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How does air pollution influence cycling behaviour? Evidence from Beijing

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ABSTRACT

It is widely believed air pollution is an obstacle to cycling as it has negative effects on cyclists' health outcomes and deteriorates their cycling experiences. However, the empirical studies investigating the impact of air pollution on cycling behaviour remains scarce. The aim of this paper is to fill the gap by looking at Beijing as a case study. The authors conducted a survey of 307 cyclists on the days with different levels of air quality in terms of concentration of $PM_{2.5}$ in 2015. The results show that in the polluted weather, those who persist in cycling are more likely to be male, over 30 years old, lower income or those who travel short distances. Specifically, female cyclists have a higher tendency to shift from cycling to public transit than the males and medium and high-income earners are more likely to shift to using a car than low income earners. The residents' subjective perceptions of safety and comfort have major effects on their cycling behaviour. A higher perception of comfort and safety is related to a higher possibility of continuing cycling when air quality became polluted. Cycling for commuting trips is less likely to be replaced by other modes than cycling for non-commuting trips, such as shopping. Results of this study reveal that improving air quality in a metropolitan area such as Beijing has co-benefits of cycling renaissance. The huge investments into cycling infrastructure should be integrated with policies designed to create an attractive environment for cycling.

1. Introduction

It is widely believed that cycling is a sustainable mode of travel. Cycling not only has health benefits as it enhances the level of physical activity, but also contributes to less environmental pollution and greenhouse emissions via reduced levels of car dependence. A cycling-friendly environment is attractive for regular and potential cyclists. The characteristics of a cycling-friendly environment usually include comfortable natural surroundings such as flat topography and warm temperatures along the route, decent built-up areas where cycling routes of choice are embedded, and city and neighbourhood design elements that provide cycling-accessible jobs and service opportunities within smooth and safe corridors (Buehler and Pucher, 2012; Moudon et al., 2005; Pucher and Dijkstra, 2000; Wang et al., 2015). A handful of studies examined the effects of generic weather on cycling in various contexts (Alam, 2015; Helbich et al., 2014; Meng et al., 2016; Motoaki and Daziano, 2015). Uncomfortable weather such as overheating or chilling, as well as excessive precipitation might reduce the attractiveness of cycling. Although abundant research has taken place, four research gaps still need to be filled.

The first gap is that the existing research on the effect of air pollution on cycling has mostly focused on the health risks of cycling when compared with other motorised modes of transport, lacking evidence on how hazardous weather influences cycling behaviour.

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Air pollution may discourage many cyclists from cycling and force them to switch to other travel modes, so understanding the impact of air quality on cycling behaviour may be helpful for environment policies towards more sustainable transportation. The second gap is that there is disproportional evidence on the impacts of some air pollutants like Sulfur Dioxide (SO_2) or Nitric Oxide (NO) on cycling, while the evidence on certain pollutants such as $PM_{2.5}$ on cycling remains rare. $PM_{2.5}$ is important in both environment research and policy, because it has a much more substantial influence on air quality, and it is the main origin of respiratory and chronic diseases (Lelieveld et al., 2015). Additionally, how air quality affects cycling behaviour through psychological perceptions still needs further investigation. Cyclists' psychological perceptions of the environment could also influence their willingness to cycle, whose effect might be substantially distinct from the empirical examined relation based on objective measurements (Baldock et al., 2012; Ma and Dill, 2015). For instance, those who have a stronger tendency to use bicycles may still keep cycling in an environment that is not attractive for common cyclists. Finally, existing literature on the impact of air pollution on cycling behaviour are dominated mainly by information from developed countries, while evidence from developing countries remain rare. The air quality is generally poorer in developing countries compared with the developed ones because of the rapid industrialization and urbanization, while the population density is much higher and active travel is more popular. Thus, investigating the relationship between air quality and cycling behaviour would be urgent for the transportation planning in the developing countries.

