Air Pollution Kills Competition: Evidence from ESports

ONLINE APPENDIX

(Not Intended for Publication)

In this appendix, we collect the analyses, discussions, figures, and tables omitted from the main text.[34]

Appendix A A Stylized Contest Model

In this section, we elaborate on the impact of air pollution on players' decisions and the equilibrium outcome in a simple contest model with asymmetric players. To better connect our model to later empirical analyses, we refer to player(s) as team(s) throughout the section. Our analysis demonstrates that (i) air pollution does not always lead to negative consequences, and may in fact increase the weak team's effort incentive in a game-theoretic environment, and (ii) whether the stronger team is more likely to win upon a negative air-quality shock hinges crucially on how air pollution varies the contest environment (or teams' adaptability to air pollution).

A.1 Model Setup

Consider a contest with two risk-neutral teams, indexed by $i \in \{s, w\}$. The two teams vie for a prize—e.g., a trophy, championship prize, and/or the opportunity to proceed to the next stage—by exerting irreversible efforts simultaneously. The prize carries a common monetary value, which we normalize to unity. Further, we assume a lottery contest success function (CSF) to capture the probabilistic nature of competition: Fixing an effort profile $(x_s, x_w) \geq (0, 0)$, team i wins with a probability

$$p_i(x_s, x_w) = \begin{cases} x_i/(x_s + x_w) & \text{if } x_s + x_w > 0, \\ 1/2 & \text{if } x_s + x_w = 0. \end{cases}$$

Following Moldovanu and Sela (2001, 2006) and Moldovanu et al. (2007), team i's effort cost takes the form of $c(x_i)/a_i$, where $a_i > 0$ refers to the team's ability and $c(\cdot)$ is a strictly increasing and weakly convex function with $c(0) = 0$. Note that a large a_i means that team i is of high ability and vice versa. Without loss of generality, we assume $a_s \geq a_w$.

Given the effort pair (x_s, x_w), team i's expected payoff is

$$\pi_i(x_s, x_w) := p_i(x_s, x_w) - c(x_i)/a_i, i \in \{s, w\}.$$

The $c(\cdot)$ function, together with teams' ability profile (a_s, a_w), defines a simultaneous-move contest game, which we denote by $\langle c(\cdot), (a_s, a_w)\rangle$. By Szidarovszky and Okuguchi (1997) and Cornes and Hartley (2005), there exists a unique pure-strategy equilibrium of the above contest game, which lays a foundation for our subsequent analysis.

For simplicity, we abstract away the free-riding problem within team members in the model laid out above by assuming that a representative player acts on behalf of each team. In Appendix C, we extend the model to allow each team to consist of multiple homogeneous players and show that all of our results remain unchanged.

34. This note is not self-contained; it is the online appendix of the paper "Air Pollution Kills Competition: Evidence from ESports."

A.2 Analysis

Next, we examine the impact of a change in air quality on each team's equilibrium effort and winning probability. Numerous studies have documented the damaging effects of air pollution. For example, Zhang et al. (2018) estimate the contemporaneous and cumulative impacts of air pollution on cognition and show that air pollution impedes cognitive performance. Put differently, it becomes more costly for an agent to achieve the same cognitive performance as air pollution worsens. Inspired by these findings, we model air pollution as an increase in a team's marginal effort cost. More formally, we assume that the deterioration of air quality results in a change in the $c(\cdot)$ function from $c_1(\cdot)$ to $c_2(\cdot)$, with $c_1'(x) < c_2'(x)$ for all $x > 0$.[35]

Remark 1 ***(Impact of Air Pollution in Symmetric Contests)*** *Analysis of the case in which the two teams have the same ability—i.e., $a_s = a_w$—is straightforward. It can be verified that both teams exert the same amount of effort in the unique equilibrium, and thus the two teams have equal probabilities of winning regardless of the level of air pollution. Further, each team's effort in the symmetric equilibrium decreases as $c(\cdot)$ changes from $c_1(\cdot)$ to $c_2(\cdot)$.*

In what follows, we focus on the case in which the two teams have different abilities.

A.2.1 Impact of Air Pollution on Equilibrium Effort

We first analyze the equilibrium individual effort and aggregate effort. For notational convenience, denote team i's equilibrium effort under contest $\langle c_\ell(\cdot), (a_s, a_w)\rangle$ by $x^*_{i,\ell}$, with $\ell \in \{1, 2\}$. Further, define $X^*_\ell := \sum_{i=1}^{2} x^*_{i,\ell}$. Three propositions are in order. All proofs are provided in Appendix B.

Proposition 1 ***(Impact of Air Pollution on Equilibrium Effort)*** *Suppose that the two teams are heterogeneous—i.e., $a_s > a_w$—and consider two strictly increasing and weakly convex functions $c_1(\cdot)$ and $c_2(\cdot)$, with $c_1(0) = c_2(0) = 0$ and $c_1'(x) < c_2'(x)$ for all $x > 0$. The following statements hold as $c(\cdot)$ changes from $c_1(\cdot)$ to $c_2(\cdot)$:*

(i) The strong team's equilibrium effort always decreases, i.e., $x^*_{s,1} > x^*_{s,2}$;

(ii) The weak team's equilibrium effort may either increase or decrease—i.e., both $x^*_{w,1} < x^*_{w,2}$ and $x^*_{w,1} > x^*_{w,2}$ are possible—depending on $c_1(\cdot)$, $c_2(\cdot)$, and (a_s, a_w);

(iii) The aggregate effort of the contest unambiguously decreases, i.e., $X^*_1 > X^*_2$.

By Proposition 1(i), the strong team's effort incentive is dampened when the air quality decreases. The same pattern can be observed for aggregate effort. By Proposition 1(iii), despite the potential effort boost from the weak team, the overall impact of air pollution on the aggregate effort elicited from the competition is clear-cut and negative.

Importantly, the proposition indicates that air pollution does not always lead to negative consequences in a strategic environment. Proposition 1(ii) predicts that the impact of air pollution on the weak team's effort incentive is ambiguous. As previously stated, two effects naturally arise. There is a direct cost effect: Air pollution is counterproductive by nature and the elevated (marginal) cost discourages both teams' efforts. On the other hand, the direct cost effect would trigger an indirect competition effect that comes into play through the reflexive interaction between teams, since each must adjust its effort choice in response to the change in the effort of its opponent. In a typical contest setting, opponents' efforts are strategic complements to the strong team and strategic substitutes to the weak team. In our context,

35. In our model, each team realizes the impact of air pollution on its cost function. We will present empirical support for players' awareness of air pollution and its health effects in Section 5.3.

the concession of the weak team allows the strong team to slack off because of the strategic complementarity, since a lower effort may still render him equally likely to win; a less aggressive strong team—due to the direct cost effect—further incentivizes the weak team to step up its effort because of the strategic substitutability. Note that both the cost and competition effects weaken the strong team's effort incentive, and hence it would reduce effort unambiguously, as stated in Proposition 1(i). In contrast, the weak team's effort choice is subject to competing forces. In particular, when the indirect competition effect outweighs the direct cost effect, the weak team would step up its effort in the equilibrium when the air quality deteriorates.

To proceed, let $\overline{x} := c_1^{-1}(a_s)$. Evidently, choosing an effort level that exceeds $\overline{x}$ yields a negative expected payoff regardless of the opponent's effort level—which is strictly dominated by choosing zero effort—and thus a team's equilibrium effort must lie between 0 and $\overline{x}$. Define $\delta(x) := c_2(x) - c_1(x)$ and $r_1 := \inf_{x\in[0,\overline{x}]} x\delta''(x)/\delta'(x)$. Similarly, define $\mathcal{C}(x;\lambda) := c_1(x) + \lambda\delta(x)$, with $\lambda \in [0,1]$, and $r_2 := \sup_{x\in[0,\overline{x}],\lambda\in[0,1]} x\frac{\partial^2\mathcal{C}(x;\lambda)}{\partial x^2}\big/\frac{\partial\mathcal{C}(x;\lambda)}{\partial x}$. It follows immediately that $c_1(x) = \mathcal{C}(x;0)$ and $c_2(x) = \mathcal{C}(x;1)$. Note that r_1 and r_2 provide an intuitive measure of the curvature of $\delta(\cdot)$ and $\mathcal{C}(\cdot;\lambda)$, respectively.

Our next result spells out sufficient conditions for the weak team's equilibrium effort level to increase or decrease upon a deterioration of the air quality.[36]

Proposition 2 ***(Impact of Air Pollution on the Weak Team's Incentive)*** *Suppose that the two teams are heterogeneous—i.e., $a_s > a_w$—and consider two strictly increasing and weakly convex functions $c_1(\cdot)$ and $c_2(\cdot)$, with $c_1(0) = c_2(0) = 0$ and $c_1'(x) < c_2'(x)$ for all $x > 0$. The following statements hold as $c(\cdot)$ changes from $c_1(\cdot)$ to $c_2(\cdot)$:*

(i) Suppose that $\delta''(x) \le 0$ for all $x \in (0,\overline{x}]$. Then the weak team's equilibrium effort decreases—i.e., $x^*_{w,1} > x^*_{w,2}$.

(ii) Suppose that $\delta''(x) > 0$ for all $x \in (0,\overline{x}]$. Then the weak team's equilibrium effort increases—i.e., $x^*_{w,1} < x^*_{w,2}$—if $r_1 \ge 1$ and

$$\left(\frac{a_s}{a_w}\right)^{\frac{r_1-1}{r_2+1}}\left[\left(\frac{a_s}{a_w}\right)^{\frac{1}{r_2+1}} - 1\right] > r_2\left(\frac{a_s}{a_w}\right)^{\frac{1}{r_2+1}} + r_2 + 2. \tag{6}$$

By Proposition 2, whether the deterioration of the air quality increases or decreases the weak team's equilibrium effort crucially depends on the shape/curvature of the $\delta(\cdot)$ function, i.e., the difference between $c_2(\cdot)$ and $c_1(\cdot)$. Intuitively, a convex effort cost function automatically handicaps the strong team because of its higher effort level, which in turn levels the playing field and fuels competition. When the $\delta(\cdot)$ function is weakly concave, a team is gradually adapted to the increased air pollution level as it continues to increase its effort. Given that the strong team always exerts more effort than the weak one in equilibrium, the equalizing effect triggered by the convexity of the effort cost function tends to lose its appeal, which limits the aforementioned competition effect. As a result, the direction of the weak team's effort response is mainly driven by the direct cost effect and thus decreases, as predicted by Proposition 2(i).

Proposition 2(ii) can again be explained in light of the rationale outlined above. Note that r_1 specifies the lower bound of the convexity of $\delta(\cdot)$ and r_2 gives the upper bound of the convexity of $\mathcal{C}(\cdot;\lambda)$, which we construct based on $c_1(\cdot)$ and $c_2(\cdot)$. The convexity of $\delta(\cdot)$ automatically holds for $r_1 \ge 1$, and condition (6) is likely to be satisfied when (i) a_s/a_w is large; (ii) r_1 is large; and (iii) r_2 is small. Intuitively, the equalizing effect triggered by the convex effort cost function becomes greater when the contest is more asymmetric—i.e., when the ability ratio a_s/a_w is large. Further, this role is magnified when a team becomes less adapted to air pollution as it

36. In Appendix D, we construct a parameterized setting with a linear quadratic effort cost function to illustrate how the conditions established in Propositions 2 and 3 translate into the parameters of the effort cost function.

increases effort—i.e., when $\delta(\cdot)$ is getting more convex—and when the equalizing effect triggered by the convexity of the effort cost function is relative small—i.e., when $\mathcal{C}(\cdot;\lambda)$ is getting less convex.

A.2.2 Impact of Air Pollution on Equilibrium Winning Probabilities

Next, we consider the impact of an air-quality shock on each team's winning probability. Denote team i's equilibrium winning probability under contest $\langle c_\ell(\cdot),(a_s,a_w)\rangle$ by $p^*_{i,\ell}:=x^*_{i,\ell}/X^*_\ell$, with $\ell\in\{1,2\}$. Propositions 1 and 2 already shed some light on the comparative statics. Recall by Proposition 1, that $x^*_{s,1}>x^*_{s,2}$ and $X^*_1>X^*_2$. In addition, $x^*_{w,1}<x^*_{w,2}$ by Proposition 2(ii) if $r_1\geq 1$ and condition (6) is satisfied. Together, these imply that $p^*_{s,1}=1-p^*_{w,1}=1-x^*_{w,1}/X^*_1>1-x^*_{w,2}/X^*_2=1-p^*_{w,2}=p^*_{s,2}$—i.e., the strong team is less likely to win as the air quality deteriorates. However, it remains unknown whether the strong team's equilibrium winning probability would increase in the case in which air pollution discourages both teams' effort incentive—e.g., where $\delta''(x)\leq 0$ for all $x\geq 0$, as required in Proposition 2(ii).

Define $\psi(x;\lambda):=\left[\frac{\partial\mathcal{C}(x;\lambda)}{\partial x}+x\frac{\partial^2\mathcal{C}(x;\lambda)}{\partial x^2}\right]/\delta'(x)$. Our next result demonstrates that the strong team's equilibrium winning probability may increase or decrease and provides sufficient conditions for each possibility to arise.

Proposition 3 ***(Impact of Air Pollution on Equilibrium Winning Probabilities)*** *Suppose that the two teams are heterogeneous—i.e., $a_s>a_w$—and consider two strictly increasing and weakly convex functions $c_1(\cdot)$ and $c_2(\cdot)$, with $c_1(0)=c_2(0)=0$ and $c_1'(x)<c_2'(x)$ for all $x>0$. The following statements hold as $c(\cdot)$ changes from $c_1(\cdot)$ to $c_2(\cdot)$:*

(i) If $\psi(x;\lambda)$ is strictly increasing in x for all $\lambda\in[0,1]$, then $p^*_{s,1}<p^*_{s,2}$.

