Impact of CNG on vehicular pollution in Delhi: a note

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Abstract

Besides mandating the use of CNG, a number of other policy instruments have been enacted that has helped improve the air quality in Delhi. This paper investigated two issues—whether enactment of policy instruments has affected ambient air quality and whether CNG conversion has impinged on the pollution profile. Daily ambient air quality data from June 1999 to September 2003 from the busiest crossing in Delhi do not indicate an all-round improvement in ambient quality. The NO\textsubscript{x} has risen after the conversion whereas SPM and PM\textsubscript{10} have shown only marginal fall; CO has shown a significant decline.

Keywords: Compressed natural gas; Delhi; Air pollution

1. Introduction

The adverse morbidity and mortality effect of air pollutants like suspended particulate matter (SPM), respirable suspended particulate matter (RSPM or PM\textsubscript{10}), sulfur dioxide (SO\textsubscript{2}), carbon monoxide (CO) and Ozone (O\textsubscript{3}) are well documented. In the case of Delhi, the situation deteriorated in the 1990s as vehicles growth outpaced population growth and economic development; vehicle had risen to nearly 3.6 million by 2001. During the period, Delhi’s population increased from 9.5 to 13.8 million and road-length from 22,000 to 25,000 km. The World Bank estimated that a person was dying every 70 min in Delhi in 1995 from air pollution (Brandon and Hommann, 1995). The Supreme Court (SC) of India ruled in 1998 that all the public transport should move away from diesel to CNG by 31 March 2001 and by December 1, 2002 all the buses were converted to CNG.

The CNG is a clean-burning alternative fuel for vehicles with a significant potential for reducing harmful emissions especially fine particles. In diesel engines, a major part of the fuel
remains unburnt, making up particulate emissions. Nylund and Lawson (2000) finds diesel combustion emits 84 grams per kilometer (gms/km) of such components as compared to 11 gms/km in CNG and the level of GHGs emitted from natural gas exhaust is 12% lower than diesel when the entire life cycle of the fuel is considered. CNG run vehicles also have quieter operation, less vibrations and less odour than equivalent diesel engines. However, high vehicle cost, shorter driving range, heavy fuel tank, expensive distribution and storage network and potential performance and operational problems compared to liquid fuels are some of the drawbacks of CNG (Watt, 2001).

2. Policy instruments in Delhi

A numbers of policy instruments—both command and control (CAC) and market-based instruments (MBI)¹—have been implemented in Delhi to combat pollution since 1998. However, the most controversial of these is the CNG conversion. Table 1 gives the chronological CNG implementation.

Table 2 offers details of the effects of policies covering June 1999 to September 2003 for the BSZM (Bahadur Shah Zafar Marg)—the busiest crossing in Delhi.² It indicates that the SO₂ level, which has never violated the legal standard, showed further decline, whereas, NO₃ levels rose continuously from 2000 and especially after CNG conversion. With respect to SPM and PM₁₀, they have fallen especially in 2003, but the level of violations have remained static. CO levels, although are still above the allowable 2% levels of violations, have shown a consistent fall, possibly due to the CNG conversion. The $t$-test shows that the mean values of all the parameters for the year 2003 are significantly different (at 5% level) than for 2002.

The assertion that the conversion to CNG reduces the particulates levels has not been established. A look at trend figures, however, shows that after every significant policy event the pollution levels do fall but not in a sustained manner (e.g., Fig. 1 relates to SO₂ and NO₂). One of the reasons for this transitory impact could be that almost 200,000 vehicles join the existing fleet annually. To see how long the effect of the policy instruments lasted, an econometric model is developed.

3. Econometrics analysis

The short term effects are investigated by considering implementation of a policy leads to an immediate fall in pollution. Since vehicle emissions depend on a number of factors such as

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¹ The policy instruments can be applied at five stages—pre-combustion stage needing upgradation in fuel quality (stage I); combustion stage requiring engine modifications (stage II); and post-combustion stage necessitating exhaust treatment devices like catalytic converters (stage III). Besides, few ‘non-technical’ instruments can be aimed at consumers, requiring behavioral adaptations either in the transport mode or necessitating periodic maintenance check. Any instrument intended for these behavioral changes would either be before stage I (i.e., stage 0) or after stage III (i.e., stage IV) (Kathuria, 2002).

