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Productivity effects of air pollution: Evidence from professional soccer

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ABSTRACT

We estimate the causal effect of ambient air pollution on individual productivity using panel data on the universe of professional soccer players in Germany over the period from 1999 to 2011 matched to hourly information on the concentration of particulate matter near each stadium at the time of kick-off. We exploit exogenous variation in players' exposure to air pollution due to match scheduling rules that are beyond the control of teams and players. The results of our analysis reveal statistically significant negative effects of air pollution on players' productivity, measured by the total number of passes per match. Allowing for a non-linear dose-response relationship further reveals that our findings are not driven by extreme levels of air pollution. Rather, negative effects already emerge at moderate levels.

1. Introduction

Air pollution is considered an important environmental risk factor for human health. The European Environment Agency estimates that exposure to air pollution causes more than 550,000 premature deaths per year in Europe alone (EEA, 2016). Against this backdrop, a vast number of epidemiological studies has been devoted to quantitatively assessing the health impacts of exposure to various air pollutants (see, for example, Pope III (2000) and Pope III and Dockery (2006) for overviews). More recent contributions by the economics literature have further added to the understanding of this relationship by highlighting the importance of individuals' optimization and avoidance behavior in response to air pollution, and widening the focus beyond traditional health outcomes (see Graff Zivin and Neidell, 2013, for an overview).[1]

In addition to causing damage to individuals' health,[2] recent empirical evidence further suggests that exposure to ambient air pollution may induce additional costs for societies by reducing individuals' labor supply and productivity, and consequently hindering economic growth. Hanna and Oliva (2015) demonstrate that poor air quality can reduce labor supply at both the extensive and intensive margin, while Graff Zivin and Neidell (2012), He et al. (2016) and Chang et al. (2016) show that air pollution significantly impairs the productivity of low-skilled agricultural and factory workers.

Our paper contributes to this strand of the literature by analyzing the effect of ambient air pollution on the productivity of young adults who are positively selected with respect to their general physiological condition, namely professional athletes. For this purpose, we make use of panel data on the universe of players and teams in Germany's top professional soccer league (the *Bundesliga*) over the period from 1999 to 2011. The richness of these data along with particular institutional features of professional soccer in Germany provide a useful setting to study the causal relationship between air pollution and individual productivity.[3] First, due to the *Bundesliga*'s match scheduling rules that are beyond the control of teams and players, individual exposure to ambient air pollution can be considered exogenous. Hence, our approach overcomes endogeneity concerns arising from residential sorting and behavioral responses to avoid exposure to pollution. Second, we are able to exploit

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[1] As discussed in more detail below, levels of air pollution may cause sorting of high-income individuals into areas with better air quality (Chay and Greenstone, 2005). Moreover, individuals may try to avoid exposure to pollution (e.g. by reducing the time spent outside), such that exposure to pollution is endogenous (Neidell, 2009).

[2] For economic studies on infant mortality, see Chay and Greenstone (2003), Luechinger (2014) or Tanaka (2015). Effects of air pollution on infants' and children's health are studied by Currie and Neidell (2005), Currie et al. (2009), Lleras-Muney (2010) and Janke (2014), among others. Deschênes et al. (2012) show that high concentrations of air pollution increase premature death among the elderly. Schlenker and Walker (2016) demonstrate that hospitalization rates among the working-age population increase with the level of air pollution.

[3] Professional sports data have been frequently used to analyze economic questions (see Kahn, 2000, for an overview). For example, Parsons et al. (2011) study behavioral implications of discrimination using umpire decisions in professional baseball. Brown (2011) shows how workers' effort in competitions depends on the relative ability among competitors by exploiting the presence of a superstar in professional golf tournaments. Kleven et al. (2013) exploit cross-country differences in labor market regulation and income taxation to analyze the effect of top-income tax rates on international migration decisions of soccer players in Europe. Using data on professional golf players, Rosenqvist and Skans (2015) investigate how past success can boost future performance.

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rich data on individual productivity, which is measured in a consistent and comparable way in 2956 matches at 32 different stadiums throughout the country on a weekly basis over a twelve-year period. Such a comprehensive coverage is generally not available for most other occupations. For each match, we combine information on individual productivity with hourly data on the concentration of particulate matter (PM10) and ozone (O_3) in spatial proximity to the stadium at the time of kick-off.

As our main measure of a player's productivity we use the total number of passes per match. As discussed in detail below, passing constitutes a decisive element of the game and has been shown to be correlated with team success (see, for example, Collet, 2013). In addition, the number of passes is related to a player's physical ability but also reflects his effort choices during a particular game. Air pollution may thus impair the overall productivity of a player by limiting his physical capacity but also by inducing him to reduce his effort level in order to avoid additional physical strain.