(ii) If $\psi(x;\lambda)$ is strictly decreasing in x for all $\lambda\in[0,1]$, then $p^*_{s,1}>p^*_{s,2}$.[37]

By Proposition 3, the comparative statics of each team's equilibrium winning probability depends sensitively on the monotonicity of $\psi(\cdot;\lambda)$, which is closely related to the curvatures of $c_1(\cdot)$ and $\delta(\cdot)$. To better understand the intuition, we illustrate with a parameterized example. Set $c_1(x)=\frac{1}{2}x^2$ and $\delta(x)=\frac{1}{k}x^k$, with $k\geq 1$. Simple algebra would then verify that $\mathcal{C}(x;\lambda)=\frac{1}{2}x^2+\lambda\frac{1}{k}x^k$ and thus $\psi(x;\lambda)=\lambda k+2x^{2-k}$. Evidently, the monotonicity of $\psi(\cdot;\lambda)$ relies on the comparison between k and 2, i.e., the convexity of $\delta(\cdot)$ and that of $c_1(\cdot)$. When $\delta(\cdot)$ is more convex—i.e, $k>2$—air pollution erodes the advantage of the strong team as an equalizing device and evens the odds, which leads to $p^*_{s,1}>p^*_{s,2}$. Similarly, when $\delta(\cdot)$ is less convex—i.e, $k<2$—air pollution further tilts the playing field in favor of the strong team and increases its winning probability, i.e., $p^*_{s,1}<p^*_{s,2}$.

Proposition 3 demonstrates that the strong team's equilibrium winning probability may increase or decrease in a more polluted environment, depending on the convexity of the cost function as well as the change in cost function due to the air-quality shock. More generally, the distributional effect of air pollution on equilibrium outcomes is theoretically indeterminant. We next employ data from the world's largest eSports tournament and exploit its quasi-experimental setting to investigate the distributional effects of air pollution.

Appendix B Proofs

Proof of Proposition 1

37. It is straightforward to verify that $p^*_{s,1}=p^*_{s,2}$ if $\psi(x;\lambda)$ is constant with respect to x for all $\lambda\in[0,1]$, which occurs when (i) $c_\ell(x)=\alpha_\ell x$, with $\alpha_2>\alpha_1>0$, or (ii) $c_\ell(x)=\beta_\ell\frac{x^2}{2}$, with $\beta_2>\beta_1>0$.

Proof. Part (ii) of the proposition follows from Proposition 2, and it suffices to prove parts (i) and (iii). The equilibrium effort pair under contest $\langle c(\cdot), (a_s, a_w)\rangle$, which we denoted by (x_s^*, x_w^*), is governed by the first-order conditions $\frac{\partial \pi_s(x_s, x_w^*)}{\partial x_s}\big|_{x_s = x_s^*} = 0$ and $\frac{\partial \pi_w(x_s^*, x_w)}{\partial x_w}\big|_{x_w = x_w^*} = 0$, which can be rewritten as follows:

$$a_s p_{w,\ell}^* = X_\ell^* c_\ell'(x_{s,\ell}^*),\ a_w p_{s,\ell}^* = X_\ell^* c_\ell'(x_{w,\ell}^*),\ \text{for } \ell \in \{1, 2\}, \tag{7}$$

where $p_{i,\ell}^* := x_{i,\ell}^*/X_\ell^*$ is team i's equilibrium winning probability under contest $\langle c_\ell(\cdot), (a_s, a_w)\rangle$, as defined in the main text.

We first show $X_1^* > X_2^*$. Suppose, to the contrary, that $X_1^* \leq X_2^*$. Then we must have $p_{s,1}^* > p_{s,2}^*$; otherwise, we have that

$$a_s(1 - p_{s,1}^*) = X_1^* c_1'(X_1^* p_{s,1}^*) \leq X_2^* c_2'(X_2^* p_{s,2}^*) = a_s(1 - p_{s,2}^*),$$

where the two equalities follow from (7) and inequality from the postulated $X_1^* \leq X_2^*$, $p_{s,1}^* \leq p_{s,2}^*$, and the definition of $c_1(\cdot)$ and $c_2(\cdot)$. A contradiction. Similarly, we can show $p_{w,1}^* > p_{w,2}^*$ if $X_1^* \leq X_2^*$. Together, these imply that

$$1 = p_{s,1}^* + p_{w,1}^* > p_{s,2}^* + p_{w,2}^* = 1,$$

which is a contradiction.

Next, we show that $x_{s,1}^* > x_{s,2}^*$. It is straightforward to verify that $p_{s,\ell}^* > \frac{1}{2} > p_{w,\ell}^*$ for $\ell \in \{1, 2\}$ given $a_s > a_w$. If $p_{s,1}^* \geq p_{s,2}^*$, then $x_{s,1}^* = X_1^* p_{s,1}^* > X_2^* p_{s,2}^* = x_{s,2}^*$. If $p_{s,1}^* < p_{s,2}^*$, then we have that

$$\begin{aligned} x_{s,1}^* c_1'(x_{s,1}^*) = p_{s,1}^* X_1^* c_1'(x_{s,1}^*) = a_s p_{s,1}^* p_{w,1}^* \\ > a_s p_{s,2}^* p_{w,2}^* = p_{s,2}^* X_2^* c_2'(x_{s,2}^*) = x_{s,2}^* c_2'(x_{s,2}^*) > x_{s,2}^* c_1'(x_{s,2}^*), \end{aligned}$$

where the first and fourth equalities follow from the definition of $p_{i,\ell}^*$; the second and third equalities from (7); the first inequality from $p_{w,\ell}^* = 1 - p_{s,\ell}^*$ and $p_{s,1}^* < p_{s,2}^*$; and the last inequality from the assumption that $c_2'(x) > c_1'(x)$ for all $x > 0$. The above condition, together with the weak convexity of $c_1(\cdot)$, again implies $x_{s,1}^* > x_{s,2}^*$. This concludes the proof. ■

Proof of Proposition 2

Proof. Fixing $\lambda \in [0, 1]$, $\mathcal{C}(x; \lambda) := c_1(x) + \lambda\delta(x) = \lambda c_2(x) + (1 - \lambda)c_1(x)$ is an increasing and convex function of x. Denote the equilibrium effort pair under contest $\langle \mathcal{C}(x; \lambda), (a_s, a_w)\rangle$ by $\big(x_s^*(\lambda), x_w^*(\lambda)\big)$. It is evident that $x_{w,1}^* = x_w^*(0)$ and $x_{w,2}^* = x_w^*(1)$. Further, (7) can be rewritten as follows:

$$\frac{a_s x_w^*(\lambda)}{\big[x_s^*(\lambda) + x_w^*(\lambda)\big]^2} = \frac{\partial \mathcal{C}\left(x_s^*(\lambda); \lambda\right)}{\partial x}, \tag{8}$$

$$\frac{a_w x_s^*(\lambda)}{\big[x_s^*(\lambda) + x_w^*(\lambda)\big]^2} = \frac{\partial \mathcal{C}\left(x_w^*(\lambda); \lambda\right)}{\partial x}. \tag{9}$$

Taking derivative of (8) and (9) with respect to λ yields that

$$\begin{aligned} (x_w^*)'(\lambda) = \frac{1}{\mathcal{M}} \Bigg\{ & \frac{\delta'\left(x_s^*(\lambda)\right) \frac{\partial \mathcal{C}\left(x_w^*(\lambda);\lambda\right)}{\partial x} \left[x_s^*(\lambda) - x_w^*(\lambda)\right]}{x_s^*(\lambda)\left[x_s^*(\lambda) + x_w^*(\lambda)\right]} \\ & - \delta'\left(x_w^*(\lambda)\right) \left[\frac{\partial^2 \mathcal{C}\left(x_w^*(\lambda); \lambda\right)}{\partial x^2} + \frac{2\frac{\partial \mathcal{C}\left(x_w^*(\lambda);\lambda\right)}{\partial x}}{x_s^*(\lambda) + x_w^*(\lambda)}\right] \Bigg\}, \end{aligned}$$

where

$$\mathcal{M} := \underbrace{\left[\frac{\partial^2 \mathcal{C}\left(x_w^*(\lambda);\lambda\right)}{\partial x^2} + \frac{2\frac{\partial \mathcal{C}\left(x_w^*(\lambda);\lambda\right)}{\partial x}}{x_s^*(\lambda)+x_w^*(\lambda)}\right]}_{>0} \times \underbrace{\left[\frac{\partial^2 \mathcal{C}\left(x_s^*(\lambda);\lambda\right)}{\partial x^2} + \frac{2\frac{\partial \mathcal{C}\left(x_s^*(\lambda);\lambda\right)}{\partial x}}{x_s^*(\lambda)+x_w^*(\lambda)}\right]}_{>0}$$
$$+ \underbrace{\frac{\frac{\partial \mathcal{C}\left(x_s^*(\lambda);\lambda\right)}{\partial x}\frac{\partial \mathcal{C}\left(x_w^*(\lambda);\lambda\right)}{\partial x}\left[x_s^*(\lambda)-x_w^*(\lambda)\right]^2}{x_s^*(\lambda)x_w^*(\lambda)\left[x_s^*(\lambda)+x_w^*(\lambda)\right]^2}}_{>0} > 0.$$

Therefore, $(x_w^*)'(\lambda) > 0$ is equivalent to

$$\underbrace{\frac{\delta'\left(x_s^*(\lambda)\right)}{\delta'\left(x_w^*(\lambda)\right)} \times \frac{x_s^*(\lambda)-x_w^*(\lambda)}{x_s^*(\lambda)+x_w^*(\lambda)}}_{\mathcal{LHS}} > \underbrace{\frac{x_s^*(\lambda)}{x_w^*(\lambda)} \times \left[\frac{x_w^*(\lambda)\frac{\partial^2 \mathcal{C}\left(x_w^*(\lambda);\lambda\right)}{\partial x^2}}{\frac{\partial \mathcal{C}\left(x_w^*(\lambda);\lambda\right)}{\partial x}} + \frac{2x_w^*(\lambda)}{x_s^*(\lambda)+x_w^*(\lambda)}\right]}_{\mathcal{RHS}}.$$

We first prove part (i) of the proposition. Suppose that $\delta''(x) \leq 0$ for all $x \in [0, \overline{x}]$. Then we can obtain

$$\mathcal{LHS} \leq \frac{x_s^*(\lambda)-x_w^*(\lambda)}{x_s^*(\lambda)+x_w^*(\lambda)} < \frac{2x_s^*(\lambda)}{x_s^*(\lambda)+x_w^*(\lambda)} \leq \mathcal{RHS},$$

where the first two inequalities follow from the weak concavity of $\delta(\cdot)$ and $x_s^*(\lambda) > x_w^*(\lambda) > 0$ and the last inequality from the convexity of $\mathcal{C}(\cdot;\lambda)$. Therefore, $x_w^*(\lambda)$ is decreasing in λ for $\lambda \in [0,1]$, which in turn implies that $x_{w,2}^* = x_w^*(1) < x_w^*(0) = x_{w,1}^*$.

Next, we prove part (ii). For notational convenience, define $k(\lambda) := x_s^*(\lambda)/x_w^*(\lambda) > 1$. Recall $r_2 := \sup_{x\in[0,\overline{x}],\lambda\in[0,1]} x\frac{\partial^2\mathcal{C}(x;\lambda)}{\partial x^2}\Big/\frac{\partial \mathcal{C}(x;\lambda)}{\partial x}$. Then $\mathcal{RHS}$ can be bounded from above by

$$\mathcal{RHS} \equiv \frac{x_s^*(\lambda)}{x_w^*(\lambda)} \times \left[\frac{x_w^*(\lambda)\frac{\partial^2 \mathcal{C}\left(x_w^*(\lambda);\lambda\right)}{\partial x^2}}{\frac{\partial \mathcal{C}\left(x_w^*(\lambda);\lambda\right)}{\partial x}} + \frac{2x_w^*(\lambda)}{x_s^*(\lambda)+x_w^*(\lambda)}\right] \leq k(\lambda) \times \left(r_2 + \frac{2}{k(\lambda)+1}\right). \tag{10}$$

Further, it follows from $\frac{\partial^2\mathcal{C}(x;\lambda)}{\partial x^2}\Big/\frac{\partial \mathcal{C}(x;\lambda)}{\partial x} \leq r_2/x$ for $x \in \left[x_w^*(\lambda), x_s^*(\lambda)\right]$ that

$$\begin{aligned}\ln\left(\frac{\partial \mathcal{C}(x_s^*(\lambda);\lambda)}{\partial x}\right) - \ln\left(\frac{\partial \mathcal{C}(x_w^*(\lambda);\lambda)}{\partial x}\right) &= \int_{x_w^*(\lambda)}^{x_s^*(\lambda)} \frac{\frac{\partial^2\mathcal{C}(x;\lambda)}{\partial x^2}}{\frac{\partial \mathcal{C}(x;\lambda)}{\partial x}} dx \\ &\leq \int_{x_w^*(\lambda)}^{x_s^*(\lambda)} \frac{r_2}{x} dx = r_2\left[\ln\left(x_s^*(\lambda)\right) - \ln\left(x_w^*(\lambda)\right)\right].\end{aligned}$$

The above inequality, together with (8) and (9), implies that

$$\frac{a_s}{a_w} = \frac{x_s^*(\lambda)}{x_w^*(\lambda)} \times \frac{\frac{\partial \mathcal{C}\left(x_s^*(\lambda);\lambda\right)}{\partial x}}{\frac{\partial \mathcal{C}\left(x_w^*(\lambda);\lambda\right)}{\partial x}} \leq \left[\frac{x_s^*(\lambda)}{x_w^*(\lambda)}\right]^{r_2+1} \implies k(\lambda) \geq \left(\frac{a_s}{a_w}\right)^{\frac{1}{r_2+1}}. \tag{11}$$

