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The effect of Beijing's driving restrictions on pollution and economic activity ☆

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ABSTRACT

We evaluate the pollution and labor supply reductions from Beijing's driving restrictions. Causal effects are identified from both time-series and spatial variation in air quality and intra-day variation in television viewership. Based on daily data from multiple monitoring stations, air pollution falls 21% during one-day-per-week restrictions. Based on hourly television viewership data, viewership during the restrictions increases by 9 to 17% for workers with discretionary work time but is unaffected for workers without, consistent with the restrictions' higher per-day commute costs reducing daily labor supply. We provide possible reasons for the policy's success, including evidence of high compliance based on parking garage entrance records.

1. Introduction

Driving restrictions are used in numerous cities around the world to reduce pollution and congestion.[2] Such restrictions may be ineffective either due to non-compliance or compensating responses such as inter-temporal substitution of driving or adding second vehicles. If effective, they may lower economic activity by increasing commute costs and reducing workers' willingness to supply labor. There is little empirical evidence of driving restrictions' effect on pollution and none about their effect on economic activity. We examine both under driving restrictions imposed by the Beijing government since July 20, 2008. The restrictions, based on license plate numbers, initially prevented driving every other day and later one day per week.

On the benefits side, the restrictions significantly reduce particulate matter, a pollutant estimated to claim 6.4 million life-years annually worldwide (Cohen et al., 2005) and a severe air pollutant in Beijing and many other cities worldwide. Using daily data and a regression discontinuity design (RD), our point estimates indicate that the every-other-day restrictions reduced particulate matter by 18% and one-day-a-week restrictions by 21%. Given that motor vehicles create roughly 50% of particulate matter in Beijing this is consistent with strong compliance. We find little evidence of inter-temporal substitution of driving.

Particulate matter's ambient properties dictate that it is deposited within a few kilometers of its release. We exploit this to develop a differences-in-differences (DD) approach that combines time-series variation with spatial variation in monitoring stations' locations and

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[2] These include Santiago, Mexico City, São Paulo, Bogotá, San Jose, La Paz, Athens, Barcelona, Amsterdam, Tokyo, all of Honduras, and several Italian cities. See Mahendra (2008), Wolff and Perry (2010), and "With Mixed Results, Cities Battle Traffic and Pollution," *Spiegel Online*, April 4, 2005.

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eliminates other explanations for the pollution reduction. Pollution drops more at stations closer to a major road.[3] This means that potential confounding factors are related to proximity to a major road and therefore traffic flow. We consider, and rule out, changes in gasoline prices, parking fees, number of taxis, emissions standards, and government-imposed working hours. Papers that use variation in distance from pollution sources for DD identification include Currie and Walker (2011) (response to toll traffic changes based on distance from toll plazas); Schlenker and Walker (2012) (response to airport congestion changes in areas downwind and upwind of airports); and Hanna and Oliva (2011) (response to a factory closure based on distance to the erstwhile factory).

On the cost side, we investigate how the driving restrictions' higher commute costs affect economic activity. Lacking direct measures of work time or traffic flows, we rely on consumption of a major substitute — leisure time watching television (TV). Viewership as a proxy biases against finding an effect because the restrictions reduce auto congestion and pollution making outdoor activities more attractive relative to indoor TV viewership.[4] To rule out confounding factors that affect viewership, we compare responses of workers with discretionary work time (self-employed) to those whose days worked and daily hours are fixed in the short run (hourly employees). Since the one-day-a-week driving restrictions apply (initially from 6:00 a.m. to 9:00 p.m. and later 7:00 a.m. to 8:00 p.m.) during most workers' regular working hours, we examine viewership during the restricted hours to measure the effect on days worked but also examine viewership outside the restricted hours to determine if changes in work day length more than compensate.

Using an RD design, viewership by self-employed workers increases by 8.9 to 16.9% during the restricted hours of the one-day-a-week policy, consistent with substitution from days worked to leisure in response to higher commute costs. Viewership changes little outside the restricted hours ruling out the possibility that longer daily work hours offset the fewer work days. Output is reduced unless efficiency increases during the fewer remaining work hours. Hourly employee viewership decreases during restricted hours consistent with their having no choice over days worked but experiencing fewer at-home sick days due to reduced pollution. Although daily work hours for these workers should remain unchanged, their leisure time could change depending on changes in commute modes and congestion. We find minor adjustments in viewership outside the restricted hours.

Using back-of-the-envelope calculations, we estimate the annual benefits from reduced morbidity and fewer reduced activity days due to the one-day-a-week restrictions to be RMB 2.56 to 3.47 billion while the cost of reduced output is RMB 0.52 to 0.94 billion. The remainder of the paper is organized as follows. Section 2 reviews Beijing's driving restriction policies and related work. Section 3 develops a simple model of driving restrictions' effects on pollution and labor supply. Section 4 describes the data. Section 5 contains the pollution results and Section 6 the viewership results. Section 7 provides some cost-benefit calculation while Section 8 provides reasons for the policy's effectiveness. Section 9 concludes.

