Winner-Take-All Labor Markets and Environmental Quality

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A Summary of our Paper

We examine the effect of extreme environmental conditions on labor supply in a tournament setting.

Workers are young, healthy, highly skilled, and experienced with severe heat and air pollution: think Australia and China.

Our setting: Professional tennis matches in Melbourne every summer and Beijing every fall.

First, we show that heat and PM2.5 pollution affect within-match player strategy and outcomes, in similar ways.

Second, we build a three-stage contest model to help us understand the channels by which heat and pollution can affect unobserved player choices.

Third, we estimate the structural model by Maximum Likelihood and interpret the economic primitives.

Fourth, we conduct counterfactuals to assess how cooler and cleaner air would have changed tournament history.

Introduction

How do harsh ambient environments affect effort dynamics when workers compete for a prize over multiple rounds?

Do (when do) some workers “give up” early, at the expense of output quality?

We seek to better understand the benefits of mitigating global warming and abating air pollution.

Effort is unobservable, so we need a model to solve for this variable as a function of observed player characteristics and environmental variables.

Quasi-experimental match variation: Similarly ranked players...

1. …Exposed to *varying* temperatures and fixed air quality: The Australian Open.
2. …Exposed to *varying* air quality and fixed temperature: The China Open.

Figure: Sharapova's effort is not observable.

Left: Beijing, October 3, 2014, with PM2.5 at 197 μg/m³ (and temperature 17.7 ⁰C) during play.

Right: Beijing, October 5, 2014, with PM2.5 at 17 μg/m³ (and temperature 16.3 ⁰C) during play.

A Model of a “Best of 3” Battle

We set up a sequential game (or “match,” in tennis parlance), and solve for the stage (“tennis set”) transition probabilities as a function of economic primitives.

Constant marginal cost of effort, $c_h \geq c_l > 0$;

Players simultaneously choose effort x_h and x_l at the start of each stage;

The production function follows $y_i = (x_i)^k + \epsilon_i, i \in \{l, h\}, k \in (0,1]$;

Player i beats player j in stage m if $y_{im} > y_{jm}$ and is beaten otherwise;

If ϵ follows an EVT1 distribution, player i's winning probability at each stage is:

$$p_i(x_i, x_j) = \frac{(x_i)^k}{(x_i)^k + (x_j)^k}$$

The reward for the 3-stage game winner is V.

Because the winner can only collect the prize at the end of the game, players discount the value of the prize.

A player will discount the future more heavily when heat or air pollution are severe: a lower δ.

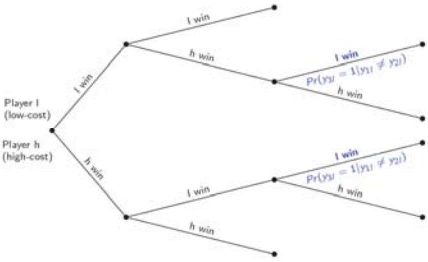

Figure: The 3-stage game, with the one-shot game embedded in the third stage.

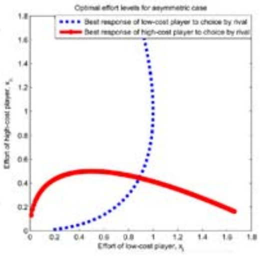

Figure: Optimal strategy in a one-shot game. Best response functions for the asymmetric player case: $c_l = 0.5c_h = 0.25V$ (illustrated)

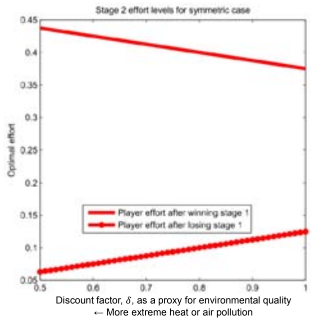

Figure: Equilibrium effort in stage 2, conditional on the stage 1 outcome, depends on heat and air pollution. Symmetric player case, $c_l = c_h = 0.5V$ (illustrated)