By the same argument, we can obtain

$$\frac{\delta'\left(x_s^*(\lambda)\right)}{\delta'\left(x_w^*(\lambda)\right)} \geq \left[k(\lambda)\right]^{r_1},$$

where $r_1 := \inf_{x\in[0,\overline{x}]} x\delta''(x)/\delta'(x)$. Therefore, $\mathcal{LHS}$ can be bounded from below by

$$\mathcal{LHS} \equiv \frac{\delta'\left(x_s^*(\lambda)\right)}{\delta'\left(x_w^*(\lambda)\right)} \times \frac{x_s^*(\lambda) - x_w^*(\lambda)}{x_s^*(\lambda) + x_w^*(\lambda)} \geq \left[k(\lambda)\right]^{r_1} \times \frac{k(\lambda)-1}{k(\lambda)+1}. \tag{12}$$

Combining (10) and (12), we can obtain that

$$\begin{aligned}
\mathcal{RHS} - \mathcal{LHS} &\leq k(\lambda) \times \left(r_2 + \frac{2}{k(\lambda)+1}\right) - \left[k(\lambda)\right]^{r_1} \times \frac{k(\lambda)-1}{k(\lambda)+1} \\
&= k(\lambda) \times \left[\left(r_2 + \frac{2}{k(\lambda)+1}\right) - \left[k(\lambda)\right]^{r_1-1} \times \frac{k(\lambda)-1}{k(\lambda)+1}\right] \\
&\leq k(\lambda) \times \underbrace{\left[\left(r_2 + \frac{2}{\left(\frac{a_s}{a_w}\right)^{\frac{1}{r_2+1}}+1}\right) - \left(\frac{a_s}{a_w}\right)^{\frac{r_1-1}{r_2+1}} \times \frac{\left(\frac{a_s}{a_w}\right)^{\frac{1}{r_2+1}}-1}{\left(\frac{a_s}{a_w}\right)^{\frac{1}{r_2+1}}+1}\right]}_{\mathcal{G}},
\end{aligned}$$

where the last inequality follows from $r_1 \geq 1$ and (11). Carrying out the algebra, $\mathcal{G} < 0$ is equivalent to

$$\left(\frac{a_s}{a_w}\right)^{\frac{r_1-1}{r_2+1}} \left[\left(\frac{a_s}{a_w}\right)^{\frac{1}{r_2+1}} - 1\right] > r_2 \left(\frac{a_s}{a_w}\right)^{\frac{1}{r_2+1}} + r_2 + 2,$$

which corresponds to (6) required in part (ii) of the proposition. To summarize, if $r_1 \geq 1$ and (6) is satisfied, then $(x_w^*)'(\lambda) > 0$ for all $\lambda \in [0,1]$, which in turn implies that $x_{w,2}^* = x_w^*(1) > x_w^*(0) = x_{w,1}^*$ and concludes the proof. ∎

Proof of Proposition 3

Proof. Recall $\mathcal{C}(x;\lambda) := c_1(x) + \lambda\delta(x)$ and that we denote the equilibrium effort pair under contest $\langle \mathcal{C}(x;\lambda), (a_s, a_w)\rangle$ by $\left(x_s^*(\lambda), x_w^*(\lambda)\right)$ in the proof of Proposition 2. For notational convenience, denote the resultant total effort and the corresponding equilibrium winning probabilities by $X^*(\lambda)$ and $\left(p_s^*(\lambda), p_w^*(\lambda)\right)$, respectively. The first-order conditions (8) and (9) can be rewritten as follows:

$$\begin{aligned}
a_s p_w^*(\lambda) &= X^*(\lambda)\frac{\partial \mathcal{C}\left(X^*(\lambda)p_s^*(\lambda);\lambda\right)}{\partial x}, \\
a_w p_s^*(\lambda) &= X^*(\lambda)\frac{\partial \mathcal{C}\left(X^*(\lambda)p_w^*(\lambda);\lambda\right)}{\partial x}.
\end{aligned}$$

Taking derivative of the above two equations with respect to λ and exploiting the fact that $dp_s^*(\lambda)/d\lambda = -dp_w^*(\lambda)/d\lambda$, we can obtain that

$$\frac{dp_s^*(\lambda)}{d\lambda} = \frac{X^*(\lambda)\delta'\left(x_s^*(\lambda)\right)\delta'\left(x_w^*(\lambda)\right)\left[\psi\left(x_s^*(\lambda);\lambda\right) - \psi\left(x_w^*(\lambda);\lambda\right)\right]}{\mathcal{Q}},$$

where

$$\mathcal{Q} := \underbrace{\left\{a_w + \left[X^*(\lambda)\right]^2 \times \frac{\partial^2 \mathcal{C}(x_w^*(\lambda);\lambda)}{\partial x^2}\right\}}_{>0} \underbrace{\psi\left(x_s^*(\lambda);\lambda\right)}_{>0} \underbrace{\delta'\left(x_s^*(\lambda)\right)}_{>0}$$

$$+\underbrace{\left\{a_s+\left[X^*(\lambda)\right]^2\frac{\partial^2\mathcal{C}(x_s^*(\lambda);\lambda)}{\partial x^2}\right\}}_{>0}\underbrace{\psi\left(x_w^*(\lambda);\lambda\right)}_{>0}\underbrace{\delta'\left(x_w^*(\lambda)\right)}_{>0}>0.$$

Therefore, $dp_s^*(\lambda)/d\lambda>0$ is equivalent to

$$\psi\left(x_s^*(\lambda);\lambda\right)>\psi\left(x_w^*(\lambda);\lambda\right).$$

Suppose that $\psi(x;\lambda)$ strictly increases with x for all $\lambda\in[0,1]$. It follows immediately from $x_s^*(\lambda)>x_w^*(\lambda)$ that $\psi\left(x_s^*(\lambda);\lambda\right)>\psi\left(x_w^*(\lambda);\lambda\right)$ and thus $dp_s^*(\lambda)/d\lambda>0$. Therefore, we can obtain that $p_{s,2}^*=p_s^*(1)>x_s^*(0)=p_{s,1}^*$. Similarly, we can show $p_{s,2}^*<p_{s,1}^*$ if $\psi(x;\lambda)$ strictly decreases with x for all $\lambda\in[0,1]$. This concludes the proof. ■

Appendix C Multiple Players on Each Team

In the baseline model, we assume that a representative player acts on behalf of each team. Next, we extend the model to allow for multiple players within a team and show that all of our results continue to hold. To distinguish between the two settings, we call the former an individual contest and the latter a group contest.

Suppose that each team has $n\geq 2$ identical individual players. The players on team $i\in\{s,w\}$ are indexed by $ij\in\{i1,\ldots,in\}$. Players in both teams simultaneously and independently choose effort levels $x_{ij}\geq 0$. The cost of effort x_{ij} to player ij is $\tilde{c}(x_{ij})/\tilde{a}_i$, where $\tilde{a}_i>0$ represents the team's ability and $\tilde{c}(\cdot)$ is a strictly increasing and weakly convex function with $\tilde{c}(0)=0$. The value an individual player receives from winning the contest is again normalized to unity.

Following Kolmar and Rommeswinkel (2013); Brookins et al. (2018); and Crutzen et al. (2020), we assume that the probability of team $i\in\{s,w\}$ winning the contest given the effort profile $(\boldsymbol{x}_s,\boldsymbol{x}_w):=\langle(x_{s1},\ldots,x_{sn}),(x_{w1},\ldots,x_{wn})\rangle$ is

$$\tilde{p}_i(\boldsymbol{x}_s,\boldsymbol{x}_w)=\begin{cases}\widetilde{\mathcal{X}}_i/(\widetilde{\mathcal{X}}_s+\widetilde{\mathcal{X}}_w) & \text{if } \widetilde{\mathcal{X}}_s+\widetilde{\mathcal{X}}_w>0,\\ 1/2 & \text{if } \widetilde{\mathcal{X}}_s+\widetilde{\mathcal{X}}_w=0,\end{cases}$$

where $\widetilde{\mathcal{X}}_i$ is given by the constant elasticity of substitution (CES) aggregation function of the efforts exerted by individual team members. That is,[38]

$$\widetilde{\mathcal{X}}_i:=\left(\frac{1}{n}\sum_{j=1}^{n}x_{ij}^{\rho}\right)^{1/\rho},\ \text{for } i\in\{s,w\},\ \text{with } \rho<1.$$

The parameter $1-\rho$ measures the degree of complementarity between individual efforts within a team.

The expected payoff of player ij is

$$\tilde{\pi}_{ij}(\boldsymbol{x}_s,\boldsymbol{x}_w):=\tilde{p}_i(\boldsymbol{x}_s,\boldsymbol{x}_w)-\tilde{c}(x_{ij})/\tilde{a}_i, i\in\{s,w\}, j\in\{1,\ldots,n\}.$$

The function $\tilde{c}(\cdot)$, together with teams' ability profile $(\tilde{a}_s,\tilde{a}_w)$ and the number of players in each team $n\geq 2$, defines a simultaneous-move group contest game, which we denote by $\langle\tilde{c}(\cdot),(\tilde{a}_s,\tilde{a}_w),n\rangle$. Denote player ij's equilibrium effort by $\tilde{x}_{ij}^*$. Recall that the individual contest game analyzed in the main text is denoted by $\langle c(\cdot),(a_s,a_w)\rangle$. The following result ensues.

38. See also Ray et al. (2007) and Cornes and Hartley (2007) for the use of CES production functions.

Proposition 4 *There exists a unique pure-strategy equilibrium of the group contest game $\langle \tilde{c}(\cdot), (\tilde{a}_s, \tilde{a}_w), n\rangle$, in which all individual players on each team remain active and exert the same amount of effort—i.e., $\tilde{x}_{i1}^* = \cdots = \tilde{x}_{in}^* =: \tilde{x}_i^* > 0$ for $i \in \{s, w\}$. Furthermore, $\tilde{x}_i^* = x_i^*$ for $i \in \{s, w\}$, where x_i^* is the equilibrium effort of team i under the individual contest $\langle c(\cdot), (a_s, a_w)\rangle = \langle \tilde{c}(x), (\tilde{a}_s/n, \tilde{a}_w/n)\rangle$.*

Proof. We first show that all individual players must exert the same amount of effort in equilibrium. Fix two arbitrary players ij and ij', with $i \in \{s, w\}$, $j, j' \in \{1, \ldots, n\}$, and $j \neq j'$. It is straightforward to verify that an individual player must remain active in equilibrium. Therefore, the following first-order conditions must be satisfied in equilibrium:

$$\frac{\tilde{a}_i \left(\widetilde{\mathcal{X}}_s + \widetilde{\mathcal{X}}_w - \widetilde{\mathcal{X}}_i\right)}{\left(\widetilde{\mathcal{X}}_s + \widetilde{\mathcal{X}}_w\right)^2} \times \left.\frac{\partial \widetilde{\mathcal{X}}_i}{\partial \tilde{x}_{ij}}\right|_{\tilde{x}_{ij} = \tilde{x}_{ij}^*} = \tilde{c}'(\tilde{x}_{ij}^*), \tag{13}$$

and

$$\frac{\tilde{a}_i \left(\widetilde{\mathcal{X}}_s + \widetilde{\mathcal{X}}_w - \widetilde{\mathcal{X}}_i\right)}{\left(\widetilde{\mathcal{X}}_s + \widetilde{\mathcal{X}}_w\right)^2} \times \left.\frac{\partial \widetilde{\mathcal{X}}_i}{\partial \tilde{x}_{ij'}}\right|_{\tilde{x}_{ij'} = \tilde{x}_{ij'}^*} = \tilde{c}'(\tilde{x}_{ij'}^*), \tag{14}$$

Suppose, to the contrary, that $\tilde{x}_{ij}^* \neq \tilde{x}_{ij'}^*$. Without loss of generality, assume $\tilde{x}_{ij}^* > \tilde{x}_{ij'}^*$. It can then be verified that $\partial \widetilde{\mathcal{X}}_i / \partial \tilde{x}_{ij}|_{\tilde{x}_{ij} = \tilde{x}_{ij}^*} < \partial \widetilde{\mathcal{X}}_i / \partial \tilde{x}_{ij'}|_{\tilde{x}_{ij'} = \tilde{x}_{ij'}^*}$ and $\tilde{c}'(\tilde{x}_{ij}^*) \geq \tilde{c}'(\tilde{x}_{ij'}^*)$, from which we can obtain

$$\tilde{c}'(\tilde{x}_{ij}^*) \Big/ \left.\frac{\partial \widetilde{\mathcal{X}}_i}{\partial \tilde{x}_{ij}}\right|_{\tilde{x}_{ij} = \tilde{x}_{ij}^*} > \tilde{c}'(\tilde{x}_{ij'}^*) \Big/ \left.\frac{\partial \widetilde{\mathcal{X}}_i}{\partial \tilde{x}_{ij'}}\right|_{\tilde{x}_{ij'} = \tilde{x}_{ij'}^*}. \tag{15}$$

However, combining (13) and (14) yields that

$$\tilde{c}'(\tilde{x}_{ij}^*) \Big/ \left.\frac{\partial \widetilde{\mathcal{X}}_i}{\partial \tilde{x}_{ij}}\right|_{\tilde{x}_{ij} = \tilde{x}_{ij}^*} = \tilde{c}'(\tilde{x}_{ij'}^*) \Big/ \left.\frac{\partial \widetilde{\mathcal{X}}_i}{\partial \tilde{x}_{ij'}}\right|_{\tilde{x}_{ij'} = \tilde{x}_{ij'}^*},$$

which contradicts (15). Therefore, we must have $\tilde{x}_{ij}^* = \tilde{x}_{ij'}^*$.