2. Background

Air pollution and its health consequences are a major concern in Beijing, which was ranked thirteenth "most polluted city" in the world in 2004 for suspended particulates.[5] The economic cost of suspended particulates to China is estimated at 22.4 billion (1997 USD) in 2005 (Matus et al., 2012). Although a particularly acute problem in developing economies (Greenstone and Hanna, 2014), particulate matter is a major concern worldwide (Watkiss et al. (2005) provide evidence for Europe). Particulate matter is linked to cardiopulmonary diseases, respiratory infections, and lung cancer (EPA, 2004), and increases infant mortality (Chay and Greenstone, 2003). Other air pollutants also have negative health effects linked to infant mortality (Currie and Neidell, 2005) and childhood asthma (Neidell, 2004).

We focus on PM_{10} which is the ambient concentration (in $\mu g/m^3$) of particulates smaller than 10 μm. Various sources create PM_{10}, but autos are the major contributor in most urban areas. Autos create PM_{10} through emissions and by creating road dust.[6] Jiang (2006) reports that approximately 53% of Beijing's PM_{10} is attributable to motor vehicles — 23% due to emissions and 30% road dust.[7] Therefore, autos create roughly half of the air pollution we examine. As this is fairly consistent across countries, reducing auto pollution is important more generally.[8]

Beijing's driving restrictions began on July 20, 2008 with an odd–even ("OddEven") policy restricting cars to drive only every-other-day. This policy applied seven days a week and to all hours except midnight to 3:00 a.m. These restrictions ended on September 20, 2008. On October 11, 2008 the government re-instated driving restrictions, preventing cars from driving one-day-per-week ("OneDay"). This policy applied on weekdays and initially between 6:00 a.m. and 9:00 p.m. We call this period "OneDay69." On April 11, 2009 the daily restriction period narrowed to 7:00 a.m. through 8:00 p.m. and remained unchanged beyond our sample period. We call this period "OneDay78" and use "OneDay" to apply to the combined OneDay69 and OneDay78 periods.

The policies restricted vehicles based on the last digit of their license plate numbers. During the OddEven policy, odd-numbered license plates could drive only on odd-numbered dates and even-numbered only on even-numbered. The OneDay policy restricted two out of the ten plate numbers each weekday so that the restrictions followed a weekly cycle. The pairing of digits remained the same week-to-week ((0, 5), (1, 6), (2, 7), (3, 8), (4, 9)) but the assignment of these pairs to weekdays was initially rotated each month and, beginning April 11, 2009, every thirteen weeks.

The OddEven and OneDay69 policies applied to all roads (regardless of size) within and including the 5th Ring Road while the OneDay78 policy applied to all roads within but not including the 5th Ring Road (Fig. 1 shows these areas). Police cars, taxis, ambulances, postal vehicles, and embassy cars were exempt although these are few in number.[9]

As Fig. 2 shows, other pollution-relevant policies occurred around the time of the driving restrictions. These included bus fare reductions and subway line openings. In addition, during the Olympic Games many non-essential businesses and factories were closed; and migrant workers (those without Beijing *hukous*) were sent home. These all may affect air pollution.[10] Factory closures and migrant worker relocation coincide with the Olympic Games and we include a dummy variable and separate time trend in our estimates to capture that period. We address the other policies – bus and subway fare reductions and subway openings – in a variety of ways. In our RD estimates, we include flexible time trends to control for these policies and perform robustness checks to test their flexibility. We also estimate the driving restrictions' effects using small

[3] As we explain later, we define a major road as a Ring Road.

[4] TV viewing on mobile devices is extremely limited during our sample period and not included in our viewership measure.

[5] "Beijing Pollution: Facts and Figures," *BBC News*, August 11, 2008 based on 2004 World Bank data.

[6] Some cities measure $PM_{2.5}$, which includes particulates below 2.5 μm and does not capture road dust.

[7] Citing "Beijing's Strategy to Control Air Pollution" by the Beijing Environmental Protection Bureau. Cui et al. (2009) estimate that autos create 62% of all air pollutants, including PM_{10}.

[8] In the U.S., the EPA's 2005 National Emissions Inventory Data attributes 10.7 (53.5%) of the 20.0 million tons of PM_{10} particulate matter nationwide to "Road Dust" and "On Road Vehicles."

[9] Two-wheel, combustion-engine vehicles such as mopeds and motorcycles were banned from Beijing's 2nd, 3rd, 4th, and 5th Ring Roads beginning December 8, 2000.

[10] Air travel also likely changed during this period but particulate matter is less than 1% of aircraft engine emissions ("Aviation & Emissions: A Primer," Federal Aviation Administration Office of Environment and Energy, January 2005, page 1). Also, since particulate matter dissipates within a few kilometers, the small amount of PM_{10} measurable by ground sensors would be produced during takeoff and landing near the Beijing airport which is 10.5 km from the nearest station in our sample.