The Effect of Driving Restrictions on Air Quality in Mexico City

Lucas W. Davis

University of Michigan

In 1989, the government of Mexico City introduced a program, *Hoy No Circula*, that bans most drivers from using their vehicles one weekday per week on the basis of the last digit of the vehicle's license plate. This article measures the effect of the driving restrictions on air quality using high-frequency measures from monitoring stations. Across pollutants and specifications there is no evidence that the restrictions have improved air quality. Evidence from additional sources indicates that the restrictions led to an increase in the total number of vehicles in circulation as well as a change in composition toward high-emissions vehicles.

I. Introduction

Whereas U.S. cities have seen dramatic improvements in air quality over the last three decades,[1] Mexico City has been considerably less successful. Levels of major air pollutants in Mexico City routinely exceed maximum exposure limits established by the World Health Organization (WHO). For example, the WHO (2005) has warned that 8-hour average ozone levels exceeding 100 micrograms per cubic meter threaten hu-

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[1] According to the U.S. Environmental Protection Agency (EPA 2003), between 1970 and 2002, emissions of nitrogen dioxide, ozone, sulfur dioxide, particulate matter, carbon monoxide, and lead in the United States decreased by an average of 48 percent.

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man health. During the period 1986–2005, this guideline was exceeded in Mexico City for 92 percent of all days.

A large literature documents the social cost of air pollution (e.g., Dockery et al. 1993; Pope et al. 1995; Chay and Greenstone 2005). Airborne pollutants have been linked to respiratory infections, chronic respiratory illness, and aggravation of existing cardiovascular disease. Some of the most convincing evidence of health effects comes from studies that have examined infant mortality. Chay and Greenstone (2003) and Currie and Neidell (2005) find significant effects of air pollution on infant mortality using variation in air pollution during the 1981–82 recession and in California during the 1990s, respectively. The total social cost of air pollution is likely even larger because of the changes in behavior undertaken to reduce exposure (Neidell 2007). In Mexico City such changes in behavior are widespread. For example, most residents of Mexico City avoid outdoor activity during periods of low air quality.

Record levels of ozone and other airborne pollutants led the Mexico City government on November 20, 1989, to introduce a program, *Hoy No Circula* (HNC), which bans most drivers from using their vehicles one weekday per week on the basis of the last digit of the vehicle's license plate. For example, vehicles with a license plate ending in 5 or 6 may not be used on Mondays. The restrictions are in place during weekdays between 5:00 a.m. and 10:00 p.m. and affect the vast majority of residential and commercial vehicles. Taxis, buses, police cars, ambulances, fire trucks, commercial vehicles operating with liquid propane gas, and commercial vehicles transporting perishable goods are exempt.[2] The restrictions apply to the entire Mexico City metropolitan area, hereafter "Mexico City," which includes Mexico City and municipalities in neighboring states. When imposed in 1989, the restrictions applied to 2.3 million vehicles, or 460,000 vehicles per day.

Compliance with the program is near universal. Since the first day the restrictions were implemented they have been enforced vigorously by the city police.[3] One of the advantages of basing the restrictions on license plates is that vehicles violating the ban are easy to spot. Mexican

[2] See Gobierno del Distrito Federal, Secretaría del Medio Ambiente (2004*a*) for a detailed history of the program. Modifications to the program in 1997 and 2004 have made certain additional low-emissions vehicles exempt from the restrictions and removed exemptions for some taxis and buses.

[3] In the days immediately following the implementation of HNC the media coverage focused on the large number of vehicles being impounded, the amount of money generated by fines, and the capacity of Mexico City facilities to handle additional impounded vehicles. Articles from *La Jornada* include "Ocho mil vehículos detenidos en la primera jornada de Hoy No Circula" (November 21); "Funciona el programa Hoy No Circula, asegura Camacho Solís" (November 22); "489 autos, al corralón por circular con engomado verde" (November 24); and "Espera recaudar el DDF, 710 mil millones en una semana" (November 26).

law stipulates that vehicles that violate the ban are to be impounded for 48 hours and their owners are to pay a fine equivalent to US$200.[4] Often these penalties can be avoided by paying a bribe to the police officers involved, though bribes are expensive and the large police presence in Mexico City means that one may need to pay many bribes in order to complete a short trip. In practice, these costs are large enough to have convinced most drivers to leave their automobiles at home on the days they are banned from driving.

This article measures the effect of HNC on air quality using hourly air pollution records from monitoring stations. Pollution levels are compared before and after the restrictions for five major pollutants, with levels in previous years acting as a comparison group to control for seasonal variation. The analysis controls for possible confounding factors by restricting the sample to a relatively narrow time window around the implementation of HNC and by using a regression discontinuity design. Across pollutants and specifications there is no evidence that the program has improved air quality. There is evidence that weekend and late night air pollution increased relative to weekdays, consistent with intertemporal substitution toward hours when HNC is not in place. However, there is no evidence of an absolute improvement in air quality during any period of the week for any pollutant.