Next, substituting $\tilde{x}_i^* := \tilde{x}_{i1}^* = \cdots = \tilde{x}_{in}^*$ into (13) or (14) yields that

$$\frac{\tilde{a}_i}{n} \times \frac{\tilde{x}_s^* + \tilde{x}_w^* - \tilde{x}_i^*}{(\tilde{x}_s^* + \tilde{x}_w^*)^2} = \tilde{c}'(\tilde{x}_i^*), \text{ for } i \in \{s, w\}. \tag{16}$$

Note that the equilibrium effort of team i in the baseline model in the main text is governed by

$$a_i \times \frac{x_s^* + x_w^* - x_i^*}{(x_s^* + x_w^*)^2} = \tilde{c}'(x_i^*), \text{ for } i \in \{s, w\}. \tag{17}$$

Comparing (16) and (17), it is straightforward to see that $\tilde{x}_i^* = x_i^*$ for $i \in \{s, w\}$, where x_i^* in the equilibrium effort of team i under individual contest $\langle c(\cdot), (a_s, a_w)\rangle = \langle \tilde{c}(x), (\tilde{a}_s/n, \tilde{a}_w/n)\rangle$. This concludes the proof. ■

By Proposition 4, the results established under individual contests in the main text remain intact under group contests in which each team consists of two or more homogeneous players.

Appendix D Linear Quadratic Effort Cost

Example 1 ***(Linear Quadratic Effort Cost)*** *Suppose that the two teams are heterogeneous—i.e., $a_s > a_w$—and the $c_\ell(\cdot)$ function takes the form $c_\ell(x) = \alpha_\ell x + \beta_\ell \frac{x^2}{2}$, with $\alpha_2 \geq \alpha_1 \geq 0$, $\beta_2 \geq \beta_1 \geq 0$, and $\ell \in \{1, 2\}$. The following statements hold:*

(i) Suppose that $\alpha_2 > \alpha_1 = 0$ and $\beta_2 = \beta_1 > 0$. In other words, we start with a quadratic $c_1(\cdot)$ function and add a linear component to obtain $c_2(\cdot)$. Then $\delta(x) = (\alpha_2 - \alpha_1)x$ is linear and thus $\delta''(x) = 0$. By Proposition 2(i), we can obtain $x^*_{w,1} > x^*_{w,2}$.

(ii) Suppose that $\alpha_2 = \alpha_1 > 0$ and $\beta_2 > \beta_1 = 0$. That is, we start with a linear $c_1(\cdot)$ function and add a quadratic term to obtain $c_2(\cdot)$. Then $\delta(x) = (\beta_2 - \beta_1)\frac{x^2}{2}$ is convex and $\overline{x} = a_s$, from which we can obtain $r_1 = \inf_{x\in[0,\overline{x}]} x\delta''(x)/\delta'(x) = 1$ and $r_2 = \sup_{x\in[0,a_s],\lambda\in[0,1]} \frac{\beta_2\lambda x}{\alpha_2+\beta_2\lambda x} = \frac{\beta_2 a_s}{\alpha_2+\beta_2 a_s}$. Note that r_2 degenerates to zero as β_2 approaches zero. With slight abuse of notation, denote the equilibrium effort profile under $c_2(\cdot) = \alpha_2 x + \beta_2\frac{x^2}{2}$ by $\left(x^*_s(\beta_2), x^*_w(\beta_2)\right)$. It follows immediately that $x^*_{w,1} = x^*_w(0)$ and $x^*_{w,2} = x^*_w(\beta_2)$. We can show that $(x^*_w)'(0) > 0$ if and only if $a_s/a_w > 3$.

Proof. First-order conditions (8) and (9) can be expressed as follows:

$$\frac{a_s x^*_w(\beta_2)}{\left[x^*_s(\beta_2) + x^*_w(\beta_2)\right]^2} = \alpha + \beta_2 x^*_s(\beta_2), \tag{18}$$
$$\frac{a_w x^*_s(\beta_2)}{\left[x^*_s(\beta_2) + x^*_w(\beta_2)\right]^2} = \alpha + \beta_2 x^*_w(\beta_2). \tag{19}$$

Next, we show that $(x^*_w)'(0) > 0$ if and only if $a_s/a_s > 3$.

Substituting $\beta_2 = 0$ into (18) and (19) yields that

$$\frac{a_s x^*_w(0)}{\left[x^*_s(0) + x^*_w(0)\right]^2} = \alpha, \tag{20}$$
$$\frac{a_w x^*_s(0)}{\left[x^*_s(0) + x^*_w(0)\right]^2} = \alpha. \tag{21}$$

Taking the derivatives of (18) and (19) with respect to β_2 at $\beta_2 = 0$ yields that

$$\frac{a_s x^*_w(0)}{\left[x^*_s(0) + x^*_w(0)\right]^2} \times \left\{\frac{(x^*_w)'(0)}{x^*_w(0)} - \frac{2\left[(x^*_s)'(0) + (x^*_w)'(0)\right]}{x^*_s(0) + x^*_w(0)}\right\} = x^*_s(0), \tag{22}$$
$$\frac{a_w x^*_w(0)}{\left[x^*_w(0) + x^*_w(0)\right]^2} \times \left\{\frac{(x^*_s)'(0)}{x^*_s(0)} - \frac{2\left[(x^*_s)'(0) + (x^*_w)'(0)\right]}{x^*_s(0) + x^*_w(0)}\right\} = x^*_w(0). \tag{23}$$

Combining (20), (21), (22), and (23), we have that

$$\frac{(x^*_w)'(0)}{x^*_w(0)} - \frac{2\left[(x^*_s)'(0) + (x^*_w)'(0)\right]}{x^*_s(0) + x^*_w(0)} = \frac{x^*_s(0)}{\alpha},$$
$$\frac{(x^*_s)'(0)}{x^*_s(0)} - \frac{2\left[(x^*_s)'(0) + (x^*_w)'(0)\right]}{x^*_s(0) + x^*_w(0)} = \frac{x^*_w(0)}{\alpha},$$

from which we can obtain that

$$(x^*_w)'(0) = \frac{x^*_s(0)x^*_w(0)\left[x^*_s(0) - 3x^*_w(0)\right]}{\alpha\left[x^*_s(0) + x^*_w(0)\right]}.$$

Note that $x^*_s(0)/x^*_w(0) = a_s/a_w$ from (20) and (21). Therefore, $(x^*_w)'(0) > 0$ if and only if $x^*_s(0)/x^*_w(0) > 3$, which is equivalent to $a_s/a_w > 3$. This concludes the proof. ■

Next, we demonstrate how the conditions established in Proposition 3 translate into the parameters of the linear quadratic effort cost function. Simple algebra would verify

$$\psi(x;\lambda) = \frac{\frac{\partial \mathcal{C}(x;\lambda)}{\partial x} + x\frac{\partial^2 \mathcal{C}(x;\lambda)}{\partial x^2}}{\delta'(x)} = \frac{\left[\alpha_1 + \lambda(\alpha_2 - \alpha_1)\right] + 2\left[\beta_1 + \lambda(\beta_2 - \beta_1)\right]x}{(\alpha_2 - \alpha_1) + (\beta_2 - \beta_1)x}.$$

Example 1 ***(Continued, Linear Quadratic Effort Cost)*** *The following statements hold:*

(i) Suppose that $\alpha_2 > \alpha_1 = 0$ *and* $\beta_2 = \beta_1 > 0$*. Then* $\psi(x;\lambda) = \left(\frac{\alpha_1}{\alpha_2-\alpha_1} + \lambda\right) + \frac{2\beta_1}{\alpha_2-\alpha_1}x$*, which strictly increases with* x*. By Proposition 3(i), we have that* $p^*_{s,1} < p^*_{s,2}$*.*

(ii) Suppose that $\alpha_2 = \alpha_1 > 0$ *and* $\beta_2 > \beta_1 = 0$*. Then* $\psi(x;\lambda) = 2\left(\frac{\beta_1}{\beta_2-\beta_1} + \lambda\right) + \frac{\alpha_1}{(\beta_2-\beta_1)x}$*, which strictly decreases with* x*. By Proposition 3(ii), we have that* $p^*_{s,1} > p^*_{s,2}$*.*

Appendix E Background and Game Mechanics of LoL

E.1 The ESports Industry

ESports is a rapidly growing form of video game-based team sports in a professional competitive tournament setting. In general, competitors play video games while being watched by a live audience as well as millions more online. The global eSports audience reached 474 million in 2021, and is expected to reach 577 million in 2024. Goldman Sachs predicts that by 2022, the market for eSports will be \$2.96 billion,[39] which has already exceeded those of several traditional sports markets, including Major League Baseball (MLB) and the National Basketball Association (NBA). The prize money in top eSports tournaments is also comparable to traditional sports. The most viewed tournament, the International 2019—which took place in Shanghai—has a total prize pool of \$34.3 million.[40] China is the leading market for eSports, grossing a total of \$360 million in 2021, owing to the popularity of eSports among millennial youth and government support.[41] The United States is the second largest eSports market, with total revenues at \$243 million in 2021, followed by Western Europe at \$206 million.

Compared with traditional sports, eSports has its fair share of professional players, commentators, and celebrities. Leading players, like their more traditional star athlete counterparts, become LeBron-like superstars to digital native millennial audiences that find them more directly relatable. According to a recent report by Forbes, League of Legends superstar Faker, for example, makes more than \$2 million annually—and that number does not include sponsorship revenues.

E.2 LoL Game Mechanics

E.2.1 Overview

League of Legends (LoL) is a multiplayer online battle arena (MOBA) game. Like other eSports games and traditional sports, LoL has a clear game objective and well-defined rules. Two teams of five players compete against each other. A team wins when the opponent's homebase is destroyed or when the opponent surrenders. The match sets no fixed time limit,

39. See the Goldman Sachs report entitled "ESports: From Wild West to Mainstream" at https://www.goldmansachs.com/insights/pages/infographics/e-sports/report.pdf.

40. The NBA Championship has a total prize pool of \$13 million in 2018, Masters (golf) \$11 million, Tour de France \$2.8 million, Melbourne Cup \$6.2 million, and Confederations Cup \$20 million.

41. For example, Hangzhou, the capital of Zhejiang Province in Eastern China, plans to build 14 eSports facilities before 2022 and is expected to invest up to RMB 15.5 billion (USD 2.22 billion). This investment is expected to make it the eSports capital of the world. Moreover, Hangzhou is going to host the Asian Games in 2022, in which eSports is already an official medal event.

but is very fast paced. In our data of top-tier tournament matches, a match lasts 33 mins on average, and ranges from 16 mins to 68 mins.

At the beginning of the game, each player takes turns selecting their champion (avatar), which has unique abilities and base statistics such as health, speed, and strength. The roster of champions is balanced in the sense that each champion has strengths and weaknesses, and may counter certain champions and be countered. Upon finishing champion selection, all champions are placed on a large symmetrical map, called the Summoner's Rift, and the competition begins.

E.2.2 The Battle Map

Figure B1 shows the map layout and basic game mechanics. All champions spawn—and respawn if killed—in their team's homebase; the homebases are located at the opposing corners of the map and are defended by turrets and AI-controlled minions.

The map has three lanes: a top lane, a middle diagonal lane, and a bottom lane. They separately cut through the top, middle, and bottom portions of the map. Moreover, each of the lanes is home to a specific type of champion: Although this is not required, the game has developed an almost universal metagame, and now most team tactics have agreed on which champion type is prioritized for each lane.

In between these lanes is a jungle full of neutral monsters. Players kill the opposing team's champions, minions, and neutral monsters to earn gold that can be used to purchase in-game items to boost their champion's abilities and other aspects of gameplay.

E.2.3 Role of Champion

The LoL game community has developed an almost universal metagame for each role of the team. The five team members fall into five roles: top-laner, attack damage carry (ADC), support, jungler, and mid-laner. The top-laner is the solo defensive player of the team who holds against the high-powered attack duo from the enemy's bottom lane. The bottom lane usually consists of two players, the ADC and the support. The ADC is essentially the firepower of the team, but is also the most vulnerable one. The support is ADC's safety guard, providing him with healing and shields and setting up kills. The jungler is the assassin; she plays in the jungle rather than in any lane, killing neutral monsters, and hiding and waiting for the opportunity to pop into a lane to give his teammates a competitive edge over the opposing team. The mid-laner is the do-it-all member of the team, and generally plays solo in the early game but is prepared to help the other lanes if the jungler is dead or preoccupied.

E.2.4 Phases of Game

A game is split into two phases, a preparation phase when teams choose active players and players choose champions, and a competition phase when the competition begins.

The Preparation Phase This is the pre-match phase. Teams first decide on the roster of five active players. Then, players from both teams take turns banning and picking champions. Each player can choose to ban one champion (5 bans per team) from the champion pool before picking their own champion. In professional matches in which teams are familiar with each other, champions that rival players can play exceptionally well are strategically banned to deter the pick. Players may also pick a champion not for their own good, but to secure it for their teammates, or simply prevent it from being picked by the rival team. Each team is allowed to swap champions between teammates at the end of the preparation phase. Considering that champions have different skills, some of which counter other champions or have been countered, this makes the banning and picking of champions extremely strategic in this pre-match phase.

After the picking is finished, team members have a chance to swap champions with teammates before heading into competition.

The Competition Phase At the beginning of the competition phase, players enter their designated lanes or areas, battle against their opponent counterparts, kill enemy minions for gold, and try to get an advantage over the enemy laners when possible. Junglers run around to help their laners; they also reconnoitre the map so that their team can have a better idea of what the enemy is doing. At this point, players are weaker than the defensive turrets on the map so that it is hard for either them to push into the enemy's territory.

After players have grown stronger and the first few turrets have been taken down, the mid-game tends to revolve around the two major neutral monsters—the Drakes and the Baron, both of which reward massive gold and team perks. Teams often fight over these mid-game objectives as five-man units, trying to both deny these monsters to the enemy and win them for themselves.

In the late game, most champions have reached their maximum strength and the game becomes one of cat-and-mouse. Even a small mistake can lead to a near-instant victory for the enemy. As such, the late game is spent mostly trying to gain more vision around the map in an attempt to catch enemies or to sneak a kill on the Baron without enemy interference.