Overall, we find significant negative effects of ambient air pollution on players' productivity. Using within-player variation and controlling for weather conditions on the matchday as well as a variety of player, team and match variables we find that a one standard deviation increase in the concentration of particulate matter (around 16 $\mu g/m^3$) reduces the number of total passes played by 0.4 – or 2.4% of a standard deviation – on average. When allowing for a non-linear dose-response relationship, our results further reveal that negative effects of PM10 concentration already emerge at moderate levels of air pollution. By contrast, we do not find a statistically significant effect of ozone concentration on players' productivity once controlling for weather conditions and the time of kick-off. We show that this is most likely due to limited variation in ozone concentration in our estimation sample, given that *Bundesliga* matches are generally not held during summer when ozone concentrations peak due to intense solar radiation and high temperatures.

While our estimates do not allow us to disentangle the relative importance of the pure physiological effect of air pollution from players' behavioral responses to the additional physiological strain, we provide suggestive evidence that both factors drive the observed reduced-form effect. More precisely, we show that air pollution affects players' pass accuracy as well as their style of play, measured by the ratio of long over short passes. While we argue that the former measure rather reflects a player's physiological ability, the latter relates more to his behavioral choice regarding the style of play as he may be able to alleviate physical strain by kicking the ball far away.

Our analysis further reveals considerable heterogeneous effects of air pollution across individuals. We find that negative effects of particulate matter on passing increase with age and are largest for players aged above 30. Lastly, we show that aggregate team- and match-level regressions yield similar results, suggesting that interaction effects between pollution, individual productivity and the player's team-mates' or opponents' productivity are either small or cancel out.

The remainder of this paper is organized as follows. Section 2 describes the institutional background and data. Section 3 introduces the empirical strategy. The results are presented in Section 4, before Section 5 concludes.

2. Background and data

2.1. Professional soccer in Germany

In our analysis, we exploit rich data on athletes' performance in matches of the *Bundesliga*, Germany's top professional league of men's soccer. Every season, eighteen teams face each other at home and away (see Fig. 1 for the geographic spread of teams across Germany). Thus, a season comprises 34 matchdays and 306 matches, which are typically held on weekends between late August and May.[4] At the beginning of every season, the German Soccer League determines the match schedule for the entire season and specifies the weekend on which a specific matchday takes place as well as which teams face each other at which stadium. The exact day and time of each match is determined several weeks in advance and subject to a set of factors, such as international soccer competitions, television agreements or security considerations.[5] Importantly, match schedules are beyond any control of teams and players.

2.2. Productivity of soccer players

Information on players' productivity is provided by *deltatre*, a commercial enterprise collecting data on professional sports and serving as an external service provider to the media and sports clubs. The dataset comprises information on all *Bundesliga* matches for every season from 1999/2000 to 2010/2011 and contains detailed information for each match (location, date and kick-off time, home and away teams) and each player who was on the pitch at any point during the match.[6] For every player, we observe the number of minutes played (up to the full duration of 90 min), the team played for, the position played (defender, midfielder or striker) as well as various measures of productivity. We exclude goalkeepers from our analysis as they constitute a very different style of play.

We use players' total number of ball passes during a match as our main measure of individual productivity. Passes generally serve as one key statistic for the assessment of players' performance in soccer matches. Although teams might be successful by pursuing a rather defensive style of play and thus passing the ball less often than their opponent, research shows that the number of passes represents an essential element of team success. For example, Redwood-Brown (2008) shows that a team's number of completed passes significantly increases in the five minutes before scoring. Moreover, focusing on the major European soccer leagues (including the *Bundesliga*), Collet (2013) documents a strong positive relationship between the number of passes and various measures of team success, such as the total number of goals scored, the likelihood of winning and the points earned in one season.[7]

We consider a player's total number of passes as a suitable measure of productivity as it reflects both individuals' physical ability as well as effort choices during a particular match; factors that determine workers' productivity in any other occupational task as well. Thus, the reduced-form effect of air pollution may be due to impaired physical capacity but may also be driven by behavioral responses in light of the additional physical strain. In order to assess the relative importance of these elements, two additional measures of players' performance are considered: pass accuracy and the ratio of long over short passes. We argue that the former measure mainly reflects players' physical ability while the latter rather represents a behavioral response in the players' style of play.[8]

[4] The season pauses for a winter break, generally lasting from late December until late January. After each season, the worst three teams are relegated, while three teams are promoted from the second division (*2. Bundesliga*).

[5] For example, teams from the same city or neighboring areas do not play matches at home on the same day.

[6] Even if matches end in a draw after 90 min, there is no overtime or penalty shootout in the *Bundesliga*.

[7] Players' running distance might serve as another interesting measure of productivity. Unfortunately, information on running distance was not collected prior to the season of 2010/2011, which precludes us from analyzing this measure. However, using publicly available data for the seasons of 2013/2014 to 2015/2016, we show that the relationship between players' running distance and the number of passes per match appears to be strongly positive (see Appendix Fig. A.1). The underlying data were obtained from the German soccer magazine *Kicker*, see www.kicker.de.

[8] Reductions in pass accuracy, lowering a team's possession of the ball, cannot be considered as a deliberate behavioral choice in order to reduce physical strain. By contrast, adjustments in the style of play, i.e. kicking the ball far away, may indeed (temporarily) reduce the overall physical burden.