² The site choice is vital for three other reasons; it measures the near-road emissions; it has a well maintained monitoring station of CPCB for PM₁₀ parameter; and it is unaffected by infrastructure related measures like metro-rail, or fly-overs.
### Table 1
Instruments/events pertaining to CNG implementation in Delhi (2001–03)

<table>
<thead>
<tr>
<th>Measure/event</th>
<th>Date</th>
<th>Impact and remark</th>
<th>Inst. type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Supreme Court directs all public transport vehicles—three-wheelers, taxis and buses to run on CNG by April 2001</td>
<td>28.07.1998</td>
<td>(+) Done with delay</td>
<td>CAC (0, I, II)</td>
</tr>
<tr>
<td>2 All pre-1990 autos and taxis to be replaced with new (subsidized) vehicles using clean fuel</td>
<td>31.03.2000</td>
<td>(+) Done</td>
<td>CAC, MBI (II)</td>
</tr>
<tr>
<td>3 Expansion of CNG Supply Network (from 9 to 80 stations)</td>
<td>31.03.2000</td>
<td>(−) Delayed</td>
<td>CAC (0)</td>
</tr>
<tr>
<td>4 New autos and taxis to be registered with only CNG or battery operated</td>
<td>01.04.2000</td>
<td>(+) Done</td>
<td>CAC, MBI (0, II)</td>
</tr>
<tr>
<td>5 &gt;8 years old bus to ply on CNG/other clean fuel (CNG kit subsidized)</td>
<td>01.04.2000</td>
<td>(−) Delayed</td>
<td>CAC, MBI (0, II)</td>
</tr>
<tr>
<td>6 Commercial and transport vehicles to meet EURO II norms</td>
<td>01.10.2000</td>
<td>(−) Done with delay</td>
<td>CAC (III)</td>
</tr>
<tr>
<td>CNG buses not ready to replace existing fleet—Delhi’s CM</td>
<td>27.02.2001</td>
<td>(−)</td>
<td></td>
</tr>
<tr>
<td>7 SC decides to force private operators to place CNG booking orders by 31.03.2001 (i.e., conditional extension to CNG)</td>
<td>26.03.2001</td>
<td>(+)</td>
<td>CAC (II)</td>
</tr>
<tr>
<td>Partial strike by autos and taxis against CNG order</td>
<td>27.03.2001</td>
<td>(−)</td>
<td></td>
</tr>
<tr>
<td>8 15–18 years old two-wheelers to be banned</td>
<td>31.03.2001</td>
<td>(−) Delayed</td>
<td>CAC (0)</td>
</tr>
<tr>
<td>9 All buses to switch over to CNG or other clean fuel</td>
<td>31.03.2001</td>
<td>(−) Delayed</td>
<td>CAC (II)</td>
</tr>
<tr>
<td>10 The bus fleet to be augmented to 10,000 from existing 6600</td>
<td>01.04.2001</td>
<td>(−) Delayed</td>
<td>CAC (0)</td>
</tr>
<tr>
<td>11 CNG conversion deadline expires. Public transport off the road. Report says CNG not the only alternative for fresh air</td>
<td>01.04.2001</td>
<td>(−) &lt; 4000 buses plying (till 04.04)</td>
<td></td>
</tr>
<tr>
<td>12 SC extends deadline for CNG permits till April 14</td>
<td>04.04.2001</td>
<td>(−)</td>
<td></td>
</tr>
<tr>
<td>13 Delhi limps to normalcy—12,000 buses to ply</td>
<td>05.04.2001</td>
<td>(−)</td>
<td></td>
</tr>
<tr>
<td>Deadline for temporary permits ends</td>
<td>14.04.2001</td>
<td>(−)</td>
<td></td>
</tr>
<tr>
<td>Two-day transport strike begins in Delhi</td>
<td>16.04.2001</td>
<td>(−)</td>
<td></td>
</tr>
<tr>
<td>14 Buses listed post-1996 can be issued CNG kits by NUGAS</td>
<td>22.04.2001</td>
<td>(+)</td>
<td>CAC (II)</td>
</tr>
<tr>
<td>15 CNG not the only clean fuel—Govt</td>
<td>25.07.2001</td>
<td>(−)</td>
<td></td>
</tr>
<tr>
<td>16 Diesel buses retrofitted with CNG kits but not meeting safety norms not allowed on roads from August 5, 2001</td>
<td>29.07.2001</td>
<td>(+)</td>
<td></td>
</tr>
<tr>
<td>Protest in Delhi against CNG shortage</td>
<td>06.08.2001</td>
<td>(−)</td>
<td></td>
</tr>
<tr>
<td>Strike against CNG shortage in Delhi</td>
<td>10.08.2001</td>
<td>(−)</td>
<td></td>
</tr>
<tr>
<td>17 Delhi Govt. asks SC to extend CNG deadline</td>
<td>16.08.2001</td>
<td>(−)</td>
<td></td>
</tr>
<tr>
<td>Ministry Claims not enough CNG</td>
<td>17.08.2001</td>
<td>(−)</td>
<td></td>
</tr>
<tr>
<td>18 Augmentation of public buses to 10,000</td>
<td>01.09.2001</td>
<td>(−) Pending</td>
<td></td>
</tr>
</tbody>
</table>

(continued on next page)
emission technology, fuel characteristics, vehicle-age, traffic speed and vehicle-size, the instruments employed in Delhi were intended to affect these factors. For the introduction of any policy instrument ($P_I$), the level of emissions ($E_i$) would be:

$$E_i = f(P_I)$$

Table 1 (continued)

<table>
<thead>
<tr>
<th>Measure/event</th>
<th>Date</th>
<th>Impact and remark</th>
<th>Inst. type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-wheeler autos using low benzene petrol permitted</td>
<td>18.09.2001</td>
<td>(−)</td>
<td>CAC (II)</td>
</tr>
<tr>
<td>CNG conversion deadline relaxed till October 18</td>
<td>28.09.2001</td>
<td>(−)</td>
<td></td>
</tr>
<tr>
<td>CNG deadline extended till January 31. SC orders to phase out diesel buses every 4 weeks</td>
<td>18.10.2001</td>
<td>(+) Every 4 weeks Govt. to file report</td>
<td></td>
</tr>
<tr>
<td>Center claims to dispense 0.44 metric square m$^3$/day (MMSCMD)</td>
<td>Nov. 2001</td>
<td>(−) 0.33 MMSCMD actual</td>
<td></td>
</tr>
<tr>
<td>Diesel run buses-off the road</td>
<td>01.12.2001</td>
<td>(+)</td>
<td></td>
</tr>
<tr>
<td>SC deadline for diesel buses ends</td>
<td>31.01.2002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNG prices go up by 8%, from 12.21/kg to 13.11/kg</td>
<td>28.02.2002</td>
<td>(+)</td>
<td></td>
</tr>
<tr>
<td>SC reserves verdict on CNG conversion</td>
<td>08.03.2002</td>
<td>(+)</td>
<td></td>
</tr>
<tr>
<td>7000 diesel buses go off the road. SC imposes a fine of Rs. 500 per bus per day for non-compliance</td>
<td>06.04.2002</td>
<td>(+)</td>
<td></td>
</tr>
<tr>
<td>1852 buses come back on road after paying fine</td>
<td>10.04.2002</td>
<td>(−)</td>
<td></td>
</tr>
<tr>
<td>IGL sets up 94 CNG stations</td>
<td>21.04.2002</td>
<td>(+) Done</td>
<td>CAC (0)</td>
</tr>
<tr>
<td>CNG fleet augmented by 1000 buses</td>
<td>22.04.2002</td>
<td>(+)</td>
<td>CAC (0)</td>
</tr>
<tr>
<td>CNG prices go up by 3.74 per kg.</td>
<td>27.04.2002</td>
<td>(−) Three-member team to study price hike</td>
<td></td>
</tr>
<tr>
<td>No change in SC ruling on CNG defaulters</td>
<td>09.05.2002</td>
<td>(+)</td>
<td></td>
</tr>
<tr>
<td>No impact of SC order on trucks in Delhi</td>
<td>16.07.2002</td>
<td>(−)</td>
<td></td>
</tr>
<tr>
<td>Last batch of 600 diesel buses go-off the road. About 75,000 CNG vehicles on Delhi’s roads</td>
<td>01.12.2002</td>
<td>(+) Public transport converted to CNG</td>
<td>CAC</td>
</tr>
<tr>
<td>Computerized PUC mandatory for vehicles registered in Delhi</td>
<td>12.01.2003</td>
<td>(+) Notification within three months</td>
<td>CAC (IV)</td>
</tr>
<tr>
<td>Expansion of IGL’s CNG supply stations from 101 to 110 and increasing capacity from 0.96 mn kg/day (mkd) to 1.61 mkd</td>
<td>01.06.2003</td>
<td>(+)</td>
<td>CAC (0)</td>
</tr>
<tr>
<td>Delhi State stops registering 15-seater CNG buses</td>
<td>02.07.2003</td>
<td>(+) 5000 buses running</td>
<td>CAC (0)</td>
</tr>
</tbody>
</table>