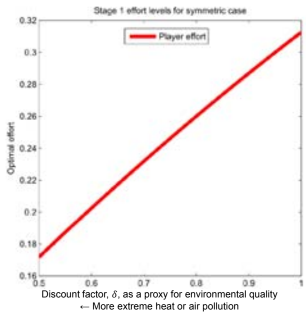

Figure: Equilibrium effort in stage 1 depends on heat and air pollution. Symmetric player case, $c_l = c_h = 0.5V$ (illustrated)

Model Predictions and Estimation

The effect of environmental severity on effort choice and transition probabilities:

1. In stage 1, higher heat or pollution (more discounting) reduce effort by both players, and the impact is larger for the low-cost player.
2. In stage 2, higher heat or pollution raise effort by the stage-1 winner and reduces effort by the stage-1 loser, and impacts are larger for the low-cost player.
   - Higher heat or pollution raise the probability that the stage-1 winner wins stage 2.
   - (This marginal effect is stark for the high-cost player, in the unlikely event she wins stage 1.)
3. In stage 3, heat or pollution do not change the players' optimal effort choice.

A match t has six mutually exclusive outcomes, captured by set $\mathcal{O}$:

$$\iota_t \in \mathcal{O} := \{\mathbf{ll}, \mathbf{lhl}, \mathbf{lhh}, \mathbf{hll}, \mathbf{hlh}, \mathbf{hh}\}$$

Prediction for observed outcomes as a function of parameters θ, e.g., **lhl**:

$$\Pr(\mathbf{lhl}|\theta) = \Pr(y_{1l} = 1)\Pr(y_{2l} = 0|y_{1l} = 1)\Pr(y_{3l} = 1|y_{1l} \neq y_{2l})$$

The likelihood across all T observed matches (Australian Open or China Open) is:

$$\prod_{t=1}^{T} \prod_{\iota_t \in \mathcal{O}} (\Pr(\iota_t|\theta))^{1(\iota_t)} \quad (1(\iota_t) = 1 \text{ iff outcome } \iota_t \text{ was observed})$$

Take logs and, given an empirical specification for marginal cost and the discount factor, find θ that maximizes the log likelihood.

Data and Reduced-Form Regressions

Our samples include all women's singles tennis matches played outdoors in:

- The Australian Open, hosted in January in Melbourne, between 2004 and 2014;
- The China Open, hosted in September in Beijing, between 2008 and 2014;
- Other recent Women's Tennis Association (WTA) tournament matches in China.

Match-level data includes: Date, start time, duration; Player-match characteristics (ranking and accumulated points, match winning probabilities from betting); Realized stage transitions within a match.

Environmental data (Victoria EPA, NASA, US Embassy, etc) includes: Hourly temperature, humidity, precipitation, wind at the time of play; Hourly ambient particle levels (Airborne Particle Index, PM2.5) and co-pollutants (e.g., ozone).

Regression example: Heat and pollution on stage 2 transition

Outcome variable: **Stage 1 loser wins stage 2.**

Sufficiently symmetric players, many controls. Marginal Effect (Robust Std.Error)

Australian Open: **Temperature** (+1 ⁰C, concurrent): -0.0166*** (0.0059)

China Open: **PM2.5** (+10 μg/m³, concurrent): -0.0225** (0.0105)

Effects are not significant for **sufficiently asymmetric** players.

Other results: (Example) Heat and pollution increase stage 1 duration for symmetric-player matches relative to asymmetric-player matches.

Structural Estimates & Takeaways

For a given parameterization of the model, θ, to illustrate with air quality:

An extra stage of exposure devalues the prize by 10 percentage points at 300 relative to 200 μg/m³: A player trades off (real or perceived) health damage from an additional stage of exposure at 10 percentage points of prize.

High? How much would top athlete Sharapova be willing to pay to avoid playing another hour exposed to severe particle pollution?

Generalizable to other tournament settings and labor markets where extreme environmental shocks may lead workers who fall behind to simply give up.

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Working paper out in the next month…