E.3 LoL Tournaments in China

The League of Legends Pro League (LPL) is the top-tier LoL professional tournament in China and the world's largest professional LOL tournament. The first season of LPL was in 2013. Since then, each year hosts two tournament seasons, in spring and summer. Each LPL season has regular-season games and playoffs, and the format is similar to other popular sports events such as the NBA. In the regular season, all teams compete in a single round robin—i.e., each team competes against all other teams in turn. Matches are all best of three and the winner takes one point. Top teams from the regular season advance to the playoffs. Playoff matches are best of five. Teams compete by elimination. The final winner takes about 40% of the prize pool, which totaled 3.5 million RMB in the 2019 summer season. Overall, the LPL tournament is held in a format similar to other competitive leagues such as the NBA and NFL. We collect game statistics from all matches of LPL regular seasons and playoffs from 2017 to 2021.

The list of host cities is determined prior to the regular season. Three to five cities jointly host each season. From 2017 to 2021, 11 cities have hosted the tournament. Shanghai has hosted most LPL tournament games so far (64%). Appendix Table A1 tabulates the number of matches hosted by different cities. The tournament schedule is also predetermined, including both the match date and the pairing of teams. The spring season starts in January and the summer season in June, and both last about 10 weeks.

All regular season and playoff matches are hosted in large indoor stadiums. We collect the location of the hosting stadiums and match them to the nearest national air pollution monitoring stations. All stadiums have standard temperature control systems. However, air pollutants, and PM2.5 in particular, exchanged between outdoor and indoor environments are not filtered. The environmental literature documents that PM2.5 penetrate indoors, with an indoor-outdoor ratio ranging from 0.6 to 0.9 (Huang et al., 2007; Chen and Zhao, 2011; Nadali et al., 2020). We use the level of hourly reported outdoor PM2.5 from the nearest national monitoring stations as the proxy for the level of indoor PM2.5 players were exposed to during the game.

Appendix F Tables

TABLE A1
Number of Historical Matches Held and Homebase of Teams Across Cities

	(1)	(2)		(3)	(4)
Host City	Num. Matches	Share	HomeBase City	Num. Teams	Share
Shanghai	1,689	64.03	Shanghai	12	44.44
Hangzhou	212	8.04	Beijing	3	11.11
Beijing	203	7.70	Wuhan	3	11.11
Xi'an	128	4.85	Shenzhen	2	7.41
Chongqing	126	4.78	Suzhou	2	7.41
Chengdu	120	4.55	Guangzhou	1	3.7
Suzhou	76	2.88	Chengdu	1	3.7
Shenzhen	53	2.01	Hangzhou	1	3.7
Nanjing	16	0.61	Xi'an	1	3.7
Guangzhou	12	0.45	Chongqing	1	3.7
Foshan	3	0.11			
Total	816	100	Total	27	100

Notes: This table presents the total number of historical LPL matches held and homebase of teams across cities during the sample period from 2017 to 2021 (10 spring seasons and 10 summer seasons).

TABLE A2
Summary Statistics for Player Performance

Variable	(1) Mean	(2) S.D.	(3) Min	(4) Max
Panel A: Measures of Player Decision in Competition Phase				
Win	0.50	0.50	0	1
Kill	2.54	2.48	0	18
Assist	6.01	4.17	0	30
Death	2.54	1.79	0	13
Gold	11,839	3,556	3,311	40,511
Kill per 10 min.	0.79	0.78	0	6.79
Assist per 10 min.	1.85	1.31	0	11.73
Gold per 10 min.	3,607	811	1,737	6,526
Panel B: Measures of Player Decision in Preparation Phase				
Decision time (sec.)	17.74	8.39	0	30
Frequency of pick-and-switch	0.64	1.63	0	28
Using less frequent champion	0.09	0.29	0	1

Notes: This table presents summary statistics of performance metrics at player level. Panel A presents the post-game statistics at the competition phase; Panel B presents the pre-game statistics at the preparation phase. See variable definitions in Table 1.

TABLE A3
Average Effects of PM2.5 on Player Performance

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
			Total			Per 10 Mins	
	Win	Kill	Assist	Gold	Kill	Assist	Gold
$PM2.5$	-0.001	-0.007	-0.035***	-28.182***	-0.000	-0.006	-1.871
	(0.002)	(0.007)	(0.013)	(8.896)	(0.002)	(0.004)	(1.713)
Player FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Champion FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Role FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Team-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Match-Type FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City×Year×Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Day-of-Week and Holiday FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	26,090	26,090	26,090	26,090	26,090	26,090	26,090
R-squares	0.229	0.304	0.263	0.502	0.308	0.279	0.710

Notes: This table presents the average effects of the level of PM2.5 on metrics of competitive performance of individual player. The dependent variable is the indicator for winning (Column 1), the total amount of kills, assists, and gold (Columns 2-4), and their per-minute counterparts (Columns 5-7). $PM2.5$ is the level of PM2.5 (in 10 $\mu g/m^3$) at the hour of the match near the match stadium. The player-level regressions across columns control for player fixed effects, champion fixed effects, role-of-team fixed effects, team pair fixed effects, match-type fixed effects, city-by-year-by-month fixed effects, and day-of-week and public holiday fixed effects. Robust standard errors in parentheses are clustered at player-by-season level. *** p <0.01, ** p <0.05, * p <0.1.

TABLE A4
Correlation of Measures of Team's Competitiveness

Panel A: Correlation of Competitiveness Index

	Competitiveness (Model 1)	Competitiveness (Model 2)	Competitiveness (Model 3)
Competitiveness (Model 1)	1		
Competitiveness (Model 2)	0.9955	1	
Competitiveness (Model 3)	0.7231	0.7087	1

Panel B: Correlation of Team Ranking based on Competitiveness Index

	Team Rank (Model 1)	Team Rank (Model 2)	Team Rank (Model 3)
Team Rank (Model 1)	1		
Team Rank (Model 2)	1	1	
Team Rank (Model 3)	0.8516	0.8516	1

Notes: This table presents the correlation of measures of team's relative competitiveness (Panel A) and the correlation of indicators for the stronger team, defined as the team's competitiveness being higher than the sample median (Panel B). Model 1 computes the competitiveness using each team's average winning rate in all regular-season games. Model 2 computes the competitiveness as the computed team fixed effect ($\hat{\delta}_i$) from regressing $Win_{ijct} = \delta_i + \eta_j + City_c + Year_t + Month_t + \mu_{ijct}$. Model 3 computes the competitiveness as the computed team fixed effect ($\hat{\delta}_i$) using Equation (3). See Equation (3) for discussion of the three models.

TABLE A5
Effects of PM2.5 on Teams' Performance Gap

	(1)	(2)	(3)	(4)	(5)	(6)
	Gap in total			Gap in every 10 mins		
	Kill	Assist	Gold	Kill	Assist	Gold
$PM2.5$	0.100**	0.182*	74.350*	0.038**	0.073*	30.520*
	(0.049)	(0.109)	(43.146)	(0.018)	(0.040)	(16.958)
Team-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes
Match-Type FE	Yes	Yes	Yes	Yes	Yes	Yes
City×Year and Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Day-of-Week and Holiday FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,611	2,611	2,611	2,611	2,611	2,611
R-squares	0.139	0.133	0.159	0.160	0.141	0.155
Mean of Gaps	9.17	23.80	10265.8	3.01	7.71	3330.5

Notes: This table presents the effects of PM2.5 on teams' performance gap. The dependent variable is the absolute difference in measures of competitive performance between teams in a matchup, including the total number of kills, assists, and gold in a match (Columns 2-4), and their per-10-minute counterparts (Columns 5-7). $PM2.5$ is the level of PM2.5 (in 10 $\mu g/m^3$) at the hour of the match. Regressions control for team-pair fixed effects, match-type fixed effects, city-by-year and month fixed effects, and day-of-week and public holiday fixed effects. Further details are specified in Equation (2). Robust standard errors in parentheses are clustered at team-pair level. *** p <0.01, ** p <0.05, * p <0.1.

TABLE A6
Distributional Effects of PM2.5 on Multiple Kills

	(1) Any multiple kills	(2) Number of multiple kills	(3) Share of multiple kills in total kills
$PM2.5$	-0.0057	-0.0736*	-0.0030
	(0.0050)	(0.0377)	(0.0024)
$PM2.5 \times Rel.Strong$	0.0100*	0.1169***	0.0046*
	(0.0058)	(0.0408)	(0.0027)
Team-pair FE	Yes	Yes	Yes
Match-Type FE	Yes	Yes	Yes
City×Year×Month FE	Yes	Yes	Yes
Day-of-Week and Holiday FE	Yes	Yes	Yes
Observations	5,222	5,222	5,194
R-squares	0.1679	0.1696	0.1498
Mean Dep. Var.	0.663	3.926	0.251

Notes: This table presents the distributional effects of PM2.5 on team's likelihood of achieving multiple kills in competition. The dependent variable is the indicator of multiple kills (Column 1), the number of multiple kills (Columns 2-4), and the share of multiple kills in total number of kills (Column 3). $PM2.5$ is the level of PM2.5 (in 10 $\mu g/m^3$) at the hour of the match. Regressions control for team-pair fixed effects, match-type fixed effects, city-by-year-by-month fixed effects, and day-of-week and public holiday fixed effects. Team's competitiveness is computed as the team fixed effects from Equation (3). Further details are specified in Section 3.2. Robust standard errors in parentheses are clustered at team-by-season level. *** p <0.01, ** p <0.05, * p <0.1.

TABLE A7
Effects of PM2.5 on the Prediction Accuracy of Match Outcome

	(1)	(2)	(3)	(4)	(5)	(6)
	Predicted outcome being the same as actual outcome					
	Prediction by Quantile Ranking			Prediction by Competitiveness Index		
	Full Sample	Exclude Same Quantiles	Same Quantiles	Full Sample	Exclude Similar Competitiveness	Similar Competitiveness
$PM2.5$	0.0119***	0.0130***	0.0000	0.0143***	0.0158***	0.0089
	(0.0033)	(0.0036)	(0.0155)	(0.0033)	(0.0038)	(0.0115)
Team-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes
Match-Type FE	Yes	Yes	Yes	Yes	Yes	Yes
City×Year×Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Day-of-Week and Holiday FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,222	4,286	936	5,222	4,176	1,046
R-squares	0.2057	0.2276	0.1158	0.2033	0.2326	0.2933
Mean Dep. Var.	0.608	0.620	0.500	0.619	0.630	0.582

Notes: This table shows that air pollution reduces the unpredictability of the match. We predict the match outcome (win or loss) based on the ranking of team's competitiveness index (see Equation 3). In Columns (1) to (3), we define five quantiles of the competitiveness index, and predict a team to be the winner of the match if a team has a higher quantile than the rival team. In Column (4), we predict a team would win the match if having a higher competitiveness index than its rival. In Columns (5) and (6), we define two teams have similar competitiveness if the difference of their indices is smaller than 20th percentile. We then define an indicator of prediction accuracy if predicted outcome is the same as the actual outcome. $PM2.5$ is the level of PM2.5 (in 10 $\mu g/m^3$) at the hour of the match. Regressions control for team-pair fixed effects, match-type fixed effects, city-by-year-by-month fixed effects, and day-of-week and public holiday fixed effects. Robust standard errors in parentheses are clustered at team-by-season level. *** p <0.01, ** p <0.05, * p <0.1.

TABLE A8
Effects of PM2.5 on Match Intensity

	(1)	(2)	(3)	(4)	(5)	(6)
	Total (both teams combined)			Total per 10 mins		
	Kill	Assist	Damages to champions	Kill	Assist	Damages to champions
$PM2.5$	-0.155**	-0.453**	-938.130**	-0.021	-0.071	-34.193**
	(0.077)	(0.192)	(372.125)	(0.022)	(0.052)	(13.666)
Team-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes
Match-Type FE	Yes	Yes	Yes	Yes	Yes	Yes
City×Year and Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Day-of-Week and Holiday FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,611	2,611	2,611	2,611	2,611	2,611
R-squares	0.052	0.035	0.054	0.103	0.072	0.055

Notes: This table presents the effects of PM2.5 on match intensity. The dependent variable is the summed performance metrics from both teams in a matchup, including the total number of kills, assists, and damages dealt to champions (Columns 1-3), and their per-10-minute counterparts (Columns 4-6). $PM2.5$ is the level of PM2.5 (in 10 $\mu g/m^3$) at the hour of the match. Regressions control for team-pair fixed effects, match-type fixed effects, city-by-year and month fixed effects, and day-of-week and public holiday fixed effects. Further details are specified in Equation (2). Robust standard errors in parentheses are clustered at team-by-season level. *** p <0.01, ** p <0.05, * p <0.1.

TABLE A9
Correlation of Last-season Performance and Current-season Pollution

	(1)	(2)	(3)
	Average Performance in Last Season Against the Same Rival		
	Win	Kill/min	Assist/min
PM2.5 in Current Season	-0.00022	0.00012	0.00071
	(0.00059)	(0.00041)	(0.00104)
Team-Pair FE	Yes	Yes	Yes
Observations	1,450	1,450	1,450
R-squared	0.515	0.579	0.532

Notes: This table presents the correlation between a team's average performance with respect to a rival in the last season and the level of PM2.5 in the current season. Robust standard errors in parentheses are clustered at the team level. *** p <0.01, ** p <0.05, * p <0.1.

TABLE A10
Robustness to Inclusion of Hour-of-Day FEs

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
			Total			Per 10 Mins	
	Win	Kill	Assist	Gold	Kill	Assist	Gold
$PM2.5$	-0.009**	-0.150**	-0.475***	-271.828**	-0.039**	-0.124***	-46.930***
	(0.004)	(0.060)	(0.151)	(118.724)	(0.018)	(0.045)	(17.980)
$PM2.5 \times Rel.Strong$	0.019***	0.268***	0.680***	276.489*	0.088***	0.218***	91.479***
	(0.006)	(0.069)	(0.170)	(144.277)	(0.021)	(0.051)	(22.305)
Hour-of-Day FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Team-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Match-Type FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City×Year×Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Day-of-Week and Holiday FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,222	5,222	5,222	5,222	5,222	5,222	5,222
R-squares	0.197	0.213	0.186	0.234	0.248	0.212	0.235

Notes: This table tests the robustness of our baseline results after additionally controlling for the hour-of-day FEs. The dependent variable is the indicator of win (Column 1), the number of kills, assists, and gold (Columns 2-4), and their per-10-minute counterparts (Columns 5-7). $PM2.5$ is the level of PM2.5 at the hour of the match. $Rel.Strong$ is a dummy variable indicating the team's competitiveness index ranks higher than the rival team in the matchup. Team's competitiveness is computed as the team fixed effects from Equation (3). Further details are specified in Section 3.2. Robust standard errors in parentheses are clustered at team-by-season level. *** p <0.01, ** p <0.05, * p <0.1.