Driving restrictions have been studied in the past (Levinson and Shetty 1992; Goddard 1997; Molina and Molina 2002), but this is one of the first attempts to provide empirical evidence. One exception is the study by Eskeland and Feyzioglu (1997), who examine gasoline sales and vehicle registrations in Mexico City during the period 1984–93. This article revisits the evidence on gasoline sales and vehicle registrations using a regression discontinuity specification to control for omitted time-varying factors and a number of additional refinements. Similar methods are then applied to examine bus ridership, subway ridership, taxi registrations, and advertised prices for used taxis and transit vans. While it was hoped that the program would cause drivers to substitute to low-emissions forms of transportation, there is no evidence of a decrease in gasoline sales or an increase in public transportation use. Instead, the evidence indicates that HNC led to an increase in the total number of vehicles in circulation as well as a change in the composition of vehicles toward high-emissions vehicles.

This analysis is relevant to current environmental policy in Mexico City. Air quality remains a severe problem in Mexico City, with ozone levels exceeding WHO standards for 79 percent of all days in 2005. HNC remains in place, and there is currently a high-profile discussion about whether or not to expand the HNC restrictions to include Saturdays.

[4] Dollar values throughout the article have been deflated to reflect year 2006 prices.

Some see HNC as the central component of Mexico City's strategy for addressing air pollution, whereas others would like to phase out HNC and replace it with other forms of pollution control. Reliable estimates of the effect of HNC on air pollution are necessary for evaluating these alternatives.

More generally, the analysis has implications for air quality and transportation policies throughout the urban developing world. According to the World Bank (2003, 168), the 10 cities with the highest average levels of airborne particulates are all in the developing world. Trends in population and vehicle growth in these urban areas threaten to exacerbate these problems.[5] Driving restrictions are one of the tools available to policy makers as they confront this growing problem. Indeed, since HNC was implemented, similar programs have been implemented such as *pico y placa* in Bogota, *restricción vehicular* in Santiago, and *rodízio* in São Paolo. In total, over 50 million people live in cities with driving restrictions based on license plates. Driving restrictions may seem like a sensible alternative because they are relatively inexpensive to enforce and require substantially smaller public investment than some alternative policies. However, it is important to have reliable empirical estimates of the impact of these policies and the substitution patterns that they induce in order to evaluate their cost-effectiveness.

II. Measuring Air Quality in Mexico City

Air quality in Mexico City is recorded by the Automated Environmental Monitoring Network maintained by the city environmental agency. Established in 1986, the network consists of monitoring stations distributed throughout Mexico City.[6] The network reports hourly measures of carbon monoxide, nitrogen dioxide, ozone, nitrogen oxides, and sulfur dioxide. These measures are widely used in scientific publications and are reported to the public in the form of the Metropolitan Air Quality Index.

Figure 1 plots average daily pollution levels during the period 1986–2005. Average daily pollution levels were constructed by averaging over

[5] Between 2000 and 2030 the number of people living in cities in less developed countries is forecast to increase by 1.96 billion. This represents 97 percent of the projected global population increase during this period. See UN Population Division (2004) for more information.

[6] Station locations in the network (Red Automática de Monitoreo Ambiental) were determined by Mexico City's Environmental Agency (Secretaría del Medio Ambiente) and are intended to reflect a representative sample of neighborhoods in Mexico City. The stations have been extensively tested and are certified annually by the U.S. EPA. The EPA certification includes testing of measurement procedures and comparisons against mobile EPA equipment. The stations are located away from direct emission sources, and measurements are believed to be highly accurate, particularly for ozone (within 3 percent). See Molina and Molina (2002) for more information about the accuracy of the network.

yet yielded no apparent improvement in air quality, making it difficult to justify on the basis of cost-effectiveness.

VI. Conclusion

This article examines the effectiveness of Mexico City's driving restrictions. Air quality is compared before and after the restrictions were implemented using high-frequency measures of five major air pollutants from monitoring stations. Across pollutants and specifications there is no evidence that the program improved air quality. The policy has engendered a relative increase in air pollution during weekends and nonpeak weekdays, but there is no evidence of an absolute improvement in air quality during any period for any pollutant. This lack of evidence of an improvement in air quality is explained by examining data from a large number of different sources. Whereas it was hoped that the driving restrictions would cause drivers to substitute to low-emissions forms of transportation, there is no evidence of increased ridership of the subway, public bus system, or private bus system. Instead, evidence from vehicle registrations and automobile sales indicates that the program led to an increase in the total number of vehicles in circulation as well as a change in the composition of vehicles toward used, and thus higher-emitting, vehicles. This pattern explains the lack of evidence of an improvement in air quality as well as the evidence from gasoline sales. In addition, although evidence from taxi registrations and used taxi prices provides no direct evidence of substitution toward taxis, the article describes how a relatively small increase in taxi utilization could have substantially contributed to the apparent lack of effectiveness of HNC. Overall, the pattern of behavioral responses indicates that the restrictions were unsuccessful in inducing drivers to substitute away from private vehicles.

The program in Mexico City has been since emulated in São Paolo, Bogota, and Santiago. Similar programs are currently being considered for Monterrey and Beijing. Driving restrictions may seem like a reasonable approach for addressing the difficult problem of urban air pollution. However, this article illustrates the importance of conducting ex ante economic analysis of the substitution patterns likely to be induced by these policies. Although the particular experiences will differ across contexts, the overall pattern of adaptation observed in Mexico City is likely to be repeated elsewhere. Drivers everywhere have a revealed preference for fast and convenient transportation and will find ways to circumvent rationing programs of this form. Depending on the emissions characteristics of available alternatives, these changes in behavior can seriously undermine the potential benefits.