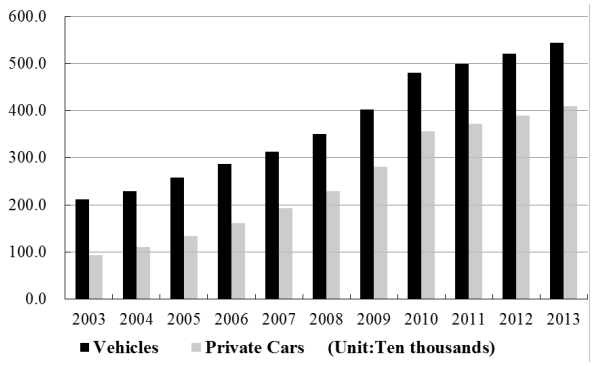
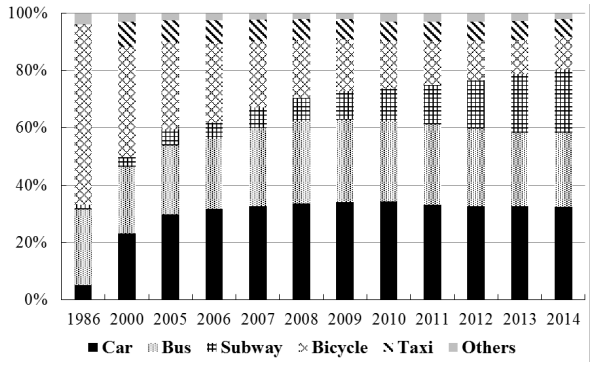
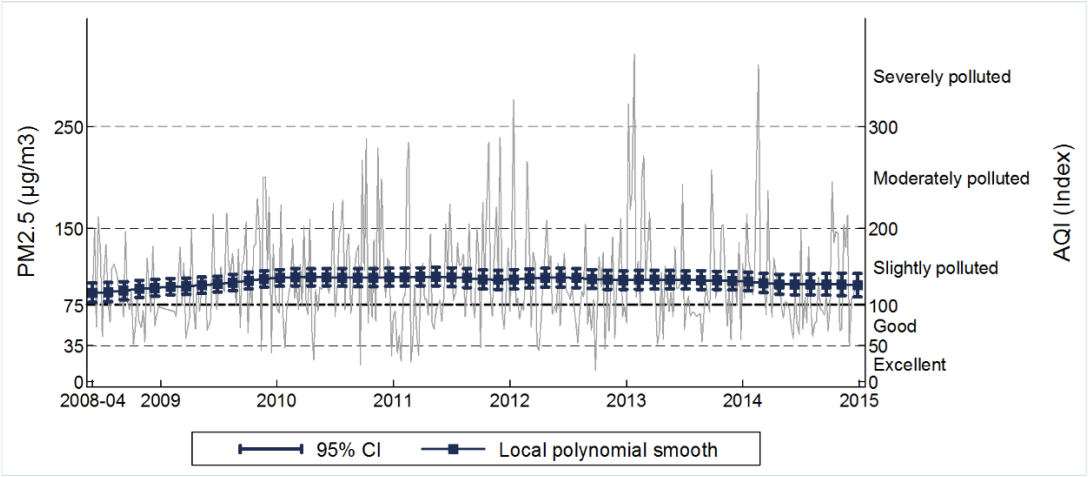
Appendix