TABLE A11
Robustness to the Inclusion of City-by-date FEs

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Total			Per 10 Mins		
	Win	Kill	Assist	Gold	Kill	Assist	Gold
$PM2.5$	-0.009	-0.400*	-1.174*	-786.805**	-0.076	-0.237	-78.659
	(0.016)	(0.229)	(0.597)	(371.112)	(0.067)	(0.175)	(58.177)
$PM2.5 \times Rel.Strong$	0.019***	0.268***	0.680***	276.489***	0.088***	0.218***	91.479***
	(0.006)	(0.059)	(0.152)	(74.069)	(0.020)	(0.050)	(22.760)
Team-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Match-Type FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City×Date FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Day-of-Week and Holiday FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,222	5,222	5,222	5,222	5,222	5,222	5,222
R-squares	0.197	0.315	0.294	0.423	0.327	0.292	0.258

Notes: This table presents the distributional effects of PM2.5 on team's competitive performance after including the city-by-date FEs. The dependent variable is the indicator of win (Column 1), the number of kills, assists, and gold (Columns 2-4), and their per-10-minute counterparts (Columns 5-7). $PM2.5$ is the level of PM2.5 (in 10 $\mu g/m^3$) at the hour of the match. $Rel.Strong$ is a dummy variable indicating the team's competitiveness index ranks higher than the rival team in the matchup. Team's competitiveness is computed as the team fixed effects from Equation (3). Regressions control for team-pair fixed effects, match-type fixed effects, city-by-date fixed effects, and day-of-week and public holiday fixed effects. Further details are specified in Equation (2). Robust standard errors in parentheses are clustered at team-by-season level. *** p <0.01, ** p <0.05, * p <0.1.

TABLE A12
Robustness to Controlling for Dynamic Effects from Previous Matches

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
			Total			Per 10 Mins	
	Win	Kill	Assist	Gold	Kill	Assist	Gold
$PM2.5$	-0.009**	-0.149**	-0.474***	-252.739**	-0.039**	-0.126***	-46.173**
	(0.004)	(0.058)	(0.144)	(125.097)	(0.017)	(0.042)	(17.874)
$PM2.5 \times Rel.Strong$	0.019***	0.261***	0.660***	273.946*	0.085***	0.209***	89.555***
	(0.006)	(0.069)	(0.169)	(155.581)	(0.020)	(0.051)	(22.475)
MatchOrder×LastWin FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Team-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Match-Type FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City×Year×Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Day-of-Week and Holiday FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,222	5,222	5,222	5,222	5,222	5,222	5,222
R-squares	0.198	0.216	0.189	0.232	0.252	0.216	0.235

Notes: This table presents the distributional effects of the level of PM2.5 on metrics of competitive performance of individual player (Panel A) and team (Panel B). The player-level regression is specified in Equation (2). The dependent variable is the indicator for winning (Column 1), the total amount of kills, assists, and gold (Columns 2-4), and their per-minute counterparts (Columns 5-7). $PM2.5$ is the level of PM2.5 (in 10 $\mu g/m^3$) at the hour of the match near the match stadium. $Rel.Strong$ is a dummy variable indicating the team's competitiveness is higher than the rival team in the matchup. Each team's competitiveness is computed as the team fixed effects from Equation (3). See table notes in Table 3 for regression specifications. *** p <0.01, ** p <0.05, * p <0.1.

TABLE A13
Robustness Check with the Inclusion of Weather Conditions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
			Total			Per 10 Mins	
	Win	Kill	Assist	Gold	Kill	Assist	Gold
$PM2.5$	-0.010*	-0.156**	-0.486***	-270.050*	-0.041**	-0.129***	-47.787**
	(0.005)	(0.067)	(0.165)	(147.973)	(0.019)	(0.048)	(21.556)
$PM2.5 \times Rel.Strong$	0.021***	0.263***	0.670***	282.268*	0.086***	0.215***	92.808***
	(0.006)	(0.071)	(0.174)	(167.150)	(0.020)	(0.051)	(23.612)
Weather Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Team-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Match-Type FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City×Year×Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Day-of-Week and Holiday FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,126	4,126	4,126	4,126	4,126	4,126	4,126
R-squares	0.185	0.217	0.192	0.215	0.243	0.211	0.221

Notes: This table presents the distributional effects of PM2.5 on team's competitive performance after including the set of weather conditions. The dependent variable is the indicator of win (Column 1), the number of kills, assists, and gold (Columns 2-4), and their per-10-minute counterparts (Columns 5-7). $PM2.5$ is the level of PM2.5 (in 10 $\mu g/m^3$) at the hour of the match. $Rel.Strong$ is a dummy variable indicating the team's competitiveness index ranks higher than the rival team in the matchup. Team's competitiveness is computed as the team fixed effects from Equation (3). Weather controls include flexible bins of temperature, precipitation, sunshine, humidity, wind speed, as well as an indicator for bad weather. The indicator equals one if any of the weather variables—i.e., temperature, precipitation, sunshine, humidity, and wind speed—exceeds 90% percentile cutoff of sample values and zero otherwise. Regressions control for team-pair fixed effects, match-type fixed effects, city-by-year-by-month fixed effects, and day-of-week and public holiday fixed effects. Further details are specified in Equation (2). Robust standard errors in parentheses are clustered at team-by-season level. *** p <0.01, ** p <0.05, * p <0.1.

TABLE A14
Distributional Effects of PM2.5 on Player Performance

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
			Total			Per 10 Mins	
	Win	Kill	Assist	Gold	Kill	Assist	Gold
$PM2.5$	-0.011***	-0.037***	-0.102***	-56.550***	-0.011***	-0.028***	-11.983***
	(0.002)	(0.008)	(0.015)	(12.091)	(0.002)	(0.005)	(2.032)
$PM2.5 \times Rel.Strong$	0.019***	0.060***	0.134***	55.897***	0.020***	0.044***	19.925***
	(0.002)	(0.011)	(0.018)	(15.282)	(0.003)	(0.006)	(2.599)
Player FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Champion FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Role FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Team-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Match-Type FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City×Year×Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Day-of-Week and Holiday FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	26,090	26,090	26,090	26,090	26,090	26,090	26,090
R-squares	0.231	0.305	0.264	0.503	0.309	0.281	0.711

Notes: This table presents the results of regressing Equation (2) at player level and controlling for player FEs, champion FEs, and the role of team FEs. Robust standard errors in parentheses are clustered at player-by-season level. *** p <0.01, ** p <0.05, * p <0.1.

TABLE A15
Distributional Effects of PM2.5 on Player Performance

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
			Total			Per 10 Mins	
	Win	Kill	Assist	Gold	Kill	Assist	Gold
$PM2.5$	-0.001	-0.007	-0.036***	-28.660***	-0.001	-0.007*	-2.029
	(0.002)	(0.007)	(0.012)	(8.513)	(0.002)	(0.004)	(1.597)
$PM2.5 \times Gap$	0.068***	0.174***	0.397***	187.724***	0.054***	0.120***	62.310***
	(0.007)	(0.038)	(0.066)	(47.708)	(0.012)	(0.021)	(8.287)
Player FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Champion FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Role FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Team-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Match-Type FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City$\times$Year$\times$Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Day-of-Week and Holiday FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	26,090	26,090	26,090	26,090	26,090	26,090	26,090
R-squares	0.231	0.305	0.264	0.503	0.309	0.280	0.711

Notes: This table presents the results of regressing Equation (4) at player level and controlling for player FEs, champion FEs, and the role of team FEs. Robust standard errors in parentheses are clustered at player-by-season level. *** p <0.01, ** p <0.05, * p <0.1.

TABLE A16
Effects of Air Pollution on Competitive Performance Using the Concentration of Other Main Air Pollutants

	(1)	(2)	(3)	(4)
		Dependent variable: Win		
Type of Air Pollutant	PM10	AQI	SO2	O3
Pollutant	-0.011***	-0.008**	-0.049	-0.001
	(0.004)	(0.004)	(0.034)	(0.002)
Pollutant × *Rel.Strong*	0.021***	0.017***	0.099***	0.002
	(0.005)	(0.004)	(0.035)	(0.003)
Team-Pair FE	Yes	Yes	Yes	Yes
Match-Type FE	Yes	Yes	Yes	Yes
City×Year×Month FE	Yes	Yes	Yes	Yes
Day-of-Week and Holiday FE	Yes	Yes	Yes	Yes
Observations	5,186	5,222	5,222	5,222
R-squares	0.199	0.197	0.196	0.195

Notes: This table presents the effects of the level of other main air pollutants on a team's winning probability. The dependent variable is the indicator for winning. *Pollutant* is the concentration level of PM10, AQI, SO2 and O3 in Columns (1) to (4), respectively. *Rel.Strong* is a dummy variable indicating that the team's competitiveness is higher than the rival team in the matchup. Each team's competitiveness is computed as the team fixed effects from Equation (3). See Section 3.2 for regression specifications. *** p <0.01, ** p <0.05, * p <0.1.

TABLE A17
Effect of Pre-match and Post-match Air Pollution on the Match Outcome

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Prior to Match Day				Post Match Day			
	7-Day	5-Day	3-Day	1-Day	1-Day	3-Day	5-Day	7-Day
$Placebo\_PM2.5$	-0.003	0.000	0.002	0.000	-0.001	0.004	-0.000	0.001
	(0.009)	(0.009)	(0.006)	(0.005)	(0.006)	(0.008)	(0.010)	(0.015)
$Placebo\_PM2.5 \times Rel.Strong$	0.006	-0.000	-0.004	-0.001	0.001	-0.009	0.000	-0.002
	(0.008)	(0.008)	(0.007)	(0.007)	(0.008)	(0.009)	(0.009)	(0.011)
Control for concurrent PM2.5	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Team-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Match-Type FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City×Year×Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Day-of-Week and Holiday FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,052	5,108	5,158	5,186	5,182	5,148	5,092	5,038
R-squares	0.202	0.199	0.199	0.198	0.198	0.199	0.200	0.199

Notes: This table presents the placebo test on the effect of pre-match and post-match air pollution exposure on a team's winning probability. The dependent variable is the indicator for winning. Placebo $PM2.5$ is defined as the match-hour PM2.5 level (in 10 $\mu g/m^3$) 1 day, 3 days, 5 days, and 7 days before and after the actual match. $Rel.Strong$ is a dummy variable indicating the team's competitiveness is higher than the rival team in the matchup. Each team's competitiveness is computed as the team fixed effects from Equation (3). *** p <0.01, ** p <0.05, * p <0.1.

TABLE A18
Nonlinear Distributional Effects of PM2.5 on Team Performance

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Total			Per 10 Mins		
	Win	Kill	Assist	Gold	Kill	Assist	Gold
PM2.5[1,2.5)×*Rel.Weak*	-0.019	-0.443	-2.057	716.547	-0.207	-0.803	-104.198
	(0.051)	(0.664)	(1.775)	(1,068.029)	(0.232)	(0.608)	(198.997)
PM2.5[2.5,5)×*Rel.Weak*	-0.018	-0.406	-1.973	479.229	-0.197	-0.728	-147.345
	(0.050)	(0.666)	(1.799)	(1,089.683)	(0.227)	(0.604)	(189.224)
PM2.5[5,7.5)×*Rel.Weak*	-0.059	-0.801	-3.226*	-349.704	-0.276	-1.059*	-308.726
	(0.055)	(0.716)	(1.888)	(1,365.470)	(0.244)	(0.638)	(218.814)
PM2.5[7.5,10)×*Rel.Weak*	-0.060	-1.360	-4.744*	-1,711.136	-0.359	-1.254	-241.551
	(0.062)	(0.921)	(2.428)	(1,521.545)	(0.299)	(0.780)	(250.569)
PM2.5[10,25)×*Rel.Weak*	-0.188**	-2.888***	-9.976***	-5,042.388***	-0.805**	-2.832***	-885.988**
	(0.090)	(1.110)	(2.829)	(1,880.961)	(0.357)	(0.923)	(342.395)
PM2.5[1,2.5)×*Rel.Strong*	0.019	0.122	-0.579	1,086.857	-0.002	-0.326	34.007
	(0.049)	(0.676)	(1.870)	(1,136.775)	(0.225)	(0.605)	(192.575)
PM2.5[2.5,5)×*Rel.Strong*	0.018	0.168	-0.514	1,094.237	0.019	-0.255	83.814
	(0.045)	(0.710)	(1.952)	(1,057.574)	(0.235)	(0.637)	(193.015)
PM2.5[5,7.5)×*Rel.Strong*	0.059	1.182*	2.036	1,400.090	0.356	0.567	277.072
	(0.053)	(0.705)	(1.914)	(1,182.243)	(0.260)	(0.681)	(224.817)
PM2.5[7.5,10)×*Rel.Strong*	0.060	0.072	-1.488	-535.684	0.177	-0.075	247.654
	(0.065)	(0.792)	(2.144)	(1,275.176)	(0.268)	(0.689)	(254.106)
PM2.5[10,25)×*Rel.Strong*	0.188**	1.768*	1.438	-364.145	0.757**	0.850	641.603*
	(0.087)	(0.989)	(2.707)	(1,784.611)	(0.360)	(0.951)	(341.504)
FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,222	5,222	5,222	5,222	5,222	5,222	5,222
R-squares	0.198	0.210	0.186	0.229	0.241	0.209	0.234

Notes: This table presents the nonlinear distributional effects of the level of PM2.5 on metrics for a team's competitive performance. The dependent variable is the indicator for winning (Column 1), the total amount of kills, assists, and gold (Columns 2-4), and their per-10-minute counterparts (Columns 5-7). $PM[1, 2.5)$ is the indicator for the level of PM2.5 being within the range 10-25 $\mu g/m^3$, $PM[2.5, 5)$ for the range 25-50 $\mu g/m^3$, and so on. *Stronger* is a dummy variable indicating that the team's competitiveness is higher than the rival team in the matchup. Each team's competitiveness is computed as the team fixed effects from Equation (3). The full set of FEs are controlled for. See Section 3.2 for details. *** p <0.01, ** p <0.05, * p <0.1.

TABLE A19
Acclimation Effects of PM2.5 on Team Performance: Home More Polluted Than Host City

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
			Total			Per 10 Mins	
	Win	Kill	Assist	Gold	Kill	Assist	Gold
Panel A							
$PM2.5$	-0.002	-0.010	-0.141	-139.203	0.008	-0.013	-0.657
	(0.005)	(0.063)	(0.157)	(107.428)	(0.019)	(0.046)	(18.911)
$HomeAcclimation$	0.034	0.687	0.728	265.003	0.298	0.434	332.361*
	(0.049)	(0.585)	(1.445)	(1,150.921)	(0.185)	(0.456)	(196.324)
$PM2.5 \times HomeAcclimation$	0.007	-0.018	0.007	67.054	-0.013	-0.019	-2.857
	(0.007)	(0.085)	(0.224)	(161.887)	(0.026)	(0.069)	(27.645)
Observations	5,222	5,222	5,222	5,222	5,222	5,222	5,222
R-squares	0.195	0.207	0.182	0.228	0.238	0.206	0.231
Panel B							
$PM2.5$	-0.011**	-0.135**	-0.456***	-264.631**	-0.033*	-0.115**	-42.858**
	(0.005)	(0.064)	(0.157)	(125.431)	(0.019)	(0.046)	(18.958)
$PM2.5 \times Rel.Strong$	0.018***	0.270***	0.684***	271.961*	0.090***	0.221***	91.504***
	(0.006)	(0.068)	(0.169)	(159.370)	(0.020)	(0.051)	(22.540)
$HomeAcclimation$	0.039	0.757	0.905	335.339	0.321*	0.491	356.027*
	(0.048)	(0.573)	(1.414)	(1,136.359)	(0.183)	(0.450)	(191.243)
$PM2.5 \times HomeAcclimation$	0.005	-0.050	-0.074	34.614	-0.024	-0.045	-13.772
	(0.006)	(0.078)	(0.205)	(157.205)	(0.024)	(0.064)	(24.630)
Observations	5,222	5,222	5,222	5,222	5,222	5,222	5,222
R-squares	0.197	0.209	0.185	0.228	0.241	0.208	0.234

Notes: This table presents the acclimation effects of PM2.5 on team's competitive performance. The dependent variable is the indicator of win (Column 1), the number of kills, assists, and gold (Columns 2-4), and their per-10-minute counterparts (Columns 5-7). $PM2.5$ is the level of PM2.5 (in 10 $\mu g/m^3$) at the hour of the match. $HomeAcclimation$ is a dummy variable indicating that the team's home city has a higher average air pollution level than the daily average pollution level in host city on the match date. $Rel.Strong$ is a dummy variable indicating the team's competitiveness index ranks higher than the rival team in the matchup. Team's competitiveness is computed as the team fixed effects from Equation (3). All regressions control for team-pair fixed effects, match-type fixed effects, city-by-year-by-month fixed effects, and day-of-week and public holiday fixed effects. Further details are specified in Section 3.2. Robust standard errors in parentheses are clustered at team-by-season level. *** p <0.01, ** p <0.05, * p <0.1.

TABLE A20

Acclimation Effects of PM2.5 on Team Performance: Home More Polluted Than Rival's Home

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Total			Per 10 Mins		
	Win	Kill	Assist	Gold	Kill	Assist	Gold
Panel A							
$PM2.5$	-0.001	-0.012	-0.157	-109.186	0.008	-0.019	1.139
	(0.005)	(0.064)	(0.158)	(104.892)	(0.019)	(0.048)	(19.696)
$PM2.5 \times Rel.HomePolluted$	0.003	-0.009	0.049	-19.947	-0.010	-0.000	-6.057
	(0.006)	(0.083)	(0.210)	(142.893)	(0.026)	(0.066)	(26.021)
Observations	5,222	5,222	5,222	5,222	5,222	5,222	5,222
R-squares	0.195	0.207	0.182	0.228	0.238	0.206	0.230
Panel B							
$PM2.5$	-0.011**	-0.150**	-0.509***	-251.511**	-0.037*	-0.132***	-45.961**
	(0.005)	(0.066)	(0.162)	(122.816)	(0.020)	(0.050)	(20.103)
$PM2.5 \times Rel.Strong$	0.019***	0.268***	0.683***	276.171*	0.088***	0.219***	91.393***
	(0.006)	(0.068)	(0.167)	(154.233)	(0.020)	(0.050)	(22.154)
$PM2.5 \times Rel.HomePolluted$	0.004	0.001	0.076	-9.007	-0.007	0.009	-2.437
	(0.006)	(0.075)	(0.190)	(133.408)	(0.024)	(0.060)	(23.217)
Observations	5,222	5,222	5,222	5,222	5,222	5,222	5,222
R-squares	0.197	0.209	0.185	0.228	0.240	0.208	0.234

Notes: This table presents the acclimation effects of PM2.5 on team's competitive performance. The dependent variable is the indicator of win (Column 1), the number of kills, assists, and gold (Columns 2-4), and their per-10-minute counterparts (Columns 5-7). $PM2.5$ is the level of PM2.5 (in 10 $\mu g/m^3$) at the hour of the match. $Rel.HomePolluted$ is a dummy variable indicating that the team's home city has a higher average air pollution level than the rival team. $Rel.Strong$ is a dummy variable indicating the team's competitiveness index ranks higher than the rival team in the matchup. Team's competitiveness is computed as the team fixed effects from Equation (3). All regressions control for team-pair fixed effects, match-type fixed effects, city-by-year-by-month fixed effects, and day-of-week and public holiday fixed effects. Further details are specified in Section 3.2. Robust standard errors in parentheses are clustered at team-by-season level. *** p <0.01, ** p <0.05, * p <0.1.

TABLE A21
Home-advantage Effects of PM2.5 on Team Performance

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
			Total			Per 10 Mins	
	Win	Kill	Assist	Gold	Kill	Assist	Gold
Panel A							
$PM2.5$	0.005	0.036	-0.006	-49.927	0.018	0.016	15.200
	(0.005)	(0.058)	(0.156)	(109.058)	(0.017)	(0.046)	(17.819)
$HomeAdvantage$	-0.017	-0.192	-0.189	9.865	-0.098	-0.164	-119.164
	(0.032)	(0.360)	(0.897)	(589.411)	(0.125)	(0.301)	(130.463)
$PM2.5 \times HomeAdvantage$	-0.011*	-0.115*	-0.297*	-150.877	-0.030	-0.077	-36.408
	(0.006)	(0.067)	(0.163)	(116.119)	(0.024)	(0.056)	(23.292)
Observations	5,222	5,222	5,222	5,222	5,222	5,222	5,222
R-squares	0.196	0.208	0.183	0.228	0.239	0.206	0.232
Panel B							
$PM2.5$	-0.006	-0.120*	-0.402**	-206.008	-0.035*	-0.114**	-38.101*
	(0.006)	(0.071)	(0.179)	(144.919)	(0.021)	(0.053)	(21.881)
$PM2.5 \times Rel.Strong$	0.017***	0.252***	0.639***	251.922	0.085***	0.209***	86.031***
	(0.006)	(0.072)	(0.174)	(158.346)	(0.022)	(0.053)	(23.527)
$HomeAdvantage$	-0.031	-0.391	-0.694	-189.272	-0.165	-0.329	-187.170
	(0.032)	(0.357)	(0.881)	(581.570)	(0.124)	(0.294)	(126.719)
$PM2.5 \times HomeAdvantage$	-0.006	-0.046	-0.123	-82.159	-0.007	-0.020	-12.941
	(0.006)	(0.070)	(0.166)	(114.016)	(0.025)	(0.057)	(23.325)
Observations	5,222	5,222	5,222	5,222	5,222	5,222	5,222
R-squares	0.198	0.210	0.185	0.228	0.241	0.209	0.235

Notes: This table presents the acclimation effects of PM2.5 on team's competitive performance. The dependent variable is the indicator of win (Column 1), the number of kills, assists, and gold (Columns 2-4), and their per-10-minute counterparts (Columns 5-7). $PM2.5$ is the level of PM2.5 (in 10 $\mu g/m^3$) at the hour of the match. $HomeAdvantage$ is a dummy variable indicating that the team's home city is the host city on the match date. $Rel.Strong$ is a dummy variable indicating the team's competitiveness index ranks higher than the rival team in the matchup. Team's competitiveness is computed as the team fixed effects from Equation (3). All regressions control for team-pair fixed effects, match-type fixed effects, city-by-year-by-month fixed effects, and day-of-week and public holiday fixed effects. Further details are specified in Section 3.2. Robust standard errors in parentheses are clustered at team-by-season level. *** p <0.01, ** p <0.05, * p <0.1.

TABLE A22
Effects of PM2.5 on Online Search Activities for Pollution-related Keywords

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	Search for PM2.5		Search for Harm of PM2.5		Search for Face Mask	
PM2.5	167.8***		3.604***		7.611***	
	(4.883)		(0.271)		(1.097)	
Severe (PM2.5>75 $\mu g/m^3$)		744.6***		17.56***		27.47***
		(49.58)		(2.433)		(9.700)
Year×Month×Week FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,025	3,025	3,025	3,025	3,025	3,025
R-squared	0.760	0.678	0.514	0.491	0.884	0.882

Notes: This table presents the effects of PM2.5 (in 10 $\mu g/m^3$) and an indicator of severe air pollution (PM2.5>75 $\mu g/m^3$) on online search activities for pollution-related keywords. Columns (1) and (2) present the search for the level of PM2.5, Columns (3) and (4) for the health damages of PM2.5, and Columns (5) and (6) for PM2.5-proof face mask. Robust standard errors in parentheses are clustered at team-by-season level. *** p <0.01, ** p <0.05, * p <0.1.

TABLE A23
Effects of Air Pollution on Decision Time and Pick-and-switch

	(1)	(2)	(3)	(4)
Panel A: Dependent Variable: Decision Time (normalized by S.D.)				
$PM2.5$	-0.006	-0.012	-0.017	-0.016
	(0.034)	(0.034)	(0.035)	(0.034)
$PM2.5 \times Abs.\ Weak$		0.017		-0.007
		(0.013)		(0.017)
$PM2.5 \times Rel.\ Weak$			0.022***	0.025**
			(0.008)	(0.010)
Observations	5,006	5,006	5,006	5,006
R-squares	0.434	0.435	0.435	0.435
Panel B: Dependent Variable: Frequency of Pick-and-switch (normalized by S.D.)				
$PM2.5$	0.016	0.010	0.005	0.006
	(0.038)	(0.039)	(0.039)	(0.039)
$PM2.5 \times Abs.\ Weak$		0.018		-0.006
		(0.020)		(0.024)
$PM2.5 \times Rel.\ Weak$			0.023*	0.026*
			(0.012)	(0.013)
Observations	5,002	5,002	5,002	5,002
R-squares	0.350	0.350	0.351	0.351

Notes: This table tests the effects of PM2.5 on team and player efforts in the preparation phase of the match. The dependent variable in Panel A is the time a player takes to finalize his choice of champion; and the dependent variable in Panel B is the number of times a player changes his choice of champion before the final decision. $PM2.5$ is the level of PM2.5 (in 10 $\mu g/m^3$) at the hour of the match near the match stadium. $Rel.Weak$ indicates that the team's competitiveness is lower than the rival team. $Abs.Weak$ indicates that the team's competitiveness is lower than half of all teams. See the computation of team's competitiveness in Equation (3). All regressions control for team-pair fixed effects, match-type fixed effects, city-by-year-by-month fixed effects, and day-of-week and public holiday fixed effects. *** p <0.01, ** p <0.05, * p <0.1.

Appendix G Figures

FIGURE B1
Map for LoL Games

Notes: This figure presents the map layout for LoL games. The diagonal corners at the bottom left and upper right, respectively, are the homebase for the two rival teams. Defensive turrets are positioned along the top, middle, and bottom lanes, while neutral minions spawn in the jungles.

FIGURE B2
Post-game Statistics for LoL Games

Notes: This figure presents the post-game statistics for a standard LoL match.

