The Impacts of Fuel Price Policies on Air Pollution: A Case Study of Tehran

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Abstract

Background: This study aims to investigate the impacts of fuel price policies on the concentration of air pollutants emitted from the transport sector.

Methods: Autoregressive distributed lag (ARDL) estimation models were used to investigate the impacts of gasoline and diesel prices along with weather and economic variables on the following traffic-related pollutants: Carbon monoxide (CO), Nitrogen dioxide (NO₂), Particular matter 10 micrometers or less (PM₁₀).

Results: In the short run, one percent increase in gasoline prices lead to 0.02 percent decrease in concentration of CO and 0.012 percent decrease in PM₁₀. In addition, one percent increase in diesel prices leads to 0.008 and 0.02 percent decrease in concentration of CO and PM₁₀ respectively. Results demonstrate that one percent increase in gasoline prices leads to 0.011 and 0.02 percent increase in NO₂ concentration in short run and long run respectively. Compared to the short run, the results for the long run showed that fuel prices had greater impacts on air pollution concentration.

Conclusion: Although the implementation of fuel price policies decreases air pollution concentration in Tehran, the results showed that other factors such as weather and economic activities and conditions, had a greater impact on air pollution. Therefore, other policies such as improving fuel quality and technology along with other economic policies can be more effective.

1. Background

Air pollution is a serious threat to public health and the environment, and it is estimated that large volumes of pollutants enter the environment each year (1). Nowadays, many major cities in the world are facing environmental problems, especially due to air pollution, which put the health of people at risk. According to public data, air pollution often has exceeded the WHO standards in these cities (2, 3). Today, almost half of the world's population live in cities with population congestion and verity of environmental problems (4).

For example, Tehran with a population of 13, 260,637, is one of the eight polluted cities in the world in term of air pollution. Although it has only 1.2% of the country's total area, it accounts for 20% of the country's total population, 40% of the industry and 85% of its total expertise.

The main causes of Tehran's air pollution comes down to one factor: motor vehicles (accounting for more than 80%). In addition, non-standard vehicles, incorrect pattern of transformation and fuel consumption, low quality of fuels, and growth of migration has resulted in an increasing trend of air pollution (5, 6). According to the statistics and reports of Iranian Air Quality Control Organization, most of Tehran's air

pollutants are carbon monoxide, particulate matter, nitrogen dioxide, sulfur dioxide, and ozone, respectively (7).

Governments on the other hand, are always seeking to alleviate environmental pollution problems and negative effects of human activities on the environment by adopting different policies and programs. Currently, air pollution has become a significant problem in many major cities of Iran, which has led the government to adopt short and long term policies and programs to address it (6).

So far, the government has dedicated huge amounts of budgeting to control air pollution in Tehran. Old vehicle retirement programs, expansion of subway lines, and implementation of traffic restrictions in the city center are examples of strategies that have been implemented to control the air pollution. Meanwhile, the implementation of fuel pricing policies to reduce air pollution and control fuel consumption in Tehran, due to its low running costs, has always been a priority among various plans (8, 9).

Elimination of energy subsidies and the gradual rise in fossil fuel prices are some fuel pricing policies that have been implemented in recent years, could improve fuel consumption patterns and some pollutants like CO, NO₂, and PM₁₀ emitted from the transport section. Therefore, as fuel prices rise, it can be expected that air pollution and emissions will decrease. This study aims to investigate the effects of gasoline and diesel fuel prices policies on the amount of pollutants (CO, NO₂, and PM₁₀) which are emitted from the transport sector.

2. Methods

2.1. Model framework

Over time, it becomes increasingly important to examine the air pollution status and its related factors. Besides human activities, changes in the atmospheric status have an important role on the air pollution status.