(a) Vehicle growth in Beijing



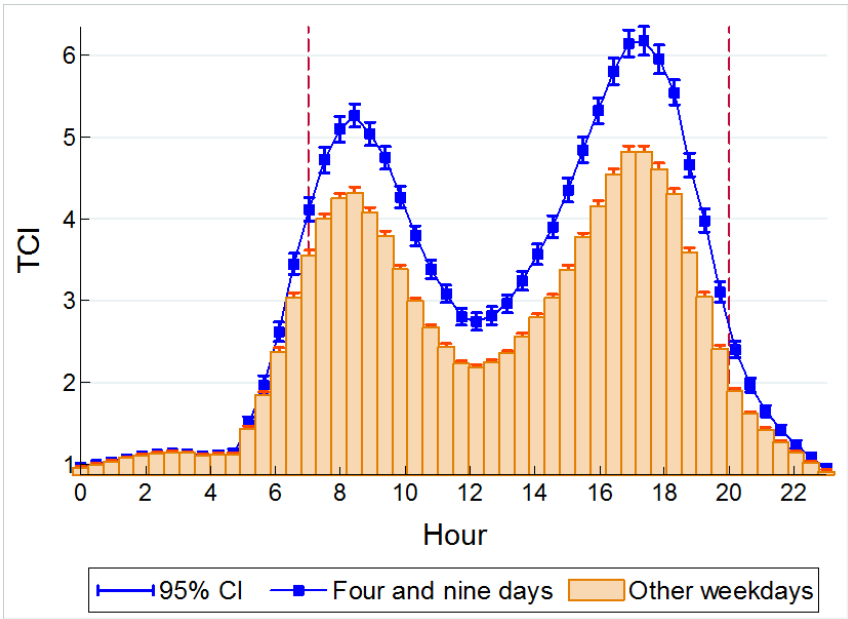
(b) Changes in share of travel modes



(c) Air pollution in Beijing

Figure A1. Vehicle growth and travel modes in Beijing

Data source: Beijing Traffic Management Bureau and The US Embassy.



(a) Hourly Distribution of TCI

Figure A2. The 24-hour Pattern of TCI on Four and Nine Days and Other Weekdays

Notes: Figure compares the hourly variation of TCI between the four and nine days and other weekdays. The overlapped confidence intervals (CIs) indicate an insignificant difference (at the 95% significance level) in TCI (or AQI) between the four and nine days and other weekdays, while the non-overlapped 95% CIs indicate such difference is statistically significant.

Table A1. Summary statistics

Variable	Def. (Unit)	Mean	SD	Min	Max	N
Air Pollutant **(2013-2014)**						
AQI	Hourly Index	122.4	86.95	6	500	16587
$PM_{2.5}$	Hourly record ($\mu g/m^3$)	89.08	80.13	3	584.2	16584
PM_{10}	Hourly record ($\mu g/m^3$)	123.2	91.77	5	1000	15866
O_3	Hourly record ($\mu g/m^3$)	56.08	55.27	1	344.8	15850
SO_2	Hourly record ($\mu g/m^3$)	23.94	27.85	1	256.6	16501
NO_2	Hourly record ($\mu g/m^3$)	62.19	33.72	3.667	235.8	16498
CO	Hourly record (mg/m^3)	1.432	1.178	0.133	9.213	16413
Traffic Congestion Index **(2013-2014)**						
TCI	Hourly Index (0-10)	2.442	1.779	0.613	9.444	16631
Alternative traffic measures **(2014 only)**						
Flows - within 5^{th} ring	Hourly record (No./hour)	1667.4	709.7	193.7	2842.7	8692
Speed -within 5^{th} ring	Hourly record (km/hour)	63.16	4.83	48.05	74.97	8692
Date Variable **(2013-2014)**						
The Four and Nine days	Dummy (0, 1)	0.126	0.332	0	1	730
Holiday	Dummy (0, 1)	0.085	0.279	0	1	730
Holiday-makeup	Dummy (0, 1)	0.023	0.151	0	1	730
Odd-even day	Dummy (0, 1)	0.014	0.116	0	1	730

Notes: Table provides air pollutant records from 4 p.m., January 18, 2013 to 7 a.m., December 25, 2014. In the raw hourly TCI records, 1.8% original records are missing on a random basis. Air pollutants consist of hourly average concentration of AQI, $PM_{2.5}$, PM_{10}, O_3, SO_2, NO_2, and CO, calculated by the eight national monitoring stations located within the Fifth Ring Road of Beijing. Holiday-makeup represents weekends when people go to work to make up forpaid days before or afterholidays.

Table A2. Summary statistics for meteorological conditions (2013-2014)

Variable	Def. (Unit)	Mean	SD	Min	Max
Temperature	Hourly average (Celsius)	13.13	11.77	-16	41
Precipitation	Hourly total (mm)	0.059	0.284	0	4.417
Relative humidity	Hourly average (%)	52.84	25.49	3	109.5
Sea-level pressure	Hourly average (hPa)	1016	10.26	991.2	1046
DewPT	Hourly average (Celsius)	1.719	14.25	-40	26.90
Wind speed	Hourly extreme (m/s)	2.817	2.075	0	17.50
Wind direction	Index (1-16)	8.477	4.552	1	16

Notes: N=17,520. All meteorological variables are derived from hourly records, except for sea-level pressure, which is recorded every two hours. Wind direction is an index denoted by 1 to 16, representing 16 wind directional quadrants.