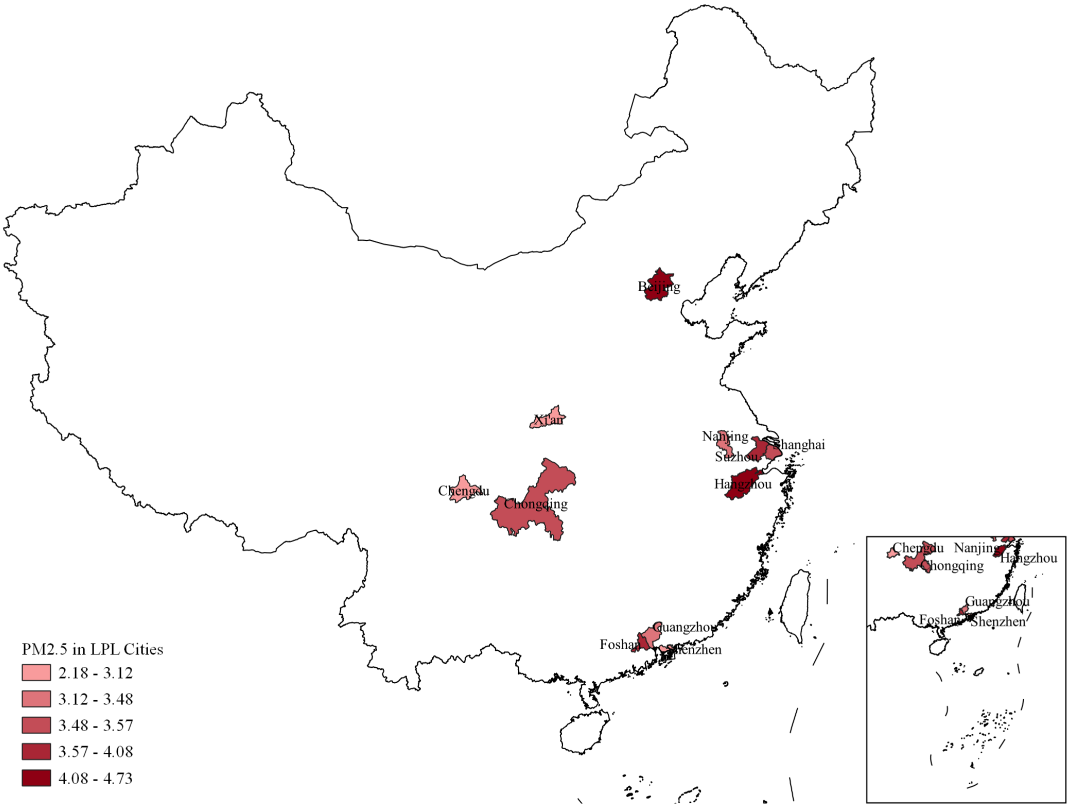


FIGURE B3
Average Concentration of PM2.5 in LPL Hosting Cities

Notes: This figure presents the spatial distribution of average concentrations of PM2.5 in LPL hosting cities during the sample period (from 2017 to 2021). Unit of PM2.5 is 10 $\mu g/m^3$.

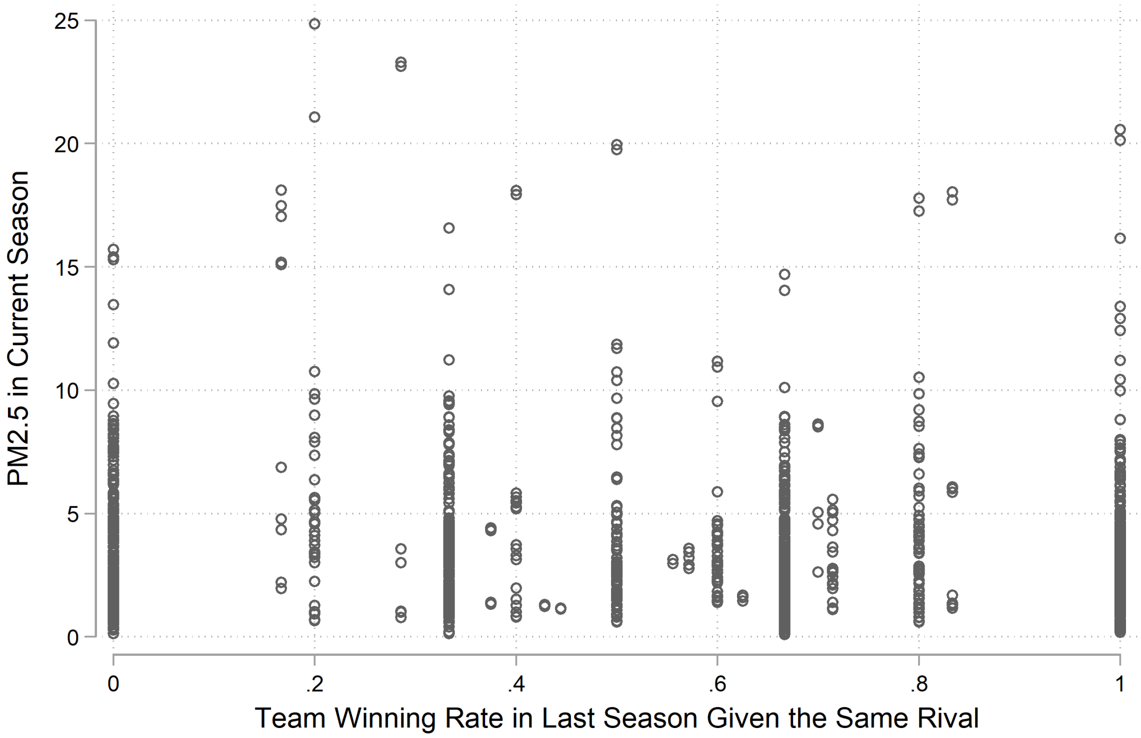
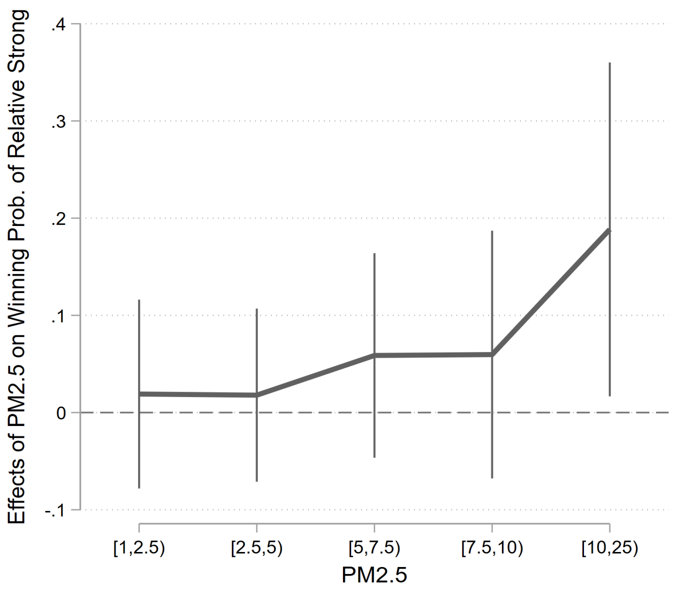
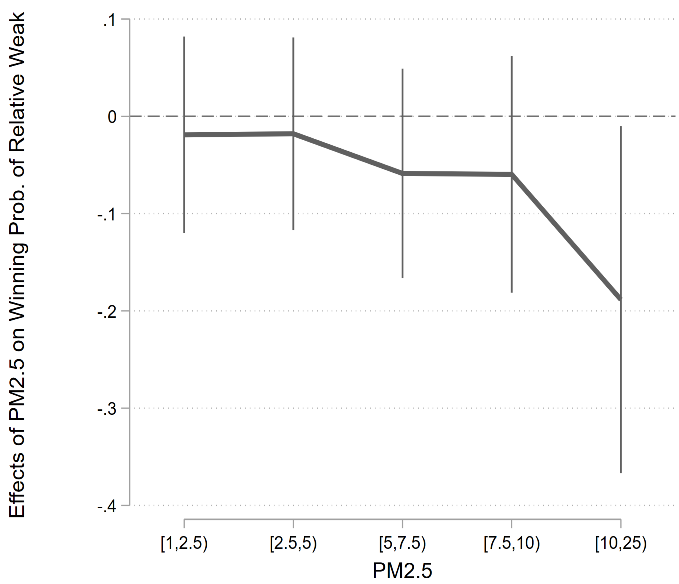


FIGURE B4
Falsification Test of Winning Rate in Last Season and PM2.5 in Current Game

Notes: This figure presents the distribution of each team's average winning rate against different rival teams in the last season to the level of PM2.5 on the match day in this season, given the same rival team. Unit of PM2.5 is 10 $\mu g/m^3$.



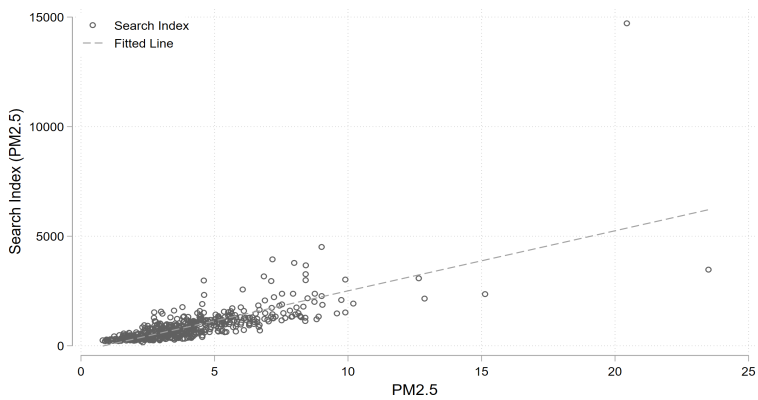
(A) Nonlinear Effects on the Stronger Team



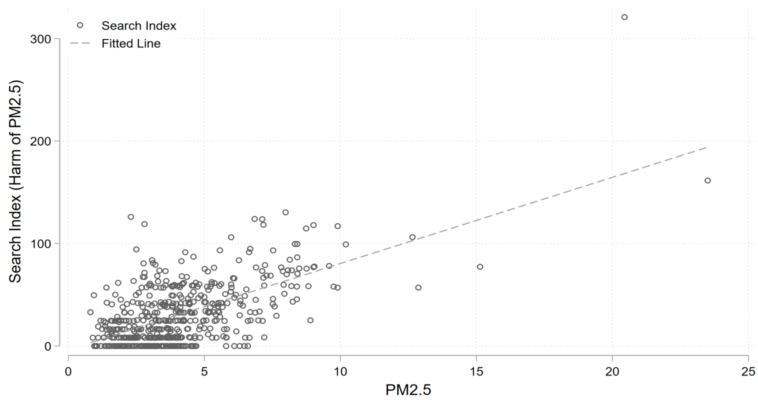
(B) Nonlinear Effects on the Weaker Team

FIGURE B5
Nonlinear Effects of Air Pollution on Competitive Performance

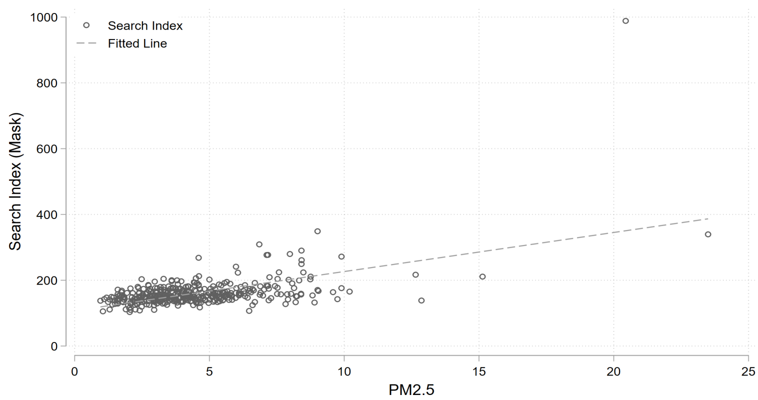
Notes: This figure presents the nonlinear distributional effects of air pollution on a team's competitive performance. Panel A plots the nonlinear effects of air pollution on the competitive performance of the stronger team in the matchup; Panel B plots the nonlinear effects on the weaker team. Detailed regression results are reported in Appendix Table A18. Unit of PM2.5 is 10 $\mu g/m^3$.



(A) Search for the level of PM2.5



(B) Search for the health damages of PM2.5



(C) Search for PM2.5-proof face mask

FIGURE B6
Scatter Plot of Pollution-related Search and PM2.5

Notes: This figure depicts the scatter plot of daily Baidu search volume of pollution-related keywords against daily level of PM2.5 in our analytical sample. Panel A presents the search for the level of PM2.5, Panel B for the health damages of PM2.5, and Panel C for PM2.5-proof face mask. Unit of PM2.5 is 10 $\mu g/m^3$.

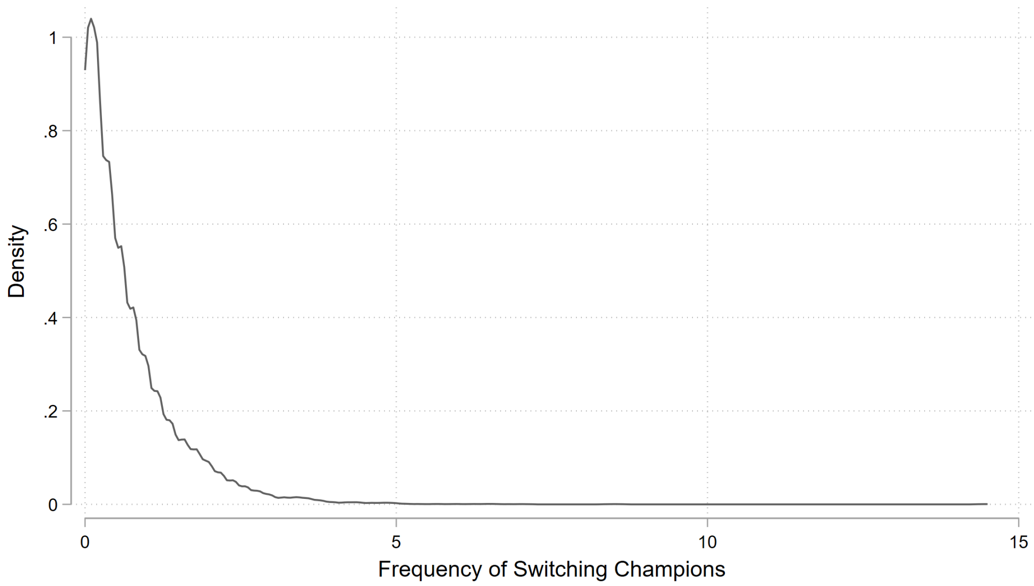


FIGURE B7
Distribution of the Number of Pick-and-switch in a Match

Notes: This figure presents the distribution of the number of pick-and-switch of a player in a given match. In the preparation phase of the match, each player in the team is allowed to pick a champion and change his choice by any number of times within a 30-second time limit.