Source: Kathuria (2002) and author’s compilation. Notes: +/− sign in parentheses of Column 4 indicates if perceived impact is favourable or not; column 5 parentheses reflect the stage of implementation of instruments. Infrastructure related measures like starting of metro-rail in Delhi, or building of fly-overs etc. that serve the dual purpose of addressing transport externalities like congestion, delays etc. besides facilitating reduction in pollution are not included.
The ambient air quality depends on two factors: the strength of the sources i.e., $E_i$, the efficiency of the dispersion of pollutants, which depends on weather and climate. This implies

$$\text{Amb. Air} = f(E_i, \text{weather, climate})$$

The topography also affects dispersion. It has relevance if analysis is across regions, unlike the present study.
From (1) and (2), we have

\[ \text{Amb Air} = f(P_I, \text{weather, climate}) \]  

Temperature, rainfall, wind speed etc. are the variables accounting for weather. With its semi-arid climate, Delhi experiences only three seasons: dry (April–June); monsoon (July–September); and winter season (October–March). Parameters like SPM increase in summer due to dusty conditions, whereas, rainfall ‘scavenges’ particulates. During winter, low ambient temperatures, lower mixing depth, temperature inversion, higher consumption of fuel aggravate the pollution problem, especially the $\text{NO}_x$.

Any pollution parameter usually has a short-term persistent effect unless strong wind disperses it or rain scavenges it. This persistent effect can be captured with one-day lags. Another variable affecting the ambient air quality is the volume of traffic. This has two components vehicles on the road ($v_{\text{road}}$) and newly registered vehicles ($v_{\text{reg}}$). Vehicles on road reflect the economic activity in the area that might vary depending upon the day of the week. Thus the model could be:

\[ \text{Amb Air}_t = f(\text{Amb Air}_{t-1}, P_I, \text{weather, climate, v_{road}, v_{reg}}) \]  

The lag values of air quality parameter forced the dropping of observations for which previous day no reading was taken. Eighteen observations had to be dropped due to dusty weather conditions which may have affected the ambient air quality. This leaves 1352 observations for SPM and $\text{NO}_x$. For $\text{PM}_{10}$ and SPM no reading on some days due to instrument failures, left 1324 and 1315 observations respectively.

The variable policy instrument ($P_I$) has been constructed as a dummy taking a value 1 if the time elapsed after enacting a policy is a week or less. Rainfall ($R_{\text{fall}}$—rain during the day in millimetre), maximum ($\text{MaxT}$) and minimum ($\text{MinT}$) temperature were taken newspapers and capture daily meteorological variations. Climatic conditions are captured through three seasonal dummies ($\text{Season dummy}$) for summer, rainy and winter seasons. Since the level of activity influences vehicles in use, and hence the ambient air quality, this is controlled for by using day dummies ($\text{Day dummy}$). In absence of data on daily registration, a daily time trend ($\text{Time}$) variable has been constructed that partially captures vehicle registration. A yearly dummy ($\text{Year dummy}$) is introduced to account for population increase and other unobserved factors.

Table 1 indicates the CNG conversion implementation was often delayed. Such events could have given inappropriate signals. To allow such delays, the variable ‘$PI_{\text{delayed}}$’ is included. A further variable (Holiday) is also included. To allow for the CNG implementation effect a dummy that takes the value 1 after December 1, 2002 and zero otherwise is included. Assuming a linear relationship between ambient air quality and various factors affecting pollution, the model is:

\[ \text{SPM} (\text{PM}_{10} \text{ or } \text{NO}_x)_t = b_0 + \delta \text{CNG} + b_1 \text{SPM (or PM}_{10} \text{ or } \text{NO}_x)_{t-1} + b_2 P_I + b_3 R_{\text{fall}} \\
+ b_4 \text{MaxT} + b_5 \text{MinT} + b_6 \text{Season dummy} \\
+ b_7 \text{Year dummy} + b_8 \text{Time} + b_9 \text{Day dummy} \\
+ b_{10} P_{\text{I delay}} + b_{11} \text{Holiday} + u_t \]  

\[ \]
where $\delta$ is the shift parameter and $u_t$ is the error term. Since CO does not linger in the atmosphere, the diurnal variation in CO is captured by measuring it every 8 h. The value is high during daytime and low at late night. Thus, Eq. (5) includes shift dummy. Hatanaka (1974) estimation is used to reduce problems of serial correlation. Because the vehicles involved are of varying technology and size, heteroscedasticity is likely, and parameters are thus estimated with correction for unknown forms of heteroscedasticity. The analysis is also confined to SPM, PM$_{10}$, NO$_x$ and CO because SO$_2$ does not exceed standards and there does not exist a standard for Ozone. Table 3 gives the results.

