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Air Pollution: Sanctions' Effect and Rival Hypotheses

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Abstract

Tehran has been grappling with irritating air pollution for a couple of years, and the challenge seems to be getting worse. However, what is the main reason for this? To answer the question, many studies have concentrated on the primary chemical ingredients, like CO, and others have focused on where such pollutants are produced, like factories. Nevertheless, we have selected a higher level of analysis by reviewing socio-economic hypotheses (including sanctions, population, mismanagement, and global climate change) from 1999 to 2023 while using descriptive and inferential statistics. We know that petrol is one of the main exported products of Iran. Thus, to evaluate sanctions as the central hypothesis, we surveyed the rate of crude oil exports, and as an assumption, there is a negative relationship between sanctions and such exportation. At this stage, we studied the relationship between sanctions and AQI (one of the best scales for calculating air pollution), and on the other hand, sanctions and the main toxic gases. For rival hypotheses, we analyzed the relationship between AQI and them (population, mismanagement, and global climate change). All in all, among them, the results demonstrate only the correlation of sanctions with CO (-.٩١۶), □□٢ (.٧١٨), □□□ □□٢ (-.۶٨٧). □□□□□□□□□□, □□ □□ □□□□□□□ □□□□ □□ □□□□□ □□□□ □□□□□□□ □□□ □□□□□□□□ standards, the government could manage the amount of CO and SO2, whereas, due to the need of mazut to maintain the economy of energy, NO2 has increased.

Keywords: International Sanctions, AQI, Clean Air, the USA, Iran, PM10, O3, FGD.

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Introduction

Tehran, the capital city of Iran, is afflicted by a multitude of environmental challenges, like waste disposal (Zand& Heir, 2020), water contamination (Nahid & Moslehi, 2008), and water scarcity (Jahani & Reyhani, 2007). However, air pollution is seen as one of the most dangerous obstacles responsible for the deaths of 5000 citizens (Iranian Diplomacy, December 5, 2016). Moreover, economically, air pollution costs the country at least $2.6 billion annually (Heger & Sarraf, 2018, p. 7). Thus, questions about attitudes toward air pollution (Mohammadkhah et al., 2017), mechanisms to control it (Delavar et al., 2019; Motlagh et al., 2021), and its adverse ramifications (Yousefi et al., 2018; Hosseinpoor et al., 2005; Dehghan et al., 2018) have been studied by many scholars.

Nevertheless, we are going to focus on the causes of this stumbling block because, without analyzing the reasons, finding solutions that are both effective and durable seems problematic. However, many scholars, as you can see in the next sections, focus on the main sources of pollutants like factories, automobiles, and agricultural activities. Although these are important, we are going to conduct our research to find other sources. In other words, the article concentrates on sanctions, climate change, mismanagement, and population. These sources are different from common knowledge in two ways:

1) They are more fundamental and could result in institutionalizing common sources of air pollution, like vehicles.
2) In terms of the humanities, they are closer to social, political, and economic aspects, while the common sources are more related to engineering and chemistry. Thus, our study is interdisciplinary research between social science and environmental science.

In addition, some experts are of the opinion that there is a link between this problem and sanctions. For instance, they put an emphasis on the role of sanctions on Iran’s industry (Feghe Majidi& Zarouni, 2020). In this term, sanctions have deprived the country of using cutting-edge devices that are eco-friendlier compared with the old ones, and wittingly or unwittingly, they have had a negative impact on the environment (Madani, 2020). Furthermore, sanctions force politicians to make wrong decisions, for example, by waiving diesel particulate filters on diesel trucks, which could deteriorate the environment (Madani, 2021, p. 237). Therefore, we will select the correlation between sanctions and Tehran’s air pollution as the main hypothesis of the article. To assess the main and rival hypotheses, we first describe the main hypotheses. In this section, we can get familiar with the literature review related to every hypothesis as well. Then methodology will explain, and hypotheses are evaluated by applying descriptive and inferential statistics.

Hypotheses About Tehran’s Air Pollution

The relationship between sanctions and air pollution is not as direct as many residents assume. The debates were split into various categories, which could be seen as rival hypotheses. Nevertheless, none of them has been tested until now in a comprehensive study.

On the one hand many scholars and politicians share the viewpoint that sanctions are the main cause of air pollution. Sanctions by reducing access to modern technology, especially new eco-friendly devices, and using fewer fossil fuels directly contribute to boosting air contamination (Ghouchani et al., 2021). In addition, Iran is subject to a lack of financial transactions, which is mainly rooted in the fear of secondary sanctions. It deteriorates the normal trade to access such technologies. The government has been compelled to use out-of-date instruments and materials to sustain its economy, especially in the oil industry. Substituting mazut as the main fuel source for factories, in particular, the power plant, is said to be the main reason for pollutants (Hosseini, Stefaniec, 2019).

On the other side, the rising population is seen as a major challenge for air quality. It could result in overusing natural resources as well as producing more toxic gases (Chen et al., 2020; Neumayer & Cole, 2004; Norton 2000; Molina & Molina, 2004). These categories demonstrate the “unidirectional causality” between population growth and toxic emissions (Khan et al., 2021). Research in this category can find out the contribution of the population to air pollution. For example, population growth has led to an increasing food system. Subsequently, its “production, processing, packaging, transport, retail, consumption, and disposal” are responsible for making 10% to 90% of air pollutants (Crippa et al., 2022).

Many people, struggling with money to make ends meet or more wealth, have an eye on natural resources at the cost of the environment, and we summarize all of them in a group called mismanagement (Hasan & Mulamoottil, 1994; Chandrappa & Kulshrestha, 2015; Zhang et al., 2022). Statistics show that the more a government focuses on the environment, the fewer toxic gases it releases (Bao & Liu, 2022). In this category, controlling methane emissions, natural resources, and urbanization by the public sector are pivotal to having clear air (Hanif et al., 2022).

Global climate change is another hypothesis, bringing up more concerns in terms of nature. Global and regional warming affect the air quality in all cities, and changing climate patterns lead to unpredictable weather. Global warming could increase pollutants like NO_x (Wu et al., 2022). In this sphere, Tehran's air pollution is said to be caused by external factors rather than interior ones. Some experts opine those environmental problems in Suadi Arabia, Syria, and Iraq are prominent factors in Iran's air quality (Hosseini & Shahbazi, 2016; Khoshnevisan et al., 2016; Al-Dabbas et al., 2012). These views all fall under the category of climate change.

Nevertheless, none of the research in all branches can illustrate the main cause of air pollution since the results are ambiguous. In addition, they have selected different methods, levels of analysis, and various scopes of study. While they can calculate the portion of one factor affecting air pollution, they are not engaged in testing rival hypotheses.

Methodology

Despite the claims, finding the best way to control intervening variables is intricate. In addition, valid data related to factors polluting Tehran is hardly available. The only data is the air quality index, and it has covered just a few years. Moreover, lack of experts, having professionals in all related dimensions, and the intrinsic forgetfulness of related data for many years led us to reject surveys as a preferential way for data gathering. To harness these limitations, we conduct our work using a combination of qualitative and quantitative analysis in various phases, as explained below.

1- Gathering data related to air pollution from the Air Quality Control Company (AQCC)[1]. The data is written based on the solar year. But the data for other variables is settled on the Georgian calendar. Thus, we converted the solar into the Georgian year. Each year compromises the duration between January 1st and December 31st .We need to collect two different categories:

I. The number of days in terms of the descriptive condition of the

1 Tehran municipality, Air Quality Control Company (AQCC)

Air Quality Index (AQI):[1] This class is defined into six groups by the company, which could be named special days: Good Days, Moderate Days, Unhealthy Days for Sensitive Groups, Unhealthy Days, Very Unhealthy Days, and Hazardous Days

II. The number of days in terms of sub-variables related to AQI: This class is defined into six major pollutants by the company: CO, O_3, NO_2, SO_2, PM_{10}, and $PM_{2.5}$.[2] Notwithstanding the availability of data for all days, the company does not provide the annual average of each pollutant. Therefore, we use a simple average equation.

2- Selecting the time duration for other variables: Since the data for the air quality of Tehran is our dependent variable, the time scope for other independent variables is limited to the independent variable. Thus, due to the available data related to the dependent variable, our time scope will be 1999-2021.

3- Gathering data related to Tehran’s population to study the impact of the variable on Tehran’s air pollution

4- Gathering data related to global climate change to study the impact of the variable on Tehran’s air pollution

5- Gathering data related to Sanction’s pressure: due to different kinds of sanctions (direct/indirect, primary/secondary, conventional/smart), their scope (individuals, parties, national), the level of cooperation to implement them (international, multilateral, unilateral), their subjected sections

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١The AQI (Air Quality Index) is the average of six major air pollutants. Think of the AQI as a yardstick that runs from 0 to 500. The higher the AQI value, the greater the level of air pollution and the greater the health concern.

AQI Values	Levels of Health Concern	Colors
۰-۵۰	Good Days (GD)	Green
۵۱-۱۰۰	Moderate Days (MD)	Yellow
۱۰۱-۱۵۰	Unhealthy for Sensitive Groups (UDS)	Orange
۱۵۱-۲۰۰	Unhealthy Days (UD)	Red
۲۰۱-۳۰۰	Very Unhealthy Days (VUD)	Purple
۳۰۱-۵۰۰	Hazardous Days (HD)	Maroon

Source: Air Now, Air Quality Index (AQI) Basics

۲ Carbon Oxide, Ozone, Nitrogen Dioxide, Sulfur Dioxide, Particular Matter having different sizes.

(economic/political/military, governmental/nongovernmental), and the difference between the sanction's law and its real commitment, we cannot count on the list and the number of sanctions annually. On the other hand, it would be hard to correlate the situation of the whole economy with sanctions because sometimes sanctions can influence some segments in a positive way. However, it is common knowledge that Iran is one of the main exporters of crude oil, and if sanctions want to put pressure on the country's economy, this area is the first target. In addition, it would be possible that some oil-related and other sections of the industry, like farming, could take advantage of sanctions on crude oil to increase their exports. Thus, the volume of other exports might not allow us to draw a link between the intensity of sanctions and their data. Moreover, for sure, Iran has been trying to find informal ways to sell crude oil (Katzman, 2014; Samadi et al., 2021). However, the data is inaccessible. Overall, the formal data about the amount of COE[1] might be the best criteria to weigh up the stringency of sanctions.

1- Gathering data related to management to study the impact of the variable on Tehran's air pollution: Despite the existence of direct indexes, for example, Natural Resource Management (NRM) and the Climate Change Performance Index, and some indirect indexes like Government Effectiveness Index, and Resource Governance Index, due to their novelty, none of them can cover the dependent time of our research. On the other hand, if we were going to gather the related data by applying a standard questionnaire and its indicators, it would be genuinely difficult for the people to answer all relevant questions precisely since many years have passed, and despite the possibility of general evaluation, it would be impossible to evaluate all indicators for all years. However, we select Government Effectiveness as a measure to calculate the general performance of government management on natural resources. This data covers the related years. Meanwhile, due to the role and power of government, Iran seems to be a state-centered country (Fakhraei, 2018). Thus, we can draw a link between the government's capability to manage public services and the overall management of the country. On the other hand, the assumption is that a higher score indicates better management in terms of the environment.

2- Categorizing variables based on hypotheses

1. Crude Oil Export

3- Analyzing by comparing descriptive statistics: we do it by drawing tables and comparing the data with the COE and AQI in two groups:

I. Data relevant to air pollution: this category is separated into two sub-categories. In the first category, toxic gases and AQI will be compare with the COE, and in the second category, we will compare special days and the COE.

II. Data related to rival hypotheses: in this phase, we will compare TP,[۱] GCC,[۲] and GEF[۳] with the AQI as the best indicator showing the air situation.

4- Analyzing by using inferential statistics: To fulfill this task, we will carry out the below steps:

I. *Normality test:* in this section, each category is computed to see whether the relation between dependent and independent variables is parametric or non-parametric. We study Skewness and Kurtosis as well as Kolmogorov-Smirnov (K-S) and Shapiro-Wilk (S-W) tests to survey normality. The formulas are:

$$\text{skewness} = \frac{\sum (X_i - \mu)^{۳}}{N\sigma^{۳}} \qquad \text{Kurtosis} = \frac{\sum (X_i - \mu)^{۴}}{N\sigma^{۴}} - ۳$$

where X_i = random variable, μ= mean of the distribution, *N*= number of population, σ = standard deviation (Cohen, 2008: 85-86).

$$K - S = \frac{Sup\ |\bar{F}_n(x) - F_x|}{x\epsilon(-\infty.\infty)}$$

where:
$\bar{F}_n(x)$ = the Cumulative Distribution Function of the hypothesized distribution,
F_x = the *empirical distribution function* of your observed data,
(Efromovich, 2008: 99).

$$S - W = \frac{\left(\sum_{i=۱}^{n} a_i x_{(i)}\right)^{۲}}{\sum_{i=۱}^{n} (x_i - \bar{x})^{۲}}$$

where:
$x_{(i)}$ = the ordered random sample values,
a_i = constants generated from the covariances, variances and means of the sample (size n) from a normally distributed sample,
$\bar{x}$ = mean of random sample,

۱Tehran's Population

۲Global Climate Change

۳Government Effectiveness

(Razali et al., 2011: 25).

II. *The correlation tests:* we use Spearman for nonparametric and Pearson correlation for parametric categories. The formulas are:

$$\text{Spearman} = ۱ - \frac{۶\sum d_i^۲}{n-(n^۲-۱)}$$

where d_i= difference between the two ranks of each observation, n = number of observations (Calmorin, 1997: 129).

$$Pearson = \frac{\sum_{i=۱}^{n}(T_{act(i)} - \bar{x}\_T_{act(i)})(MM_{y(i)} - \bar{x}\_MM_{y(i)})}{\sqrt{\sum_{i=۱}^{n}(T_{act(i)} - \bar{x}\_T_{act(i)})^۲ \sum_{i=۱}^{n}(MM_{(y)(i)} - \bar{x}\_MM_{y(i)})^۲}}$$

where i = data sample, $MM_{(y)(i)}$= estimated joint torque using mathematical model, y=1,2,3,…, $T_{act(i)}$= actual joint torque, $\bar{x}\_T_{act(i)}$= mean of actual joint torque, $\bar{x}\_MM_{y(i)}$= mean of estimated joint torque (Rodrigues et al., 2016: 456-457).

III. *Study the possibility of regression*: Firstly, we have to study the existence of four conditions: (1) linearity, (2) nearly normal residuals, (3) constant variability, and (4) uncorrelated error (Bishnu & Bhattacherjef, 2018, p. 184). Secondly, if they are present, we can use the formula of linear regression:

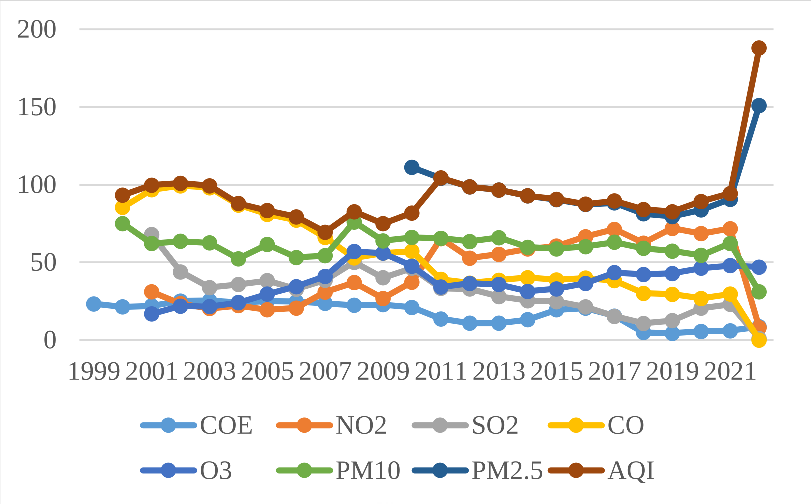
$Y = B_0 + b_1x_1 + b_2x_2 + \ldots + b_nx_n$

where Y= the dependent variable, x_i= the independent variable, b_i= the slope of the line, B_0= the intercept (the value of y when x = 0) (Anderson et al., 2020, p. 687).

Subsequent to data collection, we present a comparative analysis in tabular form. It should be noted that the scoring methods for the corresponding scales differ. However, in order to facilitate comparison within the table, the numerical values are standardized. As an example, if the scores of one variable range from 1 to 100, while another variable ranges from 0 to 1, we transformed all the data to a common scoring range of 1 to 100.

Toxic Gases, AQI and COE

In the case of CO, 2002 experienced the highest and 2020 the lowest. In addition, there is a diminishing trend since 2003. However, NO and SO are the two gases that could indicate the impact of sanctions.



Source: Tehran unicipality, Air Quality Control Company (AQCC); Fred Economic Data

Table (1): The Trends of Toxic Gases, AQI and COE

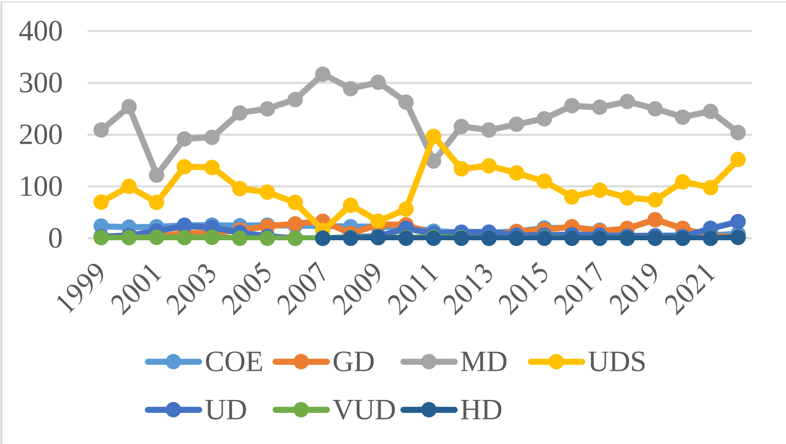
As we see, in terms of SO_2 and NO_2, two years (1999-۲۰۰۰) □□□ missed. Moreover, over the years the COE, SO_2, and CO decreased, while, NO_2, O_3, PM2.5, and AQI increased. The highest and lowest amounts of SO_2 were, respectively, in 2001 and 2022. Furthermore, the highest and lowest amounts of NO_2 were, respectively, in 2021 and 2022. In addition, the highest and lowest amounts of COE were respectively in 2003 and 2019. Thus, despite some similarities in trends, there is no overlapping between COE with NO2 and SO_2. For other variables, we have:

1- **$PM_{2.5}$**: 2022 is the highest, and 2019 is the lowest.
2- **AQI**: 2022 is the highest, and 2007 is the lowest.
3- **PM_{10}**: 2008 is the highest, and 2022 is the lowest.
4- **O_3**: 2008 is the highest, and 2001 is the lowest.

Overall, the only point of overlapping between COE and other variables is in 2019, when both COE and $PM_{2.5}$ are at their lowest levels.

Special Days and COE

The trends of COE and special days could give us a hand in analyzing their relationships.



Source: Tehran Municipality, *Air Quality Control Company* (AQCC); Fred Economic Data

Table (2): The Trends of Special Days and COE

In terms of special days on which their names are linked to a particular air situation, we have:

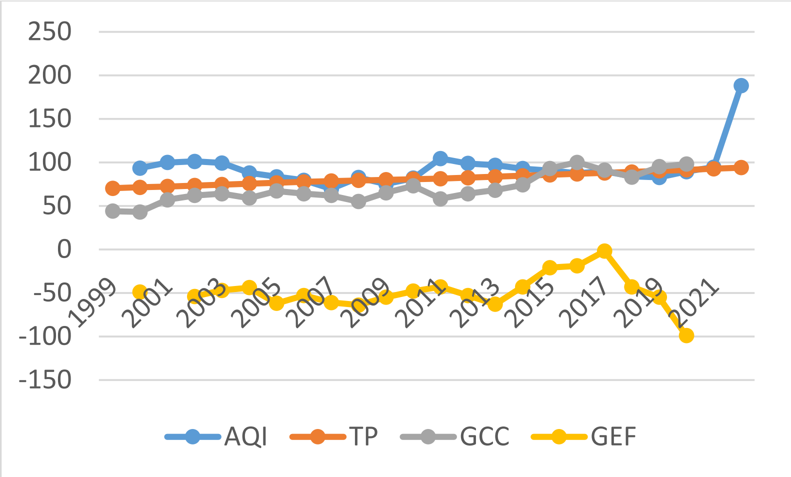
1- **MD**: 2007 is the highest, and 2001 is the lowest.
2- **UDS**: 2011 is the highest, and 2007 is the lowest.
3- **UD**: 2022 is the highest, whereas 2006 and 2007 are the lowest.
4- **GD**: 2019 is the highest, whereas 2012 and 2022 are the lowest.
5- **VUD**: the years 2001, 2003, 2011, and 2022 are the highest, whereas the years 2004 to 2007, 2013 to 2014, and 2016 to2021 are the lowest.
6- **HD**: the year 2022 stands out as having the highest value, specifically with 2 occurrences per year, while all other years exhibit a value of 0.
7- **COE**: 2003 is the highest, and 2019 is the lowest

Overall, in 2003, COE and VUD are at the highest levels. In addition, in 2019, COE and VUD are the lowest while GD is the highest.

TP, GCC, and GEF

The data about other hypotheses and their relations with the TAP (Tehran Air Pollution) is also critical. We compare them with AQI because AQI is the most important variable among the sub-variables of TAS[1]

[1] Tehran Air Situation



Source: World Population Review; Jaganmohan (2021); theglobaleconomy.com; Tehran Municipality, Air Quality Control Company (AQCC)

Table (3): The Trends of TP, GCC, GEF and AQI

In the above graph, we have:

1- TP: 2022 is the highest, and 1999 is the lowest.
2- GCC: 2016 is the highest, and 2000 is the lowest.
3- GEF: 2017 is the highest, and 2020 is the lowest.
4- AQI: 2022 is the highest, and 2007 is the lowest.

Overall, in 2022, AQI and TP are in their highest points.

Inferential Statistics

As we noticed, descriptive statistics is neither enough nor scientific to calculate different hypotheses. Therefore, in this phase, we study the normality and then the correlation below.

Table (4): Normality Test by Studying Skewness and Kurtosis

Hypotheses	Variable	Sub-variable	Skewness		Kurtosis	
			Statistic	Std. Error	Statistic	Std. Error
		COE-TAS				
Main Hypothesis	TAS	crude oil export (COE)	-.۵۸۹	.۴۷۲	-۱.۲۴۳	.۹۱۸
		AQI	۳.۶۲۳	.۴۸۱	۱۵.۶۶۲	.۹۳۵
		CO	.۲۶۳	.۴۸۱	-.۷۸۹	.۹۵۳
		O_3	-.۱۱۶	.۴۹۱	-.۴۷۷	.۹۳۵
		NO_2	-.۱۰۷	.۴۹۱	-۱.۶۰۲	.۹۳۵
		SO_2	.۳۱۶	.۴۹۱	.۸۴۶	.۹۳۵
		PM_{10}	-۱.۴۸۵	.۴۸۱	۵.۶۲۹	.۹۳۵

Hypotheses	Variable	Sub-variable	Skewness Statistic	Skewness Std. Error	Kurtosis Statistic	Kurtosis Std. Error
		$PM_{2.5}$	۲.۳۱۷	.۶۱۶	۶.۳۶۵	۱.۱۹۱
		COE-QD				
		crude oil export (COE)	-.۵۸۹	.۴۷۲	-۱.۲۴۳	.۹۱۸
	QD[1]	Good Days (GD)	.۴۹۱	.۴۷۲	-.۸۰۷	.۹۱۸
	QD[1]	Moderate Days (MD)	-.۶۳۱	.۴۷۲	.۹۹۹	.۹۱۸
	QD[1]	Unhealthy Days for Sensitive Groups (UDS)	.۳۲۴	.۴۷۲	.۵۰۷	.۹۱۸
	QD[1]	Unhealthy Days (UD)	۱.۲۱۳	.۴۷۲	۱.۰۰۶	.۹۱۸
	QD[1]	Very Unhealthy Days (VUD)	.۶۶۹	.۴۷۲	-.۸۹۶	.۹۱۸
	QD[1]	Hazardous Days (HD)	۳.۸۷۳	.۵۶۴	۹.۰۹۳	۱.۰۹۱
		AQI-TP				
Rival Hypotheses		Air Quality Index (AQI)	۳.۶۲۳	.۴۸۱	۱۵.۶۶۲	.۹۳۵
Rival Hypotheses		Tehran's population (TP)	.۱۲۶	.۴۷۲	-۱.۰۳۰	.۹۱۸
		AQI-GCC				
Rival Hypotheses		Air Quality Index (AQI)	۳.۶۲۳	.۴۸۱	۱۵.۶۶۲	.۹۳۵
Rival Hypotheses		Global Climate Change	.۴۷۱	.۴۹۱	-.۶۳۱	.۹۳۵
		AQI-GEF				
Rival Hypotheses		Air Quality Index (AQI)	۳.۶۲۳	.۴۸۱	۱۵.۶۶۲	.۹۳۵
Rival Hypotheses		Government effectiveness (GEF)	-.۴۲۴	.۵۰۱	۱.۲۰۴	.۹۷۲

As you see, we have categorized the relationship between different variables and COE. If the results of the Skewness and Kurtosis tests for all variables in each category are between (-۲, ۲), then the relation is normal. Thus, at first glance, none of the hypotheses are normal since some data in those categories, which are within italics, are not between this range.

Nevertheless, if we study sub-variables, we can realize that in just two categories, some correlations are normal, as below:

1- **In COE-TAS group:** the data related to COE-CO, COE-O_3, COE-NO_2, and COE-SO_2 are normal (parametric), and COE-$PM_{2.5}$, and COE-PM_{10} are abnormal (non-parametric).

2- **In COE-QD group:** the data related to COE-GD, COE-MD, COE-UDS, COE-UD, and COE-VUD is normal while COE-HD is the exemption.

۱. QD (Quality of Days)

Nevertheless, the examination of Skewness and Kurtosis alone does not provide sufficient evidence to support the hypothesis of normality. It is advisable to further investigate the Kolmogorov-Smirnov and Shapiro-Wilk tests across all categories in order to obtain a more comprehensive understanding

Table (5): Normality Test by Studying Kolmogorov-Smirnov, & Shapiro-Wilk

Hypotheses	Variable	Sub-variable	Kolmogorov-Smirnov			Shapiro-Wilk		
			Statistic	df	Sig.	Statistic	df	Sig.
		COE-TAS						
Main Hypotheses	TAS	crude oil export (COE)	.۱۴۵	۱۳	.۲۰۰*	.۹۱۷	۱۳	.۲۲۷
		AQI	.۳۴۴	۱۳	.۰۰۰	.۵۳۲	۱۳	.۰۰۰
		CO	.۲۴۳	۱۳	.۰۳۵	.۸۲۶	۱۳	.۰۱۴
		O_3	.۲۰۰	۱۳	.۱۶۲	.۹۰۰	۱۳	.۱۳۳
		NO_2	.۲۳۶	۱۳	.۰۴۶	.۷۵۸	۱۳	.۰۰۲
		SO_2	.۱۱۸	۱۳	.۲۰۰*	.۹۸۴	۱۳	.۹۹۳
		PM_{10}	.۲۷۲	۱۳	.۰۰۹	.۶۷۶	۱۳	.۰۰۰
		$PM_{2.5}$	.۲۲۷	۱۳	.۰۶۶	.۹۵۶	۱۳	.۰۰۲
		COE-QD						
	QD	Crude Oil Export (COE)	.۱۶۳	۱۶	.۲۰۰*	.۹۰۷	۱۶	.۱۰۵
		Good Days (GD)	.۱۱۳	۱۶	.۲۰۰*	.۹۴۵	۱۶	.۴۲۰
		Moderate Days (MD)	.۱۲۳	۱۶	.۲۰۰*	.۹۷۳	۱۶	.۸۸۴
		Unhealthy Days for Sensitive Groups (UDS)	.۰۸۴	۱۶	.۲۰۰*	.۹۹۰	۱۶	.۹۹۹
		Unhealthy Days (UD)	.۲۲۷	۱۶	.۰۲۷	.۸۳۱	۱۶	.۰۰۷
		Very Unhealthy Days (VUD)	.۳۰۹	۱۶	.۰۰۰	.۷۳۸	۱۶	.۰۰۰
		Hazardous Days (HD)	.۵۱۰	۱۶	.۰۰۰	.۴۰۵	۱۶	.۰۰۰
		AQI-TP						
Rival Hypotheses		Air Quality Index (AQI)	.۲۸۳	۲۳	.۰۰۰	.۵۹۵	۲۳	.۰۰۰
		Tehran's Population (TP)	.۰۶۶	۲۳	.۲۰۰*	.۹۶۷	۲۳	.۶۲۱
		AQI-GCC						
		Air Quality Index (AQI)	.۰۹۴	۲۱	.۲۰۰*	.۹۷۷	۲۱	.۸۷۲
		Global Climate Change	.۱۹۸	۲۱	.۰۳۱	.۹۱۰	۲۱	.۰۵۵
		AQI-GEF						
		Air Quality Index (AQI)	.۰۹۴	۲۱	.۲۰۰*	.۹۷۷	۲۱	.۸۷۲
		Government Effectiveness (GEF)	.۱۹۸	۲۱	.۰۳۱	.۹۱۰	۲۱	.۰۵۵

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

As in the previous table, we have categorized the relationship between different variables and COE. In both Kolmogorov–

Smirnov and Shapiro-Wilk tests, if all variables' sig≥0.05, then the variables are normal. Regarding the results, the normal hypothesis for all categories (COE-TAS, COE-QD, AQI-TP, AQI-GCC, and AQI-GEF) is not proved since sig<0.05 for some data, which are in italics in those categories.

Nonetheless, by scrutinizing sub-variables, it is visible that in both Kolmogorov-Smirnov and Shapiro-Wilk tests, some correlations are normal, as below:

1- **In COE-TAS group:** the data related to COE-O_3 and COE-SO_2 are parametric, and COE-CO, COE-NO2, COE-$PM_{2.5}$, and COE-PM_{10} are non-parametric.
2- **In COE-QD group:** the data related to COE-GD, COE-MD, and COE-UDS are normal, while COE-UD, COE-VUD, and COE-HD are abnormal.

In addition, AQI-GCC and AQI-GEF have been proven to be normal based on the Shapiro-Wilk test.

Table (6): Normal Correlations Based on Three Different Tests

Skewness and Kurtosis	Kolmogorov-Smirnov	Shapiro-Wilk
COE-CO	-	-
COE-O_3	COE-O_3	COE-O_3
COE-NO_2	-	-
COE-SO_2	COE-SO_2	COE-SO_2
COE-GD	COE-GD	COE-GD
COE-MD	COE-MD	COE-MD
COE-UDS	COE-UDS	COE-UDS
COE-UD	-	-
COE-VUD	-	-
-	-	AQI-GCC
-	-	AQI-GEF

Table 6 demonstrates the differences between various tests. However, in small samples, the best normality test is the Shapiro-Wilk test (Ahad et al., 2011). Thus, for normal correlations proved in the Shapiro-Wilk test, we can use Pearson's test to find out the correlation, and for others, we can use Spearman's test.

Table (7): Correlation's Tests for Hypotheses

Correlation with	Variable	Type of correlation test	Sub-variable	Correlation Coefficient	Sig. (2-tailed)	N
COE	TAS	Spearman	AQI	-.۱۷۸	.۴۱۷	۲۳
		Spearman	CO	.۹۱۶**	.۰۰۰	۲۳
		Pearson	O_3	-.۳۸۵	.۰۷۷	۲۲
		Spearman	NO_2	-.۷۱۸**	.۰۰۰	۲۲

		Pearson	SO_2	.۶۸۷**	.۰۰۰	۲۲
		Spearman	PM_{10}	.۱۳۸	.۵۹۲	۲۳
		Spearman	$PM_{2.5}$	.۴۱۸	.۱۵۶	۱۳
	QD	Pearson	Good Days (GD)	.۱۰۷	.۶۱۸	۲۴
	QD	Pearson	Moderate Days (MD)	.۰۹۶	.۶۵۷	۲۴
	QD	Pearson	Unhealthy Days for Sensitive Groups (UDS)	-.۳۲۳	.۱۲۴	۲۴
	QD	Spearman	Unhealthy Days (UD)	-.۰۹۵	.۶۵۹	۲۴
	QD	Spearman	Very Unhealthy Days (VUD)	.۲۱۷	.۳۰۸	۲۴
	QD	Spearman	Hazardous Days (HD)	.۰۹۷	.۷۲۰	۱۶
AQI		Pearson	Global Climate Change (GCC)	-.۱۶۴	.۴۷۷	۲۱
AQI		Spearman	Government Effectiveness (GEF)	.۱۶۹	.۴۶۵	۲۱
AQI		Spearman	Tehran's population (TP)	.۰۱۹	.۹۳۲	۲۳

In the above table, for the main hypothesis, we study the correlation between COE and variables, and for rival hypotheses, we analyze the correlation between AQI and other variables. In addition, for both Spearman’s and Pearson's tests, if $sig<0.05$, then the correlation is meaningful. Therefore, it demonstrates that some variables, which are in italics, are not meaningful. The meaningful ones are COE-CO, COE-NO_2, and COE-SO_2. Furthermore, the correlation coefficients for each of these variables are as follows:: .916, -.718, and .687.

It shows that the linear relationship between COE-CO, and COE-SO_2 is direct or positive. In other words, if COE increases, then CO and SO_2 will increase and vice versa, or if COE decreases, then CO and SO_2 will decrease and vice versa.

Moreover, the relationship between COE-NO_2 is indirect. In other words, if COE increases, then NO_2 will decrease and vice versa, or if COE decreases, then NO_2 will increase and vice versa. Furthermore, the correlations between COE and CO are very strong, and the correlations between COE,NO_2, and SO_2 are strong (Johnson et al., 2000).

Mazut

On January 2nd, 2019, a musty odor overwhelmed many parts of Tehran, and the phenomenon has repeated itself several times, especially when the temperature drops. Whereas there were various hypotheses, many people have pointed out mazut since it was criticized rigorously even a few years ago by conservationists. They opine that in recent years the usage of mazut has increased in the industrial section. Another sign to empower the hypothesis is the fact that, as a result of the COVID-19 outbreak, the number of cars on the streets has reduced by about 2 years. However, the air pollution had remained, and even the heaviest rainfalls could not mitigate it unless for a few hours (Financial Tribune, 2020).

The country decided to reduce the usage of mazut from 24 to 10 percent by enacting “The Clean Air Law” in July 2017 and improving the refineries with cooperation from other countries. However, the new sanctions imposed by the United States after its withdrawal from JCPOA[1] disrupted the hope. Furthermore, while the country used to export mazut or utilize it for ships, sanctions have disrupted the process by banning shipping and refinery exports. On the other hand, the internal demand for energy has gradually increased. The problems of renovating the industries, exporting the refineries, and increasing the energy demand, have forced the government to license the usage of mazut or at least lower its supervisory role to safeguard the environmental standards in the industry (Bakhtiar, 2021).

The findings of our research reveal the correlation between sanctions and the levels of CO, SO_2 and NO_2. Our findings reveal an interesting pattern, wherein sanctions exhibit a positive correlation with NO2, while demonstrating a negative correlation with CO and SO2. The underlying reasons for the positive correlation between sanctions and NO2, as well as the negative correlation between sanctions and CO and SO2, warrant further investigation. In this study, we assume responsibility for examining the potential sources of these pollutants to shed light on the observed correlations. Among different sources, on-road vehicles with 56% are the main sources of CO; interestingly, the role of industry is the lowest with 4% (Lee, 2011), and the energy sector is the main participant in SO_2 with 68.6%, while intriguingly, the share of on-road vehicles is subtle with 0.7% (European Environment Agency, 2012). For NO2, both on-road vehicles and the energy sector have the main share with 31% (Tzvetkova et al., 2016).

During the years, Iranian politicians answered the concerns about CO by increasing the standards of the fuel system of cars, produced mainly internally, and increasing the standard of fuel used in automobiles to EU4 in Tehran (Financial Tribune, 2021). These

1. Joint Comprehensive Plan of Action (2015)

could result in reducing CO even under sanctions. What about the other gases?

Previous research has provided evidence indicating that mazut is a significant contributor to the emission of NO_x and SO_x pollutants (Kouravand & Kermani, 2018). However, we observed a negative correlation between sanctions and SO_2 and a direct one with NO_2. The simultaneous increase in both gases due to the escalated usage of mazut raises an intriguing observation, prompting further consideration regarding the potential rejection of the hypothesis.

Drawing a definitive conclusion at this stage would be premature, as there exist various approaches to mitigate the adverse impacts of mazut. Nano-emulsion could lessen NO_x and SO_x respectively, by 30.8 and 42.2%. In addition, wet FGD[1] systems could cut the amount of SO_x by 80.3% while having no influence on NO_x. A mixture of two methods is the best way because it could reduce NO_x and SO_x, respectively, up to 79.8 and 78.3% (Kouravand & Kermani, 2018). Meanwhile, the combination is expