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POLLUTION AND ROAD INFRASTRUCTURE IN CITIES OF THE PEOPLE'S REPUBLIC OF CHINA

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Abstract

Urban road infrastructure is crucial in determining air pollution. Yet, little is known about the roles played by road width *vs.* road length. This paper attempts to fill this gap by estimating the effects of road infrastructure on 10-micron particulate matter (PM10) using city-level data from the People's Republic of China (PRC). Our robust modeling results show that the road density index, defined as the ratio of surface area of roads to city territory size, is negatively correlated with PM10. More importantly, when the index of road density is decomposed into road width and road length components, the width is found to help reduce PM10, whereas the length is positively correlated with PM10, although the latter relationship is statistically insignificant.

Keywords: urban infrastructure, PM10 pollution, road length, road width, People's Republic of China

JEL Classification: L92; Q53; R41; R53

Contents

1. INTRODUCTION

As unprecedented urbanization takes place, the issue of urban pollution attracts more and more attention, particularly in developing Asia, where two-thirds of cities failed to meet the European Union’s air quality standard of 40μg/m^3 of 10-micron particulate matter (PM10) (Wan and Wang 2014). Among the world’s 57 most heavily polluted cities, which had an average PM10 level of 100μg/m^3 or higher, 34 are in Asia (Asian Development Bank [ADB] 2013). According to the World Bank (2007), the PRC alone accounted for 60% of the most polluted cities in the world.

One major source of urban pollution is automobiles (Viana et al. 2008, Mugica et al. 2009, Perrone et al. 2012). According to Colvile et al. (2001), Querol et al. (2001), and Ghose et al. (2004), the transport sector is the largest contributor to anthropogenic pollutant emissions in urban environments. In the US, nearly 60% of total CO emissions can be attributed to the transport sector (Environmental Protection Agency [EPA] 2012). In the UK, it accounts for total emissions rates of approximately 18% for PM10, 24% for PM2.5, 54% for CO, and 32% for NOx (National Atmospheric Emissions Inventory [NAEI] 2010). More seriously, in mega cities of the PRC such as Beijing and Guangzhou, motor vehicles contributed more than 80% of CO emissions and around 40% of NOx emissions (Fu et al. 2001).

These emissions generate significant adverse health consequences. As pointed out by Cohen et al. (2004), annually 6.4 million years of life are lost worldwide due to urban air pollution. Anderson et al. (2011) found that vehicle traffic is related to an increased risk of wheeze among children, despite their low levels of exposure. A case study of Augsburg in southern Germany shows that exposure to traffic was linked with an increase in the risk of myocardial infarction (Peters et al. 2004). Traffic air pollution is even significantly correlated with preterm birth in Japan (Yorifuji 2011). The health status of bus drivers in Hong Kong, China and Shanghai is significantly affected by their exposures to vehicle emissions (Zhou et al. 2001, Jones et al. 2006).

The dominance of vehicle emissions in total urban pollutions and the associated serious consequences naturally lead to concerns by policy makers, the media, and the general public about traffic emissions. By definition, the total traffic emission is a product of vehicle volume and unitary emission. Thus, one way to cope with automobile pollutions is to reduce the number of vehicles on the road. However, in growing and urbanizing economies such as the PRC, this appears to be impossible. Another way is to reduce the unitary emission of vehicles. Toward this purpose, it is important to improve vehicle mobility. At lower speeds, a vehicle not only stays on road for longer time, but also has poorer fuel efficiency, leading to high emissions (Stead 1999, André and Hammarströmb 2000).

Vehicle speed is, of course, a function of road conditions or road infrastructure. The more and better quality the roads, the more mobile the vehicles would be, and the less pollution. While there are various studies examining the impacts of road infrastructure on pollution (see next section), the question of road length *vs.* road width (a proxy for lane number) for a given total surface area of roads in a city remains to be explored. Increases in road length at the cost of road width or lane number are expected to help extend roads to locations and places that were previously not accessible by vehicles, possibly bringing more automobiles onto roads and implying more average driving time of a vehicle. At the same time, reductions in the lane number or road width are likely to slow down traffic and cause traffic congestion, further aggravating the polluting impacts of road length. Thus, it can be hypothesized that, for a given road density or total surface area in a city, road length is positively correlated with air pollution, whereas road width is negatively correlated with air pollution. Testing these hypotheses can help decision makers who are faced with tradeoffs between pollution control and road accessibility, or between road length and road width, for a given resource allocation for road infrastructure.

This paper represents a first attempt to analyze the impacts of road length *vs.* road width on urban air pollution. Based on city-level data from the PRC for 2006–2010, our modeling results indicate that road infrastructure as measured by the road density index exerts a benign impact on PM10. To be more precise, a 1% increase in the density index reduces PM10 by 0.112%–0.114%. However, when the index of road density is decomposed into road length and road width components, this benign impact is found to be associated with road width only. For every one percent increase in road width, PM10 drops by 0.101%–0.109%. On the contrary, road length is found to be positively correlated with PM10, although the correlation is statistically insignificant. Our empirical estimates are fairly stable and robust.

The remainder of the paper is organized as follows. Section 2 provides literature review. Model specification and data description are presented in Section 3. This is followed by empirical modeling results and related discussions in Section 4. Finally, Section 5 concludes.

2. LITERATURE REVIEW

To reduce on-road vehicle volume, alternative transport modes such as metro and other forms of public mass transport are needed. As argued by Mohring (1972), public mass transport typically exhibits increasing returns to scale. Thus, ridership is important. It induces higher service frequencies, which reduce the average waiting times at stops, and encourage further ridership. As is known, investment in rail transit infrastructure diverts marginal automobile travelers away from their vehicles, and thereby helps improve air quality. Using daily data before and after the opening of Metro in Taipei,China, Chen and Whalley (2012) found that the opening of the Metro reduced CO emission by 5%–15%.

An administrative intervention is to directly restrict use of automobiles. For example, the Hoy No Circula implemented in Mexico City since 1989 has banned use of a vehicle one day a week based on the last digit of the vehicle's plate number. This intervention, however, did not yield significant air pollution-reducing effect, at least for the period of 1984–1993 studied by Eskeland and Feyzioğlu (1997). Similarly, during the 2008 Summer Olympics, vehicles in Beijing were only allowed to be used every other day, depending on the last digit of the plate number. However, the emission-alleviating effect appears insignificant (Sun et al. 2014). These findings are in line with those of Davis (2008), as well as those of Gallego et al. (2013), who found that the ineffectiveness of the restriction policy may be attributable to the adjustment of vehicle stock by households (i.e., households purchase more cards). It can also be caused by non-compliance and compensating responses such as inter-temporal driving substitution (Viard and Fu 2015).

Turning to studies on unitary emissions, this, in the long run, can be achieved by using alternative fuels (e.g., natural gas, biofuels and fuel cells) or new technology vehicles such as the hybrid cars. Using 2010 air quality data from Taipei,China, Li et al. (2016) evaluated the impact of electronic vehicles on pollution. Their simulation results showed that electronic vehicle penetration can reduce air pollution by up to 60%. As previously argued, unitary emissions can also be affected by the trade-off between road width (land number) and road length. For example, Ross et al. (2006) modelled the determinants of traffic pollution in 39 locations of San Diego county in the US and found that the length of road significantly induced more NO_2 emissions. This was confirmed by Rose et al. (2009) using data from Australia. In a case study of Windsor, Ontario, in 2004, Wheeler et al. (2008) discovered that the length of road and highway was positively and significantly associated with ambient pollutants. According to Cassady (2004), expansion of America's highway network spurred additional driving and induced more vehicles, leading to increased pollutions.

It appears that little attention has been paid to the road width-pollution relationship. Nevertheless, there are studies exploring the relationship between road width and vehicle mobility which has bearings on pollution. As expected, road width is found to be positively correlated with vehicle speed (Heimbach et al. 1983). According to Yagar and Aerde (1983), when the road width becomes 0.3 meters narrower, vehicle speed reduces by 1.76 km/h on average. Similarly, Fitzpatrick et al. (2001) discovered that, on suburban streets without a posted speed limit, the increase of road width significantly led to faster driving. Better mobility of vehicles, in turn, can help reduce air pollution. For example, increases in vehicle speed were found to significantly reduce the emissions of NOx and PM10 (Beevers and Carslaw 2005) or CO and CO_2 (André and Hammarströmb 2000). The benign effects of vehicle mobility are driven by traffic congestion being a major cause of pollution (Chin 1996). Congestion means more accelerations, decelerations, and idles, which reduce fuel efficiency and increase emissions (Scott et al. 1997; Grote et al. 2016).

3. MODEL SPECIFICATION AND DATA

The literature review reveals that few previous studies directly estimated the impacts of road width as a proxy of road lane number on urban pollution, although some explore the impacts of road length. In what follows, we use data from PRC cities to firstly establish the relationship between road density and PM10 and then explore the effects of road length and road width separately.

Our modeling strategy is founded on the pioneering work of Grossman and Krueger (1995). It is important to point out that we are not interested in the environmental Kuznets curve (EKC), which has been subject to debates (Stern 2004). Instead, in this paper we focus on the pollution-road infrastructure relationship. The framework of Grossman and Krueger (1995) is used to help identify control variables only. Following Grossman and Krueger (1995), an environmental variable such as PM10 is determined by economic scale, economic structure, and state of technology. Therefore, our empirical model can be specified as:

$$Pollution = f(Road, Scale, Structure, Technology), \tag{1}$$

where *Pollution* represents environmental quality, *Road* denotes road infrastructure which is our key variable, and the other three notations are self-explanatory, which represent control variables.

Using *PM10* ($\mu g/m^3$) to denote the dependent variable, *X* to denote the control variables, and *Road Density* to represent road infrastructure, model (1) can be expressed more specifically as:

$$ln(PM10_{it}) = \alpha_0 + \alpha_1 ln\big(Road\ Density_{i,t-1}\big) + X'_{i,t-1}\gamma + \mu_i + \gamma_t + \varepsilon_{it}, \tag{2}$$

where *i* indexes city and *t* indexes year, μ denotes city-fixed effect, γ denotes year-fixed effect, ε denotes the white noise, and *Road Density* is measured as the ratio of surface area of roads to total city territory size. All independent variables are lagged by one year in model (2) to alleviate possible endogeneity.

Two variables capture the scale of the city economy: Gross Domestic Product (GDP) per capita (CNY/person), and population density (persons/km^2). Both are expressed in the logarithmic form. The structure of the economy will be represented by the GDP share of the manufacturing industry. Following the conventional wisdom, time trend is used to approximate the development of technology. We also add the quadratic term of GDP per capita to capture possible non-linearity, as suggested by Grossman and Krueger (1995).

Since

$$ln(Road\ Density) \triangleq ln(Surface\ Area\ of\ Roads/City\ Territory\ Size)$$

$$= ln(Road\ Length/Territory\ Size) + ln(Road\ Width/Territory\ Size) \triangleq ln(Length) + ln(Width) \tag{3}$$

Model (2) can be written as

$$ln(PM10_{it}) = \beta_0 + \beta_1 ln(Length_{i,t-1}) + \beta_2 ln(Width_{i,t-1}) + X'_{i,t-1}\gamma + \varphi_{it}, \tag{4}$$

where φ_{it} denotes the composite error term. Model (4) can be used to estimate the potentially opposite impacts on PM10 of road width *vs.* road length.

Models (2) and (4) will be fitted to city-level data from the PRC. Monthly observations on PM10 are available from the PRC Surface Climate Dataset[1], covering the period 2003–2010. Other observations can be easily obtained from the PRC's National Bureau of Statistics (various years). Note, however, data on urban roads are inconsistent before and after 2006, as discovered by Du et al. (2013). In this paper, we simply use the 2006–2010 data. Table 1 presents the summary statistics.

Table 1: Summary Statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
ln (PM10)	430	4.461	0.295	3.588	5.257
ln (Road Density)	421	–4.643	0.953	–7.516	–1.636
ln (Road Length/Area)	422	1.666	1.072	–2.831	4.281
ln (Road Width/Area)	417	–13.77	1.198	–17.47	–10.31
Car Quantity/Population	410	1.983	1.620	0.196	12.22
ln (GDP per capita)	428	10.27	0.596	8.762	11.72
ln (Population Density)	426	6.053	0.765	3.048	7.840
Industrialization	427	0.498	0.101	0.232	0.910

Obs. = observations, std. dev. = standard deviation.

Source: Author's calculations.

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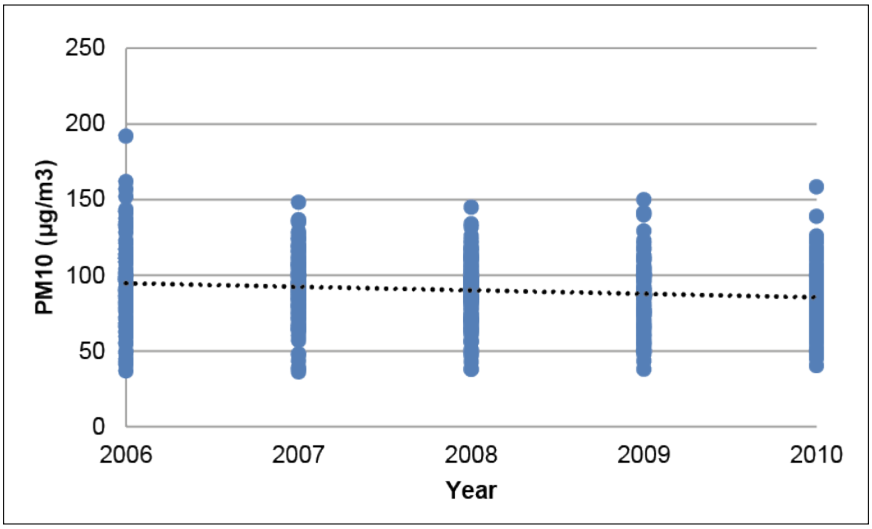
[1] Collected by the Meteorological Reference Room, National Meteorological Information Center.

Figure 1 plots the PM10 observations. It can be seen that average PM10 decreased slightly from 2006 to 2010, indicating improvement in pollution. However, most cities still experienced high levels of PM10, much higher than the European Union's air quality standard of 40μg/m^3. More than one-third of cities under study suffered serious air pollution with a level of PM10 higher than 100μg/m^3. Lanzhou recorded the highest level of PM10 in 2006: 192 100μg/m^3, followed by Beijing and Datong. The best air quality was found in Guilin with a level of PM10 around 36μg/m^3.

Figure 1: PM10 in PRC Cities, 2006–2010



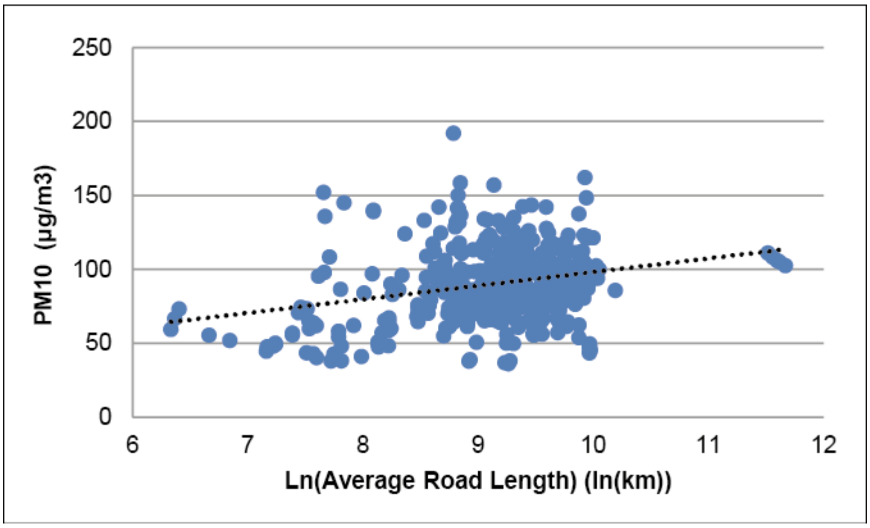
PRC = People's Republic of China.

Source: PRC Surface Climate Dataset (Monthly).

Figure 2 plots PM10, average road length, and average road width. Consistent with earlier discussions, PM10 appears to be positively correlated with the length of road while negatively correlated with the width of road.

Figure 2: PM10, Average Road Length and Road Width in PRC Cities, 2006–2010

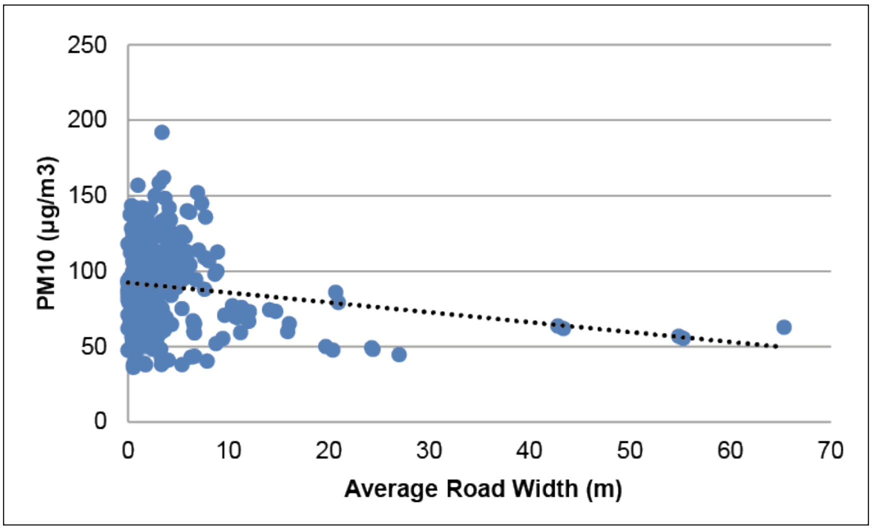
(a) PM10 and Average Road Length



continued on next page

Figure 2 *continued*

(b) PM10 and Average Road Width



PRC = People's Republic of China.

Source: PRC Surface Climate Dataset (Monthly) and CEIC database.

4. EMPIRICAL RESULTS

4.1 Road Density and PM10

Table 2 presents the empirical results based on the conventional model (2), where all regressions control for year and province-fixed effects. In column (1) of Table 2, we only include the road density variable. In subsequent columns, control variables of GDP per capita and its quadratic term, population density, industrial GDP share and time trend are added one by one. It is clear that the coefficient of road density is negative and significant under every model in Table 2. And the magnitude of the coefficient estimate is fairly stable across models. This finding is in line with those in the literature (e.g., Mohring 1972; Chen and Whalley 2012), confirming the role of road infrastructure in reducing PM10. To be more precise, a 1% increase in road density leads to an 0.11% reduction in PM10.

The signs of most control variables in Table 2 are as expected. The linear term of GDP per capita is positive while its quadratic term is negative, suggesting an inverted U-shape environmental Kuznets curve. The GDP share of the manufacturing industry tends to increase PM10. All these are consistent with what Grossman and Kruger postulated (1995).

Table 2: PM10 and Road Density

$\ln(\text{PM10})_{i,t}$	(1)	(2)	(3)	(4)	(5)	(6)
$\ln(\text{Road Density}_{i,t-1})$	–0.112***	–0.113***	–0.114***	–0.112***	–0.112***	–0.112***
	(0.0348)	(0.0344)	(0.0345)	(0.0331)	(0.0334)	(0.0334)
$\ln(\text{GDP per capita}_{i,t-1})$		–0.0295	0.170	0.252	0.0713	0.0713
		(0.133)	(0.688)	(0.695)	(0.749)	(0.749)
$[\ln(\text{GDP per capita}_{i,t-1})]^2$			–0.0102	–0.0144	–0.00745	–0.00745
			(0.0366)	(0.0370)	(0.0389)	(0.0389)
$\ln(\text{Population Density}_{i,t-1})$				–0.0382	–0.0388	–0.0388
				(0.0249)	(0.0240)	(0.0240)
$\text{Industrialization}_{i,t-1}$					0.294	0.294
					(0.529)	(0.529)
Time Trend	N	N	N	N	N	Y
City FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
N	336	336	336	335	334	334
adj. R^2	0.081	0.082	0.082	0.086	0.088	0.088

Note: Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Source: Author's calculations.

4.2 Road Length *vs.* Road Width

Table 3 reports estimation results corresponding to model (4) where the variable of road width is excluded. Not surprisingly, the coefficients of road length are positive though insignificant. This result is robust to different control variables. Thus, it can be concluded that simply increasing road length is unlikely to lead to any improvement in the environment. Recall that this finding is broadly consistent with earlier studies (see section 2 of this paper).

Table 3: Road Length and PM10

$\ln(\text{PM10})_{i,t}$	(1)	(2)	(3)	(4)	(5)	(6)
$\ln(\text{Road Length/Area})_{i,t-1}$	0.00504	0.00486	0.00380	0.000348	0.000709	0.000709
	(0.0459)	(0.0458)	(0.0462)	(0.0472)	(0.0472)	(0.0472)
$\ln(\text{GDP per capita}_{i,t-1})$		–0.00460	0.0676	0.173	0.0253	0.0253
		(0.126)	(0.700)	(0.705)	(0.777)	(0.777)
$[\ln(\text{GDP per capita}_{i,t-1})]^2$			–0.00372	–0.00920	–0.00332	–0.00332
			(0.0369)	(0.0372)	(0.0398)	(0.0398)
$\ln(\text{Population Density}_{i,t-1})$				–0.0455	–0.0458*	–0.0458*
				(0.0280)	(0.0274)	(0.0274)
$\text{Industrialization}_{i,t-1}$					0.226	0.226
					(0.516)	(0.516)
Time Trend	N	N	N	N	N	Y
City FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
N	339	339	339	338	337	337
adj. R^2	0.054	0.054	0.054	0.060	0.061	0.061

Note: Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Source: Author's calculations.

Adding the variable of road width to those regressions in Table 3, we obtain Table 4. Importantly, the coefficients of road width are negative and significant, whereas those of road length remain positive and insignificant. To be more precise, every 1% increase in road width leads to a 0.10% reduction in PM10. This result implies that the benign impact of road infrastructure on PM10 comes from road width only, not road length, confirming the significant role of vehicle mobility in reducing emissions.

Table 4: Determinants of PM10: Road Width Included

ln (PM10)$_{i,t}$	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
ln (Road Length/Area)$_{i,t-1}$	0.0135	0.0126	0.0136	0.0104	0.0103	0.0103
	(0.0406)	(0.0397)	(0.0394)	(0.0399)	(0.0396)	(0.0396)
ln (Road Width/Area)$_{i,t-1}$	–0.103***	–0.104***	–0.104***	–0.101***	–0.101***	–0.101***
	(0.0285)	(0.0286)	(0.0285)	(0.0276)	(0.0277)	(0.0277)
ln (GDP per capita$_{i,t-1}$)		–0.0207	–0.0860	0.00701	–0.0998	–0.0998
		(0.136)	(0.709)	(0.719)	(0.779)	(0.779)
[ln (GDP per capita$_{i,t-1}$)]^2			0.00336	–0.00146	0.00266	0.00266
			(0.0378)	(0.0383)	(0.0403)	(0.0403)
ln (Population Density$_{i,t-1}$)				–0.0376	–0.0380	–0.0380
				(0.0261)	(0.0253)	(0.0253)
Industrialization$_{i,t-1}$					0.176	0.176
					(0.525)	(0.525)
Time Trend	N	N	N	N	N	Y
City FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
N	334	334	334	333	332	332
adj. R^2	0.089	0.089	0.089	0.093	0.094	0.094

Note: Standard errors in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01.

Source: Author’s calculations.

4.3 Robustness Check

We explore the robustness of our findings by considering the possible problem of omitted variables first, and potential measurement errors second.

Omitted Variables

As previously mentioned, the increase of road length may bring additional vehicles onto the road, leading to more pollution. Therefore, omitting the variable of vehicle quantity may have contributed to the positive coefficient of road length. Consequently, we add car quantity per capita into model (4). The corresponding empirical results are presented in Table 5. It is clear that, comparing Tables 4 and 5, the coefficient estimates of road length and road width largely remain unchanged. The coefficient of car quantity per capita is found to be negative, but insignificant in all regressions. One possible explanation is that vehicle quantity is already captured by the variable of GDP per capita.

Table 5: Determinants of Air Quality with Car Quantity Included

ln $(PM10)_{i,t}$	(1)	(2)	(3)	(4)	(5)	(6)
ln (Road Length/Area$_{i,t-1}$)	0.0270	0.0225	0.0200	0.0165	0.0166	0.0166
	(0.0423)	(0.0414)	(0.0418)	(0.0423)	(0.0418)	(0.0418)
ln (Road Width/Area$_{i,t-1}$)	–0.106***	–0.109***	–0.109***	–0.107***	–0.107***	–0.107***
	(0.0301)	(0.0297)	(0.0298)	(0.0288)	(0.0289)	(0.0289)
(Car Quantity/Population)$_{i,t-1}$	–0.00221	–0.00136	–0.000759	–0.00197	–0.00169	–0.00169
	(0.0149)	(0.0142)	(0.0142)	(0.0140)	(0.0141)	(0.0141)
ln (GDP per capita$_{i,t-1}$)		–0.153	0.0194	0.0968	–0.106	–0.106
		(0.0996)	(0.695)	(0.706)	(0.766)	(0.766)
[ln (GDP per capita$_{i,t-1}$)]^2			–0.00899	–0.0129	–0.00536	–0.00536
			(0.0363)	(0.0370)	(0.0392)	(0.0392)
ln (Population Density$_{i,t-1}$)				–0.0341	–0.0346	–0.0346
				(0.0255)	(0.0246)	(0.0246)
Industrialization$_{i,t-1}$					0.334	0.334
					(0.532)	(0.532)
Time Trend	N	N	N	N	N	Y
City FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
N	322	322	322	321	320	320
adj. R^2	0.092	0.099	0.099	0.102	0.105	0.105

Note: Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Source: Author's calculations.

Measurement Errors

Measurement errors may occur for the variable of PM10 or road infrastructure. So far, we have used the logarithmic value of PM10 as the dependent variable, as suggested by Chen and Whalley (2012). However, there are studies that simply use the original value of PM10, e.g., Sun et al. (2014). Replacing ln(PM10) by PM10 and re-estimating model (4) did not change the magnitudes of estimated impacts of road infrastructure if one computes and compares the PM10 elasticity of road width based on estimation results reported in column (2) of Table 6 with those in column (6) of Tables 4 and 5. The estimates of this elasticity are respectively –0.105, –0.101, and –0.107.[2]

Regarding the road variable, we have used surface area of roads over city territory size to define road density. However, transportation activity is more intensive in the built-up part of a city.[3] It may be more appropriate to use the territory size of city built-up areas as the denominator. In columns (3) and (4) of Table 6, we report modeling results where road density is redefined as the ratio of road surface area to city built-up area. The results remain robust. Interestingly, as expected, the coefficient estimate of road width becomes larger in absolute values: –0.120 compared to –0.107, as reported in column 6 of Table 5.

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[2] Column (2) of Table 6 is a linear-log model. The PM10 elasticity of road width is defined as $\frac{\partial y/y}{\partial x/x} = \frac{\beta_{road\ width}}{y}$, which can be estimated as $\frac{-9.906}{\exp(4.461)} = -0.105$, where 4.461 is the mean of ln(PM10) as reported in Table 1. The elasticity estimates corresponding to column (6) of Tables 4 and 5 are simply the coefficient estimates of road width since they are log-log models.

[3] "Built-up area" refers to non-agricultural development areas within the administrative boundary of a city, including downtown and suburbs. It also includes areas used for public facilities such as airports, sewage treatment plants, etc.

Finally, columns (5) and (6) of Table 6 report modelling results, using both original value of PM10 and redefined road density variable. Once again, the results are found to be robust.

Table 6: Robustness Check

	(1)	(2)	(3)	(4)	(5)	(6)
	(PM10)$_{i,t}$	(PM10)$_{i,t}$	ln (PM10)$_{i,t}$	ln (PM10)$_{i,t}$	(PM10)$_{i,t}$	(PM10)$_{i,t}$
ln (Road Density$_{i,t-1}$)	–10.69***		–0.152***		–12.46***	
	(2.826)		(0.0438)		(3.384)	
ln (Road Length/Area$_{i,t-1}$)		0.394		–0.0140		–0.990
		(2.945)		(0.0535)		(3.519)
ln (Road Width/Area$_{i,t-1}$)		–9.096***		–0.120***		–9.534***
		(2.355)		(0.0366)		(2.756)
(Car Quantity/Population)$_{i,t-1}$	–0.703	–0.520	–0.00581	–0.00329	–0.871	–0.675
	(1.145)	(1.164)	(0.0143)	(0.0146)	(1.185)	(1.209)
ln (GDP per capita$_{i,t-1}$)	2.945	–11.36	0.0428	–0.0958	–1.397	–12.85
	(59.49)	(61.46)	(0.723)	(0.760)	(59.23)	(60.89)
[ln (GDP per capita$_{i,t-1}$)]^2	–1.101	–0.339	–0.0122	–0.00500	–0.765	–0.171
	(3.016)	(3.121)	(0.0370)	(0.0388)	(3.000)	(3.090)
ln (Population Density$_{i,t-1}$)	–3.828*	–3.716*	–0.0273	–0.0285	–3.079	–3.217
	(1.991)	(2.081)	(0.0236)	(0.0238)	(1.940)	(1.996)
Industrialization$_{i,t-1}$	10.18	6.584	0.331	0.284	6.216	2.492
	(39.58)	(39.48)	(0.541)	(0.540)	(40.31)	(39.93)
Time Trend	Y	Y	Y	Y	Y	Y
City FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
N	321	320	321	320	321	320
adj. R^2	0.122	0.119	0.117	0.111	0.128	0.120

Note: Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Source: Author's calculations.

5. SUMMARY AND CONCLUSION

More and more cities are confronted with the formidable challenge of air pollution, as unprecedented urbanization proceeds apace. The most visible source of urban pollution comes from automobiles. While using alternative fuels and transportation modes represents a partial solution, which is often unaffordable to city governments in developing countries, improving vehicle mobility becomes crucial. In this context, one well-recognized element is road infrastructure. In reality, of course, decision makers always face budget constraints, including those for road infrastructure. Consequently, there is always a possible trade-off between road length and road width that city governments can manipulate in balancing among different development objectives. Unfortunately, no previous attempt has been made to explore the role of road width in affecting pollution, although a few studies examined the impacts of road length on emissions.

This paper fills this gap in the literature by examining the effects of road length and road width on PM10 in PRC cities. Three findings are important. First, road density is negatively correlated with PM10. A 1% increase in the road density reduces PM10 by 0.112–0.114%. Second, road width, not road length, helps reduce PM10. In fact, the effect of road length on PM10 is positive although insignificant. For every 1% increase in road width, PM10 drops by 0.101–0.109%. Third, our results are robust to measurement errors and various control variables.

The policy implication is straightforward: when planning and constructing urban road infrastructure, it is necessary to consider the trade-off between road width and road length. Wider roads or more lanes not only help reduce emissions, but also lead to more supply and more efficient utilization of human resources through improved vehicle mobility.

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