Transportation Research Part D 36 (2015) 76–85

Contents lists available at ScienceDirect

Transportation Research Part D

journal homepage: www.elsevier.com/locate/trd

The environmental effects of changing speed limits: A quantile regression approach

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ARTICLE INFO

Article history:
Available online 12 March 2015

Keywords:
Traffic speed management
Urban air pollution
Quantile regression

ABSTRACT

Two speed management policies were implemented in the metropolitan area of Barcelona aimed at reducing air pollution concentration levels. In 2008, the maximum speed limit was reduced to 80 km/h and, in 2009, a variable speed system was introduced on some metropolitan motorways. This paper evaluates whether such policies have been successful in promoting cleaner air, not only in terms of average pollutant levels but also during high and low pollution episodes. To do so, we use a quantile regression approach for fixed effect panel data, which allows us analyzing different scenarios (beyond the average levels). We find that the variable speed system improves air quality with regard to the two pollutants considered here, being most effective when nitrogen oxide levels are not too low and when particulate matter concentrations are below extremely high levels. However, reducing the maximum speed limit from 120/100 km/h to 80 km/h has no effect – or even a slightly increasing effect – on the two pollutants, depending on the pollution scenario.

Introduction

Improving air quality is a major objective in most urban areas, but in metropolitan residential zones located near motorways, poor air quality is a particular concern. With pollution limits often being exceeded, a number of transboundary policies – including, the reduction in vehicle unit emissions and the introduction of new technologies and alternative fuels – have been adopted in an attempt to mitigate this situation. At the same time, various measures have been implemented at the local level – including, congestion tolling (Percoco, 2013) and traffic signal alignment (Madireddy et al., 2011). In the city of Barcelona, for example, the decision was taken to reduce the maximum speed limit from 120/100 km/h to 80 km/h on metropolitan motorways. Also, a variable speed system was implemented in specific zones of the metropolitan area.

Speed reduction policies have been analyzed on interurban and rural motorways around the world. In the case of Spain, a temporary measure of a speed limit on interurban transit (from 120 km/h to 110 km/h) was applied in 2011. This measure did imply gasoline consumption savings around 1.5–3% (Asensio et al., 2014; Castillo-Manzano et al., 2014). Studies examining the impact of a change in the speed limit in metropolitan areas have failed to find a clear pattern; yet, a reduction in pollutants would appear to be the principal outcome. Here, our prime concern is in detecting whether the effects of

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http://dx.doi.org/10.1016/j.trd.2015.02.003
1361-9209/

Barcelona's speed limit policy (i.e., a fixed 80 km/h limit and a variable speed system) vary depending on the atmospheric pollution state. To do so, we generalize Bel and Rosell's (2013) findings when taking into account various pollution scenarios and combine them with a new econometric approach.

All previous econometric approaches have been conducted using average values, and so overlook the fact that policy impacts might vary with levels of pollution. Here, the quantile regression approach allows us to analyze the effects of speed limit policies at different pollution concentrations. As such, the main contribution of this paper is determining whether different atmospheric scenarios have a differentiated impact on a given speed limit policy. To the best of our knowledge, this is the first time that this methodology has been applied to such an analysis.

The rest of this paper is organized in five sections. In the first section, we briefly describe the two speed limit policies and, in the second, we review the empirical evidence reported to date on the impact of such policies on air pollution. Third, we explain the quantile regression methodology and, in the fourth, we report our empirical results. Finally, we highlight the conclusions to be drawn from our analysis and discuss the main policy implications.

Speed management policies

The regional government of Catalonia introduced regulations to reduce the maximum speed limit from 120 or 100 km/h to 80 km/h on motorways in the Barcelona metropolitan area, with the aim of attenuating pollution and the number of traffic accidents and reducing congestion (Fig. 1). Before the new limit was introduced, a speed limit of 100 km/h operated on 63.2% of the roads, while a limit of 120 km/h operated on 20.4% of them (the remaining roads correspond to the Barcelona ring roads which already had an upper limit of 80 km/h). The new measure came into force on the first day of 2008 and remained in place until December 2010 when the newly elected regional government lifted the 80 km/h maximum speed limit, in fulfillment of its electoral promise. One of the key issues related to the actual impact of measures limiting road speeds is that of enforcement by means of radar control. Because of this, the new speed limit was severely enforced. Most roads returned to similar speed limits to those in force in 2007, although a central government regulation issued in March 2011 reduced the maximum speed on all Spanish motorways from 120 to 110 km/h, which affected some of Barcelona's metropolitan motorways.

In January 2009, a second measure, a variable speed limit on the city's southern motorways, was introduced. Henceforth, the limit was to vary in accordance with traffic density, specific incidents impacting road safety (accidents, construction and maintenance work, etc.), air pollution levels and poor weather conditions (rain, fog, winds, etc.). The system provided for incremental reductions of 10 km/h from a maximum of 80 to a minimum of 40 km/h, the speed limit being communicated to drivers via variable message boards located approximately every kilometer and enforced by means of radar detection and traffic authority penalties. In addition to seeking to improve environmental conditions, this variable speed limit system also sought to reduce stop-and-go traffic. In this case, the newly elected regional government did not restore the previous system but rather, after cancelling the 80 km/h speed limit, expanded the variable speed system to other highways in the area.

Related literature

It is widely accepted that lower speeds result in lower traffic emissions, adhering to a U-shaped curve that describes the relationship between emissions and average speed, especially at constant speeds (LAT, 2006). However, when vehicle accelerations and decelerations (stop-and-go traffic) are included in the model, the reduction in emissions attributable to the reduction in speed is much lower (Int Panis et al., 2006). As such, reducing the speed limit might eventually be counterproductive in terms of environmental controls, though these are not the only reasons for implementing these policies (Int Panis et al., 2011). Additionally, inconsistent results are reported for trucks, when their maximum speeds are reduced from 90 to 80 km/h, on levels of nitrogen oxides (NO_x) and on particulate matter less than 10 μm in diameter (PM_{10}). Their results illustrate the scientific uncertainties that policy makers face when considering the implementation of speed management policies.[4]

Most previous studies of the environmental impact of reductions in speed limits involve computations based on theoretically established parameters, as shown in Table 1 below. For example, Keller et al. (2008) examine modeled effects according to changing scenarios (a reference scenario with a maximum speed limit of 120 km/h on motorways and a limited scenario with a maximum of 80 km/h). They conduct a simulation for Switzerland, in which they analyze the impact on ozone levels of such a reduction in speed. The authors employ an air quality model package and examine different emission factors depending on speed. The modeled effects imply a 1% reduction in ozone concentrations, which translates into an equivalent decrease of about 4% in NO_x emissions.

In one of the first metropolitan studies, Keuken et al. (2010) study the effect of speed management in Amsterdam and Rotterdam. They adopt two different approaches: (a) one based on air quality monitoring in combination with dispersion modeling, and (b) one based on applying relevant emission factors relating to the change in traffic dynamics. The authors conduct a linear regression of the measured and modeled contributions of NO_x and PM_{10} during periods with and without the 80 km/h restriction. The study found no significant change in PM_{10} emissions and a reduction in NO_x of between 30% and

[4] Furthermore, the type of fuel used by the fleet is a factor that also influences the emissions. In this regard, Coelho et al. (2009) find higher NO_x emissions by diesel vehicles than by gasoline ones.