The aim of this study is to fill the above gaps by examining the case of Beijing, China. Beijing is the capital city of China. At the end of 2015, the number of permanent residents in Beijing reached 21.7 million, with US$17,064 in GDP per capita. As a country ever dominated by cycling travel just three decades ago, China is now facing a big challenge in the substantial reduction of cycling. For example, cycling decreased from 62.7% in 1986 to 13.9% in 2012, while car use share increased from 5% in 1986 to 32.6% in 2012 in Beijing (Beijing Transportation Research Center, 2005; Zhao, 2011; Zhao et al., 2010,2011). In contrast, the number of private vehicles reached 4.403 million in Beijing in 2015, increasing 0.41 million from 2010 (Beijing Statistical Bureau, 2016). This shift caused a serious problem with traffic congestion, air quality, and health. In 2012, average road speed in rush hour was reduced to 25 km/h and the daily congestion reached four hours (Zhong et al., 2017). Traffic emissions contributed to 22% of the total annual $PM_{2.5}$ in the city (Shi et al., 2017). Polluted days with higher concentrations of $PM_{2.5}$ were linked with respiratory and chronic diseases and also more serious health problems such as cardiometabolic sickness and adverse pregnancy outcomes, based on studies in Beijing (Brook et al., 2017; Song et al., 2017).

With cycling regaining its popularity by promoting physical activity and mitigating the city's traffic congestion and vehicle-related pollution, many cities in China are now providing more policy and infrastructure support for cycling (Beijing Morning Post, 2015). In Beijing, the state and the municipal government has been making efforts to promote cycling. These policies include comprehensive efforts to promote cycling-exclusive infrastructures, priority policies for cyclists, bicycle sharing schemes, and behaviour education. In Beijing, the length of bicycle lanes increased to 700 km in 2016 (Beijing Statistical Bureau, 2016). Apart from privately owned bikes, the amount of public share-bikes increased rapidly. In just two years, 15 bicycle sharing scheme providers added more than 2.35 million dockless share-bikes to Beijing's streets, powered by strong venture capital competition (Beijing Youth Daily, 2017). Promoting cycling has also been addressed in the new Beijing Municipal Master Plan. According to the plan, many policies will be implemented to facilitate cycling in Beijing, for instance, exclusive bicycle lanes, a narrow street cycling priority policy and cycling friendly pilot zones in the coming years (Beijing Traffic Management Bureau, 2010; Central Govenment of China, 2017).

However, air pollution could be a barrier to the potential renaissance of cycling in Beijing. In 2015, Beijing had 303 days with $PM_{2.5}$ concentration higher than the daily limit of 25 $\mu g/m^3$, which is seen as a minimum health level by the World Health Organization (WHO, 2006). Even when considering the mildest WHO Interim Target 1 of 75 $\mu g/m^3$ adopted by the Chinese government, Beijing still had 142 days with $PM_{2.5}$ exceeding this criteria (Fontes et al., 2017; U.S. Department of State, 2016). Such bad air pollution created an unattractive environment for cycling and affected cycling trips in Beijing. However, the impact of $PM_{2.5}$ on cycling behaviour in a developing metropolis like Beijing remains scarce.

This paper provides evidence that air pollution influences cycling behaviour. It aims to investigate whether air pollution may contribute to bicycle behaviour changes, and how does this happen where perception and socio-economic variables are mediators. The authors did a survey that collected questionnaires from 307 cyclists on the days with different levels of hazardous air quality. The remaining part of the paper is organized as follows. Section 2 reviews the relationship between air pollution and cycling behaviour. Section 3 introduces the data context and the survey content. Sections 4–6 present results and discussion of the modelling findings and policy implications. Section 7 provides a summary and policy implications based on the research findings.

2. Literature review

2.1. Air pollution, cycling and health

This section reviews the existing literature investigating the impact of air pollution on cycling and the related health outcomes and potential determinants of cycling behaviour. There have been multiple studies examining the health impact of cycling in polluted air. It is generally believed that residents inhale more hazardous pollutants during transportation (for example, black carbon; (Dons et al., 2012)). There are two contradicting arguments regarding the health performance of cycling in polluted days, with one suggesting that the active travel benefits of cycling outweigh the health risks of air pollution (summarised by Cepeda et al. (2017)) and the other stating that the risks of ambient pollutants for cyclists cannot be negated (Briggs et al., 2008). These arguments come from studies either comparing health benefits and risks of cycling or horizontally comparing exposure in different modes of transport. We review the recent literature and summarise three reasons that potentially lead to the different conclusions in the above two issues.