The table shows that pollution has a persistent effect; the lagged value significantly impacts the current value. With respect to climatic conditions, the rainfall has a varying impact on the ambient air quality. Rain scavenges particulate matter, but has no impact on NO$_x$ and CO, whereas hot weather leads to high pollutant formation. Time, a proxy for new registered vehicles, has not only the anticipated sign, but also is significant for PM$_{10}$, NO$_x$ and CO. The day dummies are significance in the case of SPM, NO$_x$ and CO, but only for PM$_{10}$ on Thursdays when the

<table>
<thead>
<tr>
<th>Variable</th>
<th>SPM</th>
<th>PM$_{10}$</th>
<th>NO$_x$</th>
<th>CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPM$<em>{t-1}$/PM10$</em>{t-1}$/NO$<em>x$$</em>{t-1}$/CO$_{t-1}$</td>
<td>0.68* (5.61)</td>
<td>0.74* (6.72)</td>
<td>0.57* (3.66)</td>
<td>0.348* (8.427)</td>
</tr>
<tr>
<td>MinT</td>
<td>-6.85* (-2.7)</td>
<td>-3.8* (-2.76)</td>
<td>-0.456* (-2.36)</td>
<td>-93.53* (-6.789)</td>
</tr>
<tr>
<td>MaxT</td>
<td>6.76* (2.52)</td>
<td>2.025* (1.836)</td>
<td>0.338* (1.8)</td>
<td>62.13* (4.974)</td>
</tr>
<tr>
<td>Rfall</td>
<td>-1.237* (-3.28)</td>
<td>-0.53* (-2.86)</td>
<td>-0.443 (0.822)</td>
<td>4.01 (1.323)</td>
</tr>
<tr>
<td>Day$_1$ (Monday)</td>
<td>36.62* (2.08)</td>
<td>-0.052 (-0.006)</td>
<td>7.75* (5.118)</td>
<td>-267.31* (-1.921)</td>
</tr>
<tr>
<td>Day$_2$ (Tuesday)</td>
<td>33.55* (2.047)</td>
<td>0.545 (0.072)</td>
<td>5.53* (4.35)</td>
<td>-94.57 (-0.68)</td>
</tr>
<tr>
<td>Day$_3$ (Wednesday)</td>
<td>39.75* (2.48)</td>
<td>8.84 (1.08)</td>
<td>5.185* (4.04)</td>
<td>-179.15 (-1.34)</td>
</tr>
<tr>
<td>Day$_4$ (Thursday)</td>
<td>47.81* (2.96)</td>
<td>14.55* (1.87)</td>
<td>5.114* (4.12)</td>
<td>-210.27 (-1.55)</td>
</tr>
<tr>
<td>Day$_5$ (Friday)</td>
<td>20.78 (1.15)</td>
<td>2.63 (0.334)</td>
<td>5.10* (3.82)</td>
<td>-353.52 (-2.58)</td>
</tr>
<tr>
<td>Day$_6$ (Saturday)</td>
<td>24.8 (1.53)</td>
<td>6.14 (0.79)</td>
<td>5.24* (4.312)</td>
<td>-256.56 (-1.84)</td>
</tr>
<tr>
<td>Season_dumy$_1$ (Summer)</td>
<td>23.27* (1.6)</td>
<td>19.8* (2.58)</td>
<td>-0.226* (-0.165)</td>
<td>-850.43* (-6.33)</td>
</tr>
<tr>
<td>Season_dumy$_2$ (Rain)</td>
<td>-29.24 (-1.3)</td>
<td>4.29 (0.65)</td>
<td>-1.89* (1.265)</td>
<td>-365.88* (-2.81)</td>
</tr>
<tr>
<td>Yr_dumy$_1$ (1999)</td>
<td>111.31 (1.41)</td>
<td>73.15* (1.71)</td>
<td>27.72* (2.51)</td>
<td>2751.07* (7.32)</td>
</tr>
<tr>
<td>Yr_dumy$_2$ (2000)</td>
<td>96.59 (1.49)</td>
<td>40.29 (1.29)</td>
<td>14.73* (2.1)</td>
<td>2228.57* (9.20)</td>
</tr>
<tr>
<td>Yr_dumy$_3$ (2001)</td>
<td>57.02 (1.13)</td>
<td>13.08 (0.57)</td>
<td>8.62* (1.80)</td>
<td>1262.90* (7.41)</td>
</tr>
<tr>
<td>Yr_dumy$_4$ (2002)</td>
<td>38.88 (0.98)</td>
<td>13.99 (0.75)</td>
<td>2.27 (0.75)</td>
<td>-896.76* (-4.39)</td>
</tr>
<tr>
<td>Time</td>
<td>0.133 (1.53)</td>
<td>0.1* (2.11)</td>
<td>0.039* (2.576)</td>
<td>4.33* (6.152)</td>
</tr>
<tr>
<td>P.I (7 days)</td>
<td>7.43 (0.518)</td>
<td>1.81 (0.26)</td>
<td>0.776 (0.701)</td>
<td>503.53* (2.92)</td>
</tr>
<tr>
<td>Holiday</td>
<td>-1.498 (-0.336)</td>
<td>-1.126 (-0.069)</td>
<td>0.066 (0.194)</td>
<td>-88.85 (-0.35)</td>
</tr>
<tr>
<td>PI delayed</td>
<td>-14.99 (-1.14)</td>
<td>3.44 (0.34)</td>
<td>3.54 (1.41)</td>
<td>@</td>
</tr>
</tbody>
</table>

| Shift1 (8 a.m.)   | @    | @     | @ | -1160.29* (-15.59) |
| Shift2 (4 p.m.)   | @    | @     | @ | 0.80* (7.56) |
| CNG_dumy          | 17.90 (0.49) | -13.98 (0.89) | -0.221 (0.08) | -1999.05* (-5.88) |
| Constant          | -82.2 (-1.17) | -19.83 (0.509) | -6.315 (-1.03) | 513.04 (1.29) |
| Durbin–h test     | -3.81 | -4.847 | -7.265 | -6.21 |
| Rho               | -0.052 | -0.084 | -0.1197 | 0.192 |
| Adjusted $r$-square | 0.56 | 0.643 | 0.611 | 0.46 |
| $N$               | 1314 | 1324 | 1351 | 3520 |

Note: Figures in parenthesis are $t$-values. * is significance level at 10%. @—not applicable.
economic activity is at its peak. The sign and significance of year dummies reflect that pollution in 1999 to 2002 higher than for 2003 and especially so for PM$_{10}$, NO$_x$ and CO.

It is also seen that enacting a policy instrument (P$_I$) has not led to any fall in the air-pollution, and indeed for CO, the impact seems to be perverse. The success of any instrument depends mainly on the expectation of the people. The conjecture that this may be the result of the population’s experiences with delays in policy implementation in the past (i.e., P$_I$ delayed), however, is not verified in terms of statistical significance, although it has the right sign in the cases of PM$_{10}$ and SPM.

The insignificance of (P$_I$) and perverse sign for CO raises a question; is the 7-day period too long? If in the intervening period, a number of new vehicles are registered, the pollution load would have reverted back to the old level. To see whether even for a brief period, the instrument affected the pollution profile, the model is run with P$_I$ constructed as a dummy variable taking a unitary value for 5 days, 3 days, 2 days, and 1 day respectively after an enactment. The results indicate that the impacts of P$_I$ on different pollutants, though insignificant was negative (except for PM$_{10}$) in the first two days but after that become positive. In case of PM$_{10}$, pollution level fall significantly immediately after the enactment of a policy.

The results also show that the introduction of CNG has led only to a fall in CO. The decline however may not continue for long. This is because the present downward shift has taken place from an initially very high value (i.e., above 3500 mg/m$^3$ for CO), which is much higher than the standard levels of the pollutant (2000 mg/m$^3$). An important reason for the insignificant (and unanticipated) effect of CNG conversion for SPM, PM$_{10}$ and NO$_x$ could be the retrofitted CNG vehicles. To meet deadlines, several buses operators, as well as gasoline-driven three-wheelers operators, retrofitted their engines from liquid fuel to CNG. The studies from elsewhere indicate that poor conversions of some gasoline vehicles to CNG vehicles$^5$ have led to higher emissions, operational problems and even accidents.

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References


$^5$ For example, the International Association for Natural Gas Vehicles in a study has found that of 1.5 million vehicles running on natural gas worldwide most are gasoline vehicles converted to CNG. (Source: www.iangv.org/html/ngv/stats.html.)