In this study, a fixed-effects regression method was used to estimate the model. Due to differences in the atmospheric variables of each region in Tehran, using fixed effects method would show better estimations of the effects caused by differences between regions. Hence the following model was used to examine the impacts of fuel prices and atmospheric variables on air pollutant concentration:

$$\ln A_{sm}: \alpha_0 + \alpha_1 \ln P_m + \alpha_2 S_s + \alpha_3 X_m \varphi + \alpha_4 \text{Dum} + \varepsilon_{sm}$$

Where, m indexes month and s indexes air pollution monitoring Stations. α_0 denotes the station fixed effect, which controls for unobserved permanent differences in the dependent variables. A is a dependent variable and denotes air pollutant concentration. In this study, pollutants such as PM₁₀, CO, and NO₂ are examined separately. P denotes real fuel price per liter in dollars. Also, X is a vector for control variables. In this model, log of maximum wind speed in knot, total rainfall in millimeter (mm), average temperature degree in Celsius (Centigrade), a public holidays dummy, and a linear time trend are considered as control

variables. Also, this study considered log of manufacturing production index (MAP) and the log of value added tax (VAT) revenue as other control variables. Dum represents dummy variable. ε is an error term. Reasons for controlling these variables are described below.

Wind speed, temperature, and rainfall are considered due to their impacts on air pollutants concentration. There is evidence showing the influence of wind speed and rainfall on air pollutants concentration (10, 11). As the wind speed and rainfall increases, the concentration of pollutants is reduced. Also, increase in the number of holidays and weekends in each month would lead to reduction for fuel demand followed by the reduction of air pollution emission.

Furthermore, this study considers the number of holidays as a control variable. Commonly, people use fewer personal vehicles to get their children to school or to work in holidays. Log of manufacturing production index (MAP) and log of value added tax (VAT) revenue used as a proxy for measuring the changes in manufacturing production activity and consumption spending respectively. In fact, increase in each of these two variables would likely lead to an increase in ambient air pollution.

With reference to the fact that the population and quality of fuels change gradually over time, time trend is considered as a control variable for measuring factors in this model. Unfortunately, the fuel quality in Iran has been decreasing overtime due to international economic sanctions; meanwhile, the population is growing gradually. Therefore, the concentration of pollutants is expected to increase. In addition, this model uses a dummy variable to measure increasing fuel price shocks that occurred in five time periods (2009/04, 2010/12, 2014/04, 2015/03, and 2019/10) by the government.

2.2. Data

Tehran is the 8th polluted city in the world (12). The center of the city is on latitude 35°41' N and longitude 51°26' E. Tehran has had a permanent resident population of 8.73 million people in 2017 (13), and 13, 267,637 during working days. Figure 1 shows the location of Iran, Tehran, and monitoring stations in the 22 districts of Tehran.

This study collected monthly data's for CO, NO₂, and PM₁₀ pollutants from 22 monitoring stations in Tehran from Air Quality Control Company (AQCC) from March 21, 2009 to December 21, 2019. Figure 2–4 shows the trends of monthly air pollutant changes during this study period.

The real prices for gasoline and diesel in Iran between January of 2009 to December of 2019, were used in this study (see Fig. 5). These data were collected by National Iranian Oil Product Distribution Company (NIOPDC). This study used real fuel prices data, consequently fuel price data's were expressed as consumer price index based on constant price of 2016.

Also, this study gathered monthly averages of weather data (Rainfall, wind speed, and temperature) across 10 weather stations from Tehran meteorological organization.

In order to measure manufacturing production index and value added tax (VAT) revenue, national data's were used. These variables gathered at constant 2016 prices from Central Bank of Islamic Republic of Iran.

3. Results

3.1. Monthly estimates

The first step in analysis of longitudinal studies is the examination of the stationarity of variables. Due to high variation in investigated variables during the course of study, all variables were used in logarithmic form. To check stationarity, the Augmented Dickey-Fuller test and the Phillips-Perron test were used. The null hypothesis in both tests implies the existence of a single root for each variable, which in nature is a non-stationary variable. Consequently, this study carried out these unit root tests on the log of pollution (average across 22 stations), fuel prices, and weather variables with linear time trend. Table (1) represents the results of stationarity test.

According to the results in table (1), all variables become stationary after one- differentiating ($I(1)$) except for PM₁₀. PM₁₀ were stationary at level ($I(0)$). Therefore, it can be concluded that the relationship between the time series is sufficient, so the results of the regression are to be true.

Since variables in this study, are a combination of different stationary ($I(0)$ and $I(1)$), the use of the autoregressive distributed lag (ARDL) method is more preferable with respect to other methods. In this model, the Hannan-Quinn criterion (HQ) was used to determine the optimum length of lags.

The findings on dynamic models (short run) showed that change in gasoline fuel price has greater impact on CO concentration than the other pollutants. According to the results of short run, one percent increase in gasoline fuel prices lead to 0.02, 0.011, and 0.012 percent decrease in CO, PM₁₀, and NO₂ concentrations, respectively. Also, one percent increase in diesel fuel prices lead to 0.008, 0.02, and 0.015 percent decrease in CO, PM₁₀, and NO₂ concentrations, respectively. The findings indicated that diesel price had greater impact on NO₂ and PM₁₀ concentrations.

The findings on weather variables, revealed that rainfall had no significant impacts on CO and NO₂ concentrations. However, rainfall had a significant negative impact on PM₁₀ concentration. Higher temperature was also associated with less air pollution. Wind blow had a significant effect on the concentration of all pollutants, and this relationship was inverse. That is one percent increase in wind speed resulted in 0.11, 0.09, and 0.44 percent decrease in the concentration of CO, NO₂, and PM₁₀, respectively.

The findings revealed that time trend had positive impacts on CO and NO₂ concentrations in a significant manner but no significant effect on PM₁₀ concentration was observed. In other words, an increase in the population and change in fuel quality led to an increase in concentrations of CO and NO₂.

The findings also indicated that coefficient of log VAT and MPI had positive impacts on air pollutant concentration, but not a significant effect.

In regards to the holidays, the findings indicated that an increase in the number of holidays and weekends in each month had a negative impact on the concentrations of CO, NO₂, and PM₁₀; so that, one percent increase in the number of holidays in each month, led to 0.11, 0.09, and 0.07 percent decrease in air pollutants respectively. However, this effect was not significant for PM₁₀ concentration.

In this study the coefficients of determination (R^2) in all models was 0.8, which indicates that the models had a relatively high explanatory power. Also, the Durbin-Watson statistics in all three models were near 2, which means no autocorrelation problem was present in the models.

This study implemented several diagnostic tests to ensure models appropriateness, such as 1-test for the correctly specified model (Ramsey's RESET Test), 2- serial correlation (LM test), 3-heteroscedasticity (ARCH test) and 4-normality (Jarque -Bera (N)). The diagnostic tests results showed that there are no problems associated with the correctly specified model, serial correlation, normality or heteroscedasticity. Table (2) shows the results of the dynamic equation estimation for three pollutants in three columns along with several diagnostic tests to ensure the accuracy of estimation models.

Furthermore, this study conveyed cumulative sum control chart (CUSUM) test to investigate stability of the model's coefficients. In this test, the confidence interval is two straight lines that show 95% confidence level. If the test statistics are located between these two lines, then the null hypothesis would not be rejected (H_0 : stability of parameters). The findings of this test indicated that all estimated parameters were stable at 5% significant level. Based on Figure (6), value for the CUSUM test is located between these 2 lines, which indicates the stability of the parameters.

The Boundary test was also used to investigate existence of cointegration and the long-run relationship between variables. In this method, two critical bounds are presented, upper bound for time series I(1) and lower bound for series I(0). In this test, if the F statistic is greater than the upper bound value, the null hypothesis (lack of cointegration) is rejected; and if F statistic is less than the lower bound value, the null hypothesis is confirmed. Moreover, if the F statistic locates between two bounds, no conclusions can be made. Results of boundary test showed that F statistic was higher than upper bound which is provided by Narayan and Pesaran et al. consequently, there is a long run relationship between variables. Table 3 shows the results of Boundary test for models.