Table A3. Summary Statistics of Vehicle Properties

Last digit [Obs.]	Engine Displacement	Fuel Expenditure	VKT	Last digit [Obs.]	Engine Displacement	Fuel Expenditure	VKT
1	1.638	0.694	14.17	6	1.656	0.688	13.72
[1366]	(0.391)	(0.474)	(10.93)	[1755]	(0.379)	(0.436)	(8.951)
2	1.644	0.690	14.24	7	1.672	0.720	14.53
[1364]	(0.383)	(0.424)	(9.632)	[1390]	(0.394)	(0.464)	(10.87)
3	1.623	0.698	13.96	8	1.672	0.719	14.03
[1325]	(0.357)	(0.464)	(9.703)	[1720]	(0.408)	(0.497)	(8.985)
4	1.601	0.687	14.54	9	1.679	0.728	14.44
[310]	(0.400)	(0.478)	(12.11)	[1496]	(0.407)	(0.453)	(9.647)
5	1.637	0.694	13.67	0	1.655	0.717	14.09
[1384]	(0.381)	(0.440)	(9.032)	[1457]	(0.398)	(0.463)	(9.062)

Notes: Table presents mean values of Engine Displacement (Liters), monthly average fuel payment (thousand RMB), and vehicle-kilometers traveled (VKT, thousand km) accordingly; standard deviations are listed in parentheses; square brackets report the sample size. *Data sources*: 2010 Beijing Household Travel Survey.

Table A4. Systematic Difference of Vehicles with Different License Plate Tail Numbers

Dep. Var.	Engine Displacement			Fuel Expenditure			VKT		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Last digit 0	0.0446*	-0.0225		0.0431**	-0.0010		-0.7953	-0.1787	
	(1.90)	(-1.62)		(1.96)	(-0.08)		(-1.45)	(-0.70)	
Last digit 1	0.0354	-0.0317**		0.0188	-0.0254*		-0.4311	0.1855	
	(1.50)	(-2.26)		(0.83)	(-1.89)		(-0.76)	(0.62)	
Last digit 2	0.0436*	-0.0235*		0.0125	-0.0317**		-0.3140	0.3027	
	(1.85)	(-1.69)		(0.56)	(-2.43)		(-0.56)	(1.06)	
Last digit 3	0.0181	-0.0490***		0.0279	-0.0162		-0.6965	-0.0799	
	(0.78)	(-3.61)		(1.24)	(-1.21)		(-1.24)	(-0.28)	
Last digit 4		-0.0671***			-0.0441**			0.6167	
		(-2.85)			(-2.02)			(1.12)	
Last digit 5	0.0321	-0.0350**		0.0324	-0.0117		-0.9001	-0.2834	
	(1.37)	(-2.53)		(1.48)	(-0.94)		(-1.64)	(-1.09)	
Last digit 6	0.0545**	-0.0126		0.0252	-0.0189		-0.7696	-0.1529	
	(2.36)	(-0.96)		(1.17)	(-1.61)		(-1.42)	(-0.62)	
Last digit 7	0.0621***	-0.0050		0.0321	-0.0120		-0.3899	0.2268	
	(2.63)	(-0.36)		(1.46)	(-0.95)		(-0.69)	(0.79)	
Last digit 8	0.0615***	-0.0056		0.0465**	0.0024		-0.8920	-0.2754	
	(2.63)	(-0.41)		(2.09)	(0.18)		(-1.63)	(-1.07)	
Last digit 9	0.0671***			0.0441**			-0.6167		
	(2.85)			(2.02)			(-1.12)		
Pair 1&6			-0.0094			-0.0232			-0.4471
			(-0.85)			(-1.28)			(-1.52)
Pair 2&7			-0.0026			-0.0130			-0.0319
			(-0.23)			(-1.01)			(-0.10)
Pair 3&8			-0.0129			-0.0061			-0.4025
			(-1.16)			(-0.47)			(-1.39)
Pair 5&0			-0.0171			-0.0079			-0.4743
			(-1.51)			(-0.62)			(-1.64)
Base group	Last digit 4	Last digit 9	Pair 4&9	Last digit 4	Last digit 9	Pair 4&9	Last digit 4	Last digit 9	Pair 4&9
R^2	0.106	0.106	0.105	0.404	0.404	0.098	0.405	0.405	0.020

Notes: N=13,567; Standard errors are robust to heteroscedasticity. t-statistics are listed in parentheses; $^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$.

