alpha+2\beta}{1-2\alpha-2\beta}}(3 - 4\alpha).$$

This condition is identical to the condition obtained by Madden [16]: $S^{p*} < S^{w*}$ if and only if

$$(2\alpha)^{2\alpha+2\beta}(3 - 4\alpha)^{1-2\alpha-2\beta} < 1. \tag{33}$$

If there are environmental problems and each firm must abate its emissions costly, that is, $d_i > 0$ and $k_i > 0$, we obtain $S^{p*} < S^{w*}$ if and only if

$$(2\alpha)^{2\alpha+2\beta}\left[\frac{3-4\alpha+2(1-2\alpha)k_1\mu_1(1-\theta)^2-2d_1\mu_1\theta^2}{1-2d_1\mu_1\theta^2}\right]^{1-2\alpha-2\beta}<1. \tag{34}$$

When we compare the contents of the second factor on the left-hand side of (33) and (34), we obtain

$$\begin{aligned}3-4\alpha-\frac{3-4\alpha+2(1-2\alpha)k_1\mu_1(1-\theta)^2-2d_1\mu_1\theta^2}{1-2d_1\mu_1\theta^2} &= -\frac{2(1-2\alpha)\{2d_1\mu_1\theta^2+k_1\mu_1(1-\theta)^2\}}{1-2d_1\mu_1\theta^2},\\ &< 0.\end{aligned}$$

From the above result, we find

$$(2\alpha)^{2\alpha+2\beta}(3-4\alpha)^{1-2\alpha-2\beta}<(2\alpha)^{2\alpha+2\beta}\left[\frac{3-4\alpha+2(1-2\alpha)k_1\mu_1(1-\theta)^2-2d_1\mu_1\theta^2}{1-2d_1\mu_1\theta^2}\right]^{1-2\alpha-2\beta}.$$

The result implies that the condition that social welfare is larger in the win maximizers' league than in the profit maximizers' league when there are environmental problems and the emissions that are restricted are narrower than that when there are no environmental problems. □

References

[1] J.C. Bárcena-Ruiz, Environmental taxes and first-mover advantages, Environ. Resour. Econ. 35 (2006) 19-39.
https://doi.org/10.1007/s10640-006-9004-4

[2] H.M. Dietl, M. Grossmann, M. Lang, Competitive balance and revenue sharing in sports leagues with utility-maximizing teams, J. Sports Econ. 12 (2011) 284–308.
https://doi.org/10.1177/1527002511404787

[3] H.M. Dietl, M. Lang, S. Werner, Social welfare in sports leagues with profit-maximizing and/or win-maximizing cubs, South. Econ. J. 76 (2009) 375–396.
https://doi.org/10.4284/sej.2009.76.2.375

[4] U. Ebert, Relative standards: a positive and normative analysis, J. Econ. 67 (1998) 17–38.
https://doi.org/10.1007/BF01227761

[5] M. El Hodiri, J. Quirk, An economic model of a professional sports league, J. Political Econ. 79 (1971) 1302-1319.

https://doi.org/10.1086/259837

[6] S. Falconieri, F. Palomino, J. Sakovics, Collective versus individual sale of television rights in league sports, J. Eur. Econ. Association. 2 (2004) 833-862.

https://doi.org/10.1162/1542476042782305

[7] R. Fort, J. Quirk, Optimal competitive balance single-game ticket leagues, J. Sports Econ. 11 (2010) 587-601.

https://doi.org/10.1177/1527002509359906

[8] R. Fort, J. Quirk, Optimal competitive balance in a season ticket league, Econ. Inq. 49 (2011) 464-473.

https://doi.org/10.1111/j.1465-7295.2010.00264.x

[9] G.E. Helfand, Standards versus standards: the effects of different pollution restrictions, Am. Econ. Rev. 81 (1991) 622–634.

[10] H. Ino, T. Matsumura, The equivalence of emission tax with tax-revenue refund and emission intensity regulation, Econ. Lett. 182 (2019) 126–128.

https://doi.org/10.1016/j.econlet.2019.06.017

[11] H. Ino, T. Matsumura, Optimality of emission pricing policies based on emission intensity targets under imperfect competition, Energy Econ. 98 (2021) 105238.

https://doi.org/10.1016/j.eneco.2021.105238

[12] S. Késenne, The economic theory of professional team sports, an analytical treatment - second edition, Edward Elgar, Cheltenham, UK·Northampton, MA, USA, 2014.

[13] S. Lahiri, Y. Ono, Relative emission standard versus tax under oligopoly: the role of free entry, J. Econ. 91 (2007) 107–128.

https://doi.org/10.1007/s00712-006-0243-1

[14] P. Lin, Y. Pang, Command-and-control regulation, an incentive for pollution abatement, and market structure, J. Regulatory Econ. 57 (2020) 159–180.

https://doi.org/10.1007/s11149-020-09403-2

[15] S.L. Locke, Estimating the impact of major league baseball games on local air pollution, Contemporary Econ. Policy. 37 (2019) 236-244.

https://doi.org/10.1111/coep.12404

[16] P. Madden, Fan welfare maximization is a club objective in a professional sports league, Eur. Econ. Rev. 56 (2012) 560–578.

https://doi.org/10.1016/j.euroecorev.2011.12.006

[17] R. Pal, B. Saha, Pollution tax, partial privatization, and environment, Resour. Energy Econ. 40 (2015) 19–35.

https://doi.org/10.1016/j.reseneeco.2015.01.004

[18] Y. Qin, W. Jing, R. Zhang, Can professional football players adapt to air pollution? J. Sports Econ. 23 (2022) 277–300.

https://doi.org/10.1177/15270025211049793

[19] S. Szymanski, The economic design of sporting contests, J. Econ. Lit. 41 (2003) 1137-1187.

https://doi.org/10.1257/002205103771800004

[20] S. Szymanski, Professional team sports are only a game; the Walrasian fixed-supply conjecture model, contest-Nash equilibrium, and the invariance principle, J. Sports Econ. 5 (2004) 111-126.

https://doi.org/10.1177/1527002503261485

[21] S. Szymanski, S. Késenne, Competitive balance and gate revenue sharing in team sports, J. ind. Econ. 52 (2004) 165-177.

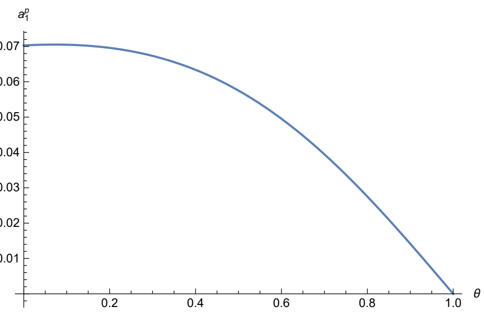
https://doi.org/10.1111/j.0022-1821.2004.00220.x

[22] A. Ulph, Environmental policy and international trade when governments and producers act strategically, J. Environ. Econ. Manag. 30 (1996) 265-281.

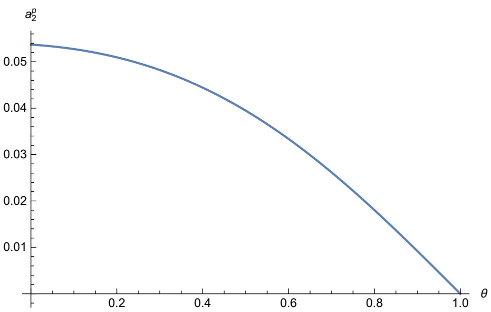
https://doi.org/10.1006/jeem.1996.0018

[23] J. Vrooman, Theory of the perfect game: competitive balance in monopoly sports leagues, Rev. Ind. Org. 34 (2009) 5-44.

https://doi.org/10.1007/s11151-009-9202-7



(a) a_1^{p*}



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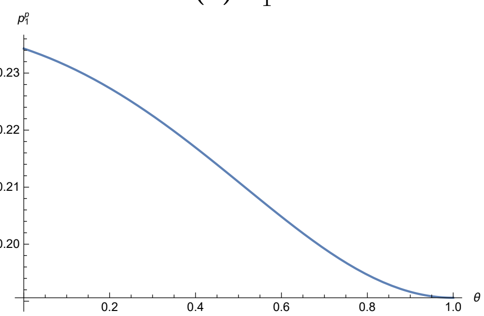

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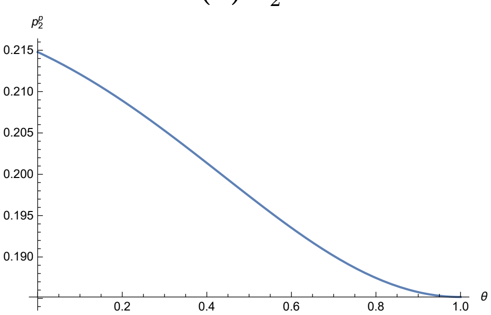
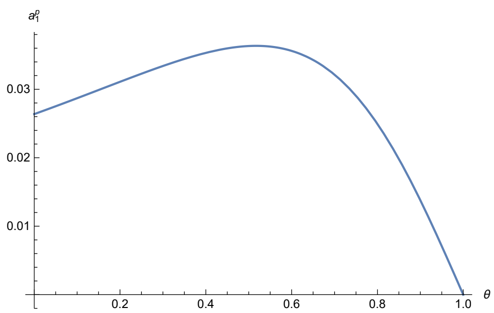


(d) p_2^{p*}

Figure 1: The relationships among a_i^{p*}, p_i^{p*}, and θ in the case that k_1=1, k_2=1; $\alpha = 1/8$, $\beta = 1/16$, $\mu_1 = 3/4$, $\mu_2 = 1/2$



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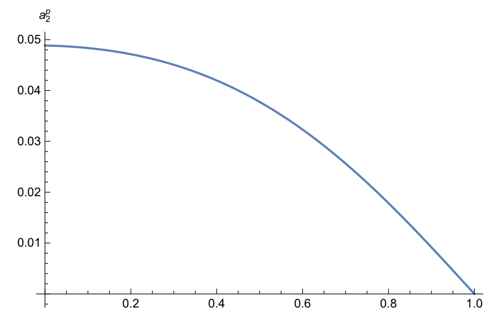

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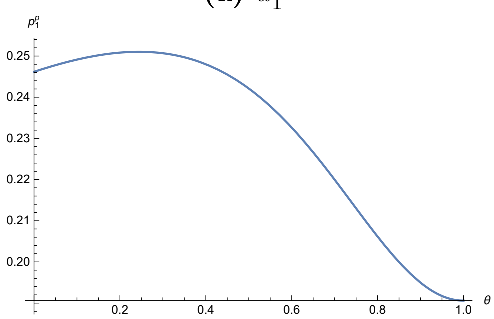

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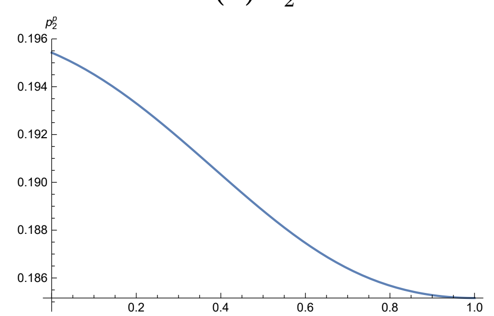
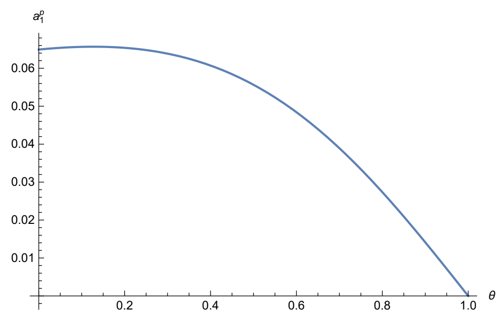


(d) p_2^{p*}

Figure 2: The relationships among a_i^{p*}, p_i^{p*}, and θ in the case that k_1=4, k_2=1; $\alpha = 1/8$, $\beta = 1/16$, $\mu_1 = 3/4$, $\mu_2 = 1/2$



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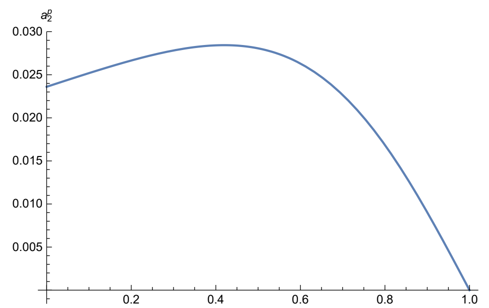

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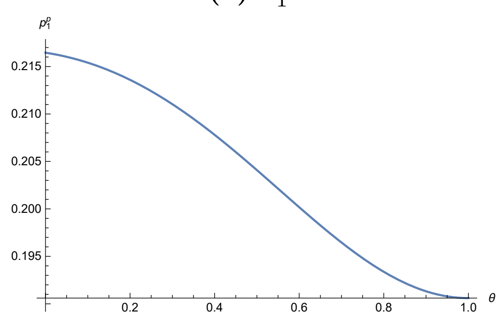

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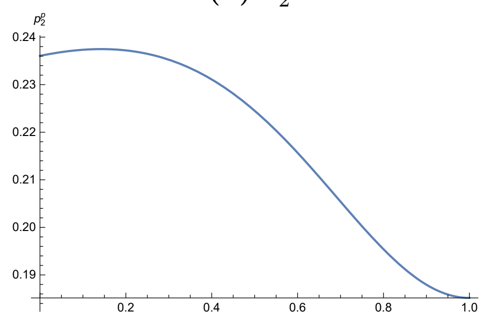
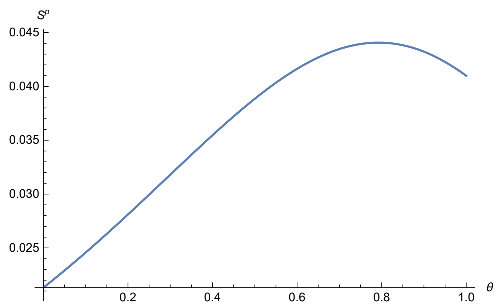
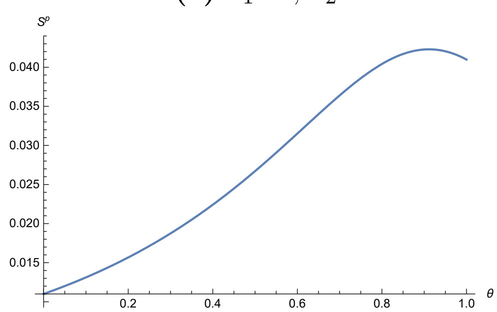


(d) p_2^{p*}

Figure 3: The relationships among a_i^{p*}, p_i^{p*}, and θ in the case that k_1=1, k_2=4; $\alpha = 1/8$, $\beta = 1/16$, $\mu_1 = 3/4$, $\mu_2 = 1/2$



(a) k_1=1, k_2=1



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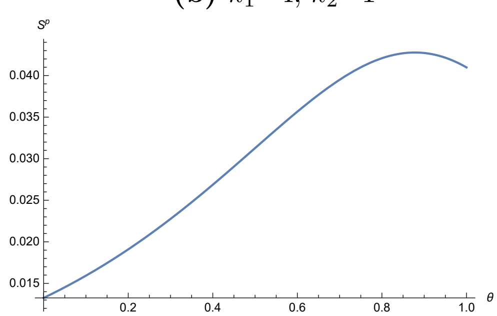

(c) k_1=1, k_2=4

Figure 4: The relationships between S^{p*} and θ in the case that $\alpha = 1/8$, $\beta = 1/16$, $\mu_1 = 3/4$, $\mu_2 = 1/2$