Table 1
Results of stationarity test.

variable	Test statistics (p-value)	Test result
Ln CO	-1.62 (0.46)	Non-stationary
Δ Ln CO	-7.13 (0.00)	stationary
Ln NO ₂	-2.80 (0.058)	Non-stationary
Δ Ln NO ₂	-12.4 (0.00)	stationary
Ln PM ₁₀	-4.67 (0.00)	stationary
Ln gasoline price	-2.40 (0.14)	Non-stationary
Δ Ln gasoline price	-11.66 (0.00)	stationary
Ln diesel price	-2.31 (0.16)	Non-stationary
Δ Ln diesel price	-11.45 (0.00)	stationary
Mean temperature	-2.01 (0.4)	Non-stationary
Δ Mean temperature	-5.31 (0.00)	stationary
Rainfall	-2.00 (0.65)	Non-stationary
Δ Rainfall	-2.33 (0.00)	stationary
wind speed	-1.12 (0.14)	Non-stationary
Δ wind speed	-2.11 (0.00)	stationary
Number of holidays and weekend days	-2.71 (0.059)	Non-stationary
Δ Number of holidays and weekend days	-12.4 (0.00)	stationary

Table 2

Results of dynamic relationship for models with three different pollutants (CO, NO₂, and PM₁₀)

Dependent variable	lnCO		Dependent variable	lnNO ₂	
Optimum lag	(1, 0, 0, 2, 0, 0, 2, 0)		Optimum lag	(1, 2, 0, 0, 1, 1, 0, 0)	
	Coefficient	t-value (prob)		Coefficient	t-value (prob)
lnCO (-1)	0.48	6.005 (0.00)	lnNO ₂ (-1)	0.61	8.77 (0.00)
lnMPI	0.67	-1.75 (0.08)	lnMPI	0.79	0.97 (0.33)
lnRain	0.01	2.39 (0.11)			
lnTempreture	-0.006	2.33 (0.02)	lnMPI(-1)	0.36	1.26
lnTempreture (-1)	-0.002	-0.52 (0.59)			-0.2
lnTempreture (-2)	0.005	1.78 (0.07)	lnMPI(-2)	-1.96	-2.45 (0.01)
lnVAT	0.01	-0.25 (0.8)	lnRain	0.01	1.1
ln Gasoline price	-0.02	-1.97 (0.05)			-0.1
lnTrend	0.1	-2.23 (0.02)	lnTempreture	-0.001	1.29 (0.19)
lnTrend (-1)	0.13	2.33 (0.02)	lnVAT	1.39	-1.51 (0.13)
ln Trend (-2)	-0.009	-2.56 (0.01)	lnVAT (-1)	1.9	2.03 (0.04)
ln Diesel price	-0.008	1.43 (0.06)	ln Gasoline price	0.011	1.34 (0.18)
DUM	-0.24	2.24 (0.02)	ln Gasoline price (-1)	0.016	-1.91 (0.05)
Wind	-0.11	2.5	lnTrend	0.001	0.06 (0.04)
		-0.01	ln Diesel price	-0.015	-1.9 (0.05)
Number of holidays and weekend days	-0.11	3.05 (0.00)	DUM	-0.03	0.38 (0.69)

C	8.001	0.98 (0.3)	Wind	-0.09	2.5
R ²	0.8				-0.01
Diagnostic tests			Number of holidays and weekend days	-0.09	3.24 (0.01)
Durbin-Watson	2.05		C	-7.44	-0.95 (0.33)
stat			R ²	0.8	
Autocorrelation test	078 (0.66)		Diagnostic tests		
Ramsey's RESET Test	0.59 (0.44)		Durbin-Watson	1.91	
Jarque -Bera	1.77 (0.41)		Stat		
Engle's ARCH LM	0.64 (0.42)		Autocorrelation test	0.72 (0.48)	
			Ramsey's RESET Test	0.74 (0.46)	
			Jarque -Bera	1.65 (0.39)	
			Engle's ARCH LM	1.19 (0.27)	

Table 3
Boundary test results for the models

F-statistic			critical bounds for Narayan		critical bounds for Pesaran		Significant level
model with CO dependent variable	model with NO ₂ dependent variable	model with PM ₁₀ dependent variable					
6.15	4.98	5.14	I(0)	I(1)	I(0)	I(1)	
			2.01	3.05	1.92	2.89	10%
			2.33	3.45	2.17	3.21	5%
			3.02	4.35	2.73	3.9	1%

Table 4
Long run estimations for the models

Model with dependent variable:			
	CO	NO ₂	PM ₁₀
Variable	Coefficient (P-Value)	Coefficient (P-Value)	Coefficient (P-Value)
lnDieselprice	-0.011 (0.002)	-0.024 (0.002)	-0.029 (0.03)
lnGasolineprice	-0.027 (0.01)	0.02 (0.01)	-0.016 (0.27)
lnMPI	2.96 (0.007)	2.96 (0.007)	0.88 (0.001)
lnRain	0.008 (0.62)	0.008 (0.62)	-0.01 (0.01)
lnTemreture	-0.07 (0.14)	-0.07 (0.14)	-0.01 (0.05)
Wind	-0.1 (0.1)	-0.52 (0.2)	-1.07 (0.06)
lnVAT	0.31 (0.05)	0.31 (0.05)	1.21 (0.01)
lnTimetrend	1.78 (0.01)	1.93 (0.01)	0.05 (0.00)
Number of holidays and weekend days	-0.8 (0.04)	-0.8 (0.07)	-0.92 (0.07)
DUM	-1.1(0.5)	-1.0 (0.5)	-0.93 (0.4)
C	-10.91 (0.49)	-10.91 (0.49)	-16.15 (0.3)

Table 5
Fuel price impacts on CO, NO₂, and PM₁₀ during period (1) and period (2)

Model with dependent variable						
Variable	CO		NO ₂		PM ₁₀	
	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2
lnDieselprice	-0.02	-0.018	-0.019	-0.019	-0.26	-0.027
lnGasolineprice	-0.02	-0.029	-0.016	0.014	-0.016	-0.019
R ²	0.8	0.8	0.8	0.79	0.81	0.81

The long run results of the models showed that, one percent increase in gasoline fuel price lead to 0.027 and 0.016 percent decrease in the concentrations of CO and PM₁₀ respectively; and 0.02 percent increase in NO₂ concentration. However, the impact on PM₁₀ was not significant in the long run. Furthermore, one percent increase in diesel fuel price leads to 0.011, 0.024, and 0.029 percent decrease in concentrations of CO, NO₂, and PM₁₀ respectively. Therefore, in the long run, fuel price changes had a greater impact on

the concentrations of pollutants compared to the short run. In the short term however, changes in gasoline fuel prices had a greater impact on the concentrations of pollutants, than diesel fuel prices.

Other variables such as VAT and MPI had a positive impact on the concentration of all air pollutants in significant manner. So that one percent increase in VAT causes a 0.31, 0.31, and 1.21 percent increase in CO, NO₂, and PM₁₀ concentrations, respectively. Also, one percent increase in MPI causes a 2.96, 2.96, and 0.88 percent increase in CO, NO₂, and PM₁₀ concentrations, respectively. Consequently, these two variables had greater impacts in the long run compared to the short run.

For other coefficients related to weather variables, the findings revealed that rainfall, wind blow, and temperature had no significant impacts on pollutant concentration except for PM₁₀. That is one percent increase in the amount of rainfall and temperature leads to 0.01 percent decrease in PM₁₀ concentration in the long run. The stated coefficients were greater in the long run than for the short run.

The findings also indicated that time trend had maximum impacts on all pollutant concentrations in the long run. This means the increase in the population and decrease in fuel quality in the long run, lead to 1.78, 1.93, and 0.05 percent increase in CO, NO₂, and PM₁₀ concentration respectively. Table (4) shows the results of long run relationship between variables for models with three different dependent variables (i.e. CO, NO₂, and PM₁₀).

3.2. Sub-period analysis gasoline- compressed natural gas (CNG) substitution

Over the past decade, the Iranian government has paid a lot of attention to the production of CNG vehicles in order to reduce gasoline consumption and air pollution. As part of such plan, gasoline-fuelled, vehicles have been converted to CNG and, the number of CNG stations has been increased around the nation. However, the CNG-fueled vehicles emit less CO and more NO₂ than the gasoline powered vehicles. In order to increase the validity of the results, the models were studied in two different periods – during 01. 2009– 03.2013 (period 1) and 04. 2013-12.2019 (period 2) (Table, 5).

Results showed that an increase in gasoline price leads to an increase in NO₂ concentration in recent years and the second period of study as well. Based on substitution between gasoline and CNG, an increase in gasoline fuel price lead to increases in CNG consumption and consequently increases NO₂ emission.

4. Discussion

Tehran, as a megacity and capital of Iran, has been dealing with air pollution problems for years; problems largely originated from high traffic density, and gases emitted from all kinds of vehicles. This study focused on the effect of fuel prices and weather on concentrations of CO, NO₂, and PM₁₀ as main pollutants that are emitted from fossil fuel consumption in transport sectors.

The findings of the present study showed that the trend of CO and PM₁₀ concentration in Tehran was diminishing over the investigated period; but NO₂ had an increasing trend. Expanding the culture of using subway and public transportation, and promoting vehicles with a Euro 2 standard or higher, has played a key role in the downward trend of condensation of CO and PM₁₀ pollutants concentrations (14). Also, replacing the consumption of vehicles' fuel from gasoline to CNG plays an important role on the growth of NO₂ concentration (15, 16).

In a review study done on developing and developed countries, Baldasano et al showed that the trend of PM₁₀ and CO concentration levels were declining (17). While, the study conducted in Korea, showed that CO and PM₁₀ concentration had an increasing trend and NO₂ had no clear and steady trend (18).

Overall, our results showed that fuel prices have significant negative impacts on CO and PM₁₀ concentration for both short, and long run. The increase in gasoline and diesel prices leads to decrease in CO and PM₁₀ concentrations. Increase in the gasoline and diesel price as the main price policies to control air pollution, reduces fuel consumption. Since high consumption of fuel in transport section of the country is one of the main contributors to air pollutants emission, reducing the consumption of these carriers results in reduction of pollutant emission and consequently concentration of pollutants. In contrast to other pollutants, gasoline price had positive impact on NO₂ concentration.

Increasing government investments in using clean fuels such as CNG and increase in the number of CNG-fueled vehicles, results in increased demand for CNG due to rising gasoline prices. Since the use of natural gas has a higher carbon dioxide emission rate than other fuels, the increase in gasoline prices was associated with increased emission and concentration of NO₂. These results are consistent with the results of the Ninpanit study (19).

In a study conducted in New Zealand, Shaw et al showed 1% increase in gasoline price was associated with a 0.32% (- 1.21 to 0.58) reduction in NO₂ concentration in short run (20). Although, in another study that was conducted in Brisbane, Brannet showed that changes in petrol prices had no impact on air pollution (21). In a study conducted by Heger et al in Cario, results showed that 30% and 80% increase in fuel price lead to the overall decline in traffic, and consequently 1.6% and 2.3% decrease in PM₁₀ concentration (22).

Also, results showed that a changes in gasoline price had a greater impact on CO concentration compared to NO₂ and PM₁₀ concentrations. Considering that the volume of CO pollutant emitted from gasoline-powered personal vehicles is higher than NO₂ and PM₁₀ and its effect on consumption by gasoline-powered cars (don't understand this sentence), increase in gasoline prices will result in a greater reduction in CO concentration compared to other pollutants. These results are consistent with the findings of other studies (19, 23).

On the other hand, as nearly as 80% of the PM₁₀ emission created in the transportation sector comes from diesel fuel consumption (24). Therefore, increasing the diesel fuel price and reducing its

consumption proportionally, causes a further reduction in emissions and pollution of PM_{10} . A study conducted by Ninpanit showed that one percent increase in gasoline price leads to 0.36% decrease in CO concentration, while 1% increase in gasoline price leads to 0.23% and 0.25% change in NO_2 and PM_{10} concentrations respectively (19).

The comparison of the findings on short and long run models revealed that an increase in fuel prices had greater impacts for diminishing the pollutants concentration in the long run compared to the short run. These findings were consistent with Mousavi et al and Ninpanit findings (19, 25). In a time series study conducted by Mousavi et al, results showed that 1% increase in fuel price leads to 0.06% and 0.14% decrease in CO concentration in short and long run respectively (25). Researchers believe that introduction of optimum fuel technologies in the transport sector, improvement of public transportation system and expanding the usage of hybrid or low-power vehicles in the long run, leads to a significant reduction in fuel consumption. In addition, rising fuel prices leads to reduction in emissions of pollutants caused by transporting vehicles. In the long run, people are also more capable of changing their pattern of fuel consumption, which results in more people's capability to respond to fuel price policies (26, 27).

In this study comparison of estimated coefficients for fuel prices with the coefficients for other variables extracted from the models, revealed that the fuel policies had low impact on air pollutants concentration. In other words, weather status and other variables such as MPI and VAT had greater impacts on pollutants concentrations. An increase in economic growth, production, and consequently MPI require an increase in fuel consumption. On the other hand, due to the low productivity and efficiency of industries, increasing production (MPI) lead to increases in emissions of various pollutants. Hence, policy makers should try to enhance the utilization efficiency of inputs, such as fuels, to maintain production and finally reduce the growth of emission pollutants (28, 29). Also, many studies have revealed the role of meteorological conditions on air pollution (30, 31). Results of a study conducted by Ma et al in the Yangtze River Delta (YRD) region in China showed that meteorological conditions mainly influence day-to-day variations in pollutant concentrations. $PM_{2.5}$ concentration was inversely related to wind speed, while concentrations of other pollutants was negatively correlated with relative humidity and positively correlated with temperature (32). In conditions such as increased relative humidity of the air accompanied by the phenomenon of rainfall, the washing operation can reduce air pollutants concentrations.

The findings of the present study also revealed that rising number of holidays and weekends had a significant effect on decreasing the concentrations of pollutants. This fact is evident in patternal changes of vehicular usage of individuals in weekends and holidays. Most people do not use a personal vehicle on weekends or holidays because of the shutdown of schools and offices. In two studies conducted by Bahreini et al and Harley et al, results showed that emissions from fuel consumption can be reduced by 60–80% on the weekends due to reductions in road traffic (33, 34).

5. Conclusion

The results of this study showed that the pollutants concentrations in Tehran have been decreasing in general, however, this trend has been increasing for some pollutants or in some districts in this city. According to the extracted results from study models, fuel pricing policies reduce the concentration of pollutants that are emitted from the transport sector in the long and short run. However, considering the impact of other factors, fuel price policies and increase in gasoline and diesel prices had low impact on Tehran's air pollution. In other words, weather and economic conditions, as well as improved technology, have a greater impact on the concentration of pollutants. Therefore, focus on policies such as improved technology and enhancing the quality of fuel can be more effective.

Also, given the different impact of gasoline and diesel prices, increase in the price of energy carriers requires paying attention to their relative prices. Therefore, unbalanced and dissimilar increase in prices can lead to fuels substitution. This will lead to an increase in alternative and cheaper fuel consumption and ultimately increase in related pollutants.

Abbreviations

CO

Carbon monoxide, NO₂, Nitrogen dioxide, PM₁₀:Particular matter 10 micrometers or less

Declarations

Ethics approval and consent to participate

No applicable.

Consent for publication

No applicable.

Availability of data and materials

The datasets generated and analyzed for this study are not publicly available due to participant privacy but are available from the corresponding author upon reasonable request.

Competing interest

The authors declare that they have no conflict of interest.

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Author contributions

THK had the idea for the article, MH and PR performed data analysis, and THK performed drafted and critically revised. SA performed data gathering. All authors reviewed and approved the final manuscript

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Figures

Figure 1

Map of the study area and the location of the stations

Figure 2

Monthly average concentration of PM10 in Tehran during 03. 21. 2009 to 12.21.2019

Figure 3

Monthly average concentration of NO2 in Tehran during 03. 21. 2009 - 12.21.2019

Figure 4

Monthly average concentration of CO in Tehran during 03. 21. 2009 - 12.21.2019

Figure 5

Monthly fuel prices in Iran (real IRR/liter) during 03. 21. 2009 - 12.21.2019

Figure 6

Results of CUSUM tests for models