Table A5. OLS estimates

	(1)	(2)	(3)	(4)
Panel A: OLS comparison	*Dependent Variable*: **AQI**			
TCI	0.5604***	0.5046***	0.3057*	0.2768*
	(0.1524)	(0.1330)	(0.1560)	(0.1657)
R-squared	0.9564	0.9579	0.9584	0.9584
Panel B: OLS comparison	*Dependent Variable*: **Log(AQI)**			
TCI	0.0071***	0.0063***	0.0027*	0.0024
	(0.0017)	(0.0013)	(0.0014)	(0.0015)
R-squared	0.9446	0.9468	0.9475	0.9476
Weather controls	No	Yes	Yes	Yes
Fixed effects	No	No	Yes	Yes
Date character	No	No	No	Yes

Notes: N=15,706; Number of days=701. Dependent variable is AQI for all Columns (1)-(4). Weather controls include second order polynomials in temperature, precipitation, sea-level pressure, DewPT, and relative humidity. We control wind-specific impacts by including 16 wind directional-quadrant dummies and interact these with wind speed. Date character includes dummies for holidy, holiday-makeup, and odd-even day. Fixed effects denotes yearly fixed effects, monthly fixed effects, weekdays fixed effects and hourly fixed effects. Robust standard errors are clustered by the hour and are listed in parentheses; $^{*}p< 0.1$, $^{**}p< 0.05$, $^{***}p< 0.01$.

Table A6. Different functional forms

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Var.	AQI	Log(AQI)	Log(AQI)	AQI	ΔAQI	ΔAQI
TCI	16.4845***	0.1330***		17.5999***		
	(5.1672)	(0.0409)		(3.9766)		
Log(TCI)			0.5163***			
			(0.1493)			
Lagged AQI				0.1000**		
				(0.0471)		
ΔTCI					19.6688***	18.3528***
					(5.2234)	(4.3888)
Lagged ΔAQI						0.0509
						(0.0385)
Weather controls	Yes	Yes	Yes	Yes	Yes	Yes
Date character	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	15,706	15,706	15,706	14,929	15,506	14,763
KP *F*-statistics	24.135	24.135	32.691		21.191	
AR(1)-*p*				0.008		0.001
AR(2)-*p*				0.126		0.452
Estimation	2SLS	2SLS	2SLS	GMM	2SLS	GMM

Notes: Columns (1)-(3) report the 2SLS estimates of marginal effect, semi-elasticity, and elasticity, using the specification of level-level, log-level, and log-log, respectively. Column (4) is a dynamic specification in which the `Lagged AQI' is included. Since the lagged dependent variable `Lagged AQI' is naturally endougenous in dynamic panel case, the GMM estimation, using *the four and nine days* and *longer lags of AQI* to instument TCI and `Lagged AQI', is implemented and the estimates is reported in Column (4). The notation Δ in Columns (5) and (7) denotes the value changes between hours. The 2SLS estimates of the effects of the changes in TCI (i.e., $\Delta TCI=TCI_t-TCI_{t-1}$) on the changes in AQI (i.e., $\Delta AQI=AQI_t-AQI_{t-1}$) is reported in Column (5). Just as Column (5), Column (6) report the GMM estimates with the further consideration of `Lagged ΔAQI', where *the four and nine days* and *longer lags of ΔAQI* are adopted to instument TCI and `Lagged ΔAQI'. Weather controls include second order polynomials in temperature, precipitation, sea-level pressure, DewPT, and relative humidity. In addtion, we control wind-specific impacts by including 16 wind directional-quadrant dummies and interact these with wind speed. Date character includes dummies for holidy, holiday-makeup, and odd-even day. Fixed effects denotes yearly fixed effects, monthly fixed effects, and hourly fixed effects. Robust standard errors are clustered by the hour and are listed in parentheses; $^{*}p< 0.1$, $^{**}p< 0.05$, $^{***}p< 0.01$.

Table A7. Heterogeneous analysis by different times of the day

Dependent Var.	AQI				
	Daytime	Morning peak	Evening peak	Peak hours	Daytime
	(1)	(2)	(3)	(4)	(5)
TCI×Dum1(7:00-20:00)	6.8033***				
	(2.4506)				
TCI×Dum2(7:00-9:00)		8.8128***		8.6328***	8.6261***
		(3.1766)		(3.1727)	(3.1833)
TCI×Dum3(17:00-20:00)			11.3176**	13.3374**	13.3135**
			(5.7123)	(5.7645)	(5.7600)
TCI×Dum4(10:00-16:00 & 19:00-20:00)					-0.1464
					(2.4293)
KP *F*-statistics	47.86	61.27	34.91	17.87	18.89
Base group	Night	Other parts of the day			Night

Notes: N=15,706. Dependent variable is AQI for all Columns (1)-(5). We interact the hourly dummies (Dum1 - Dum4) with the `Four and Nine Days' to instrument TCI interactions in this table. In line with our baseline specification, all models include second order polynomials in weather controls, yearly fixed effects, monthly fixed effects, hourly fixed effects, and date characters. Robust standard errors are clustered by the hour and are listed in parentheses; $^{*}p< 0.1$, $^{**}p< 0.05$, $^{***}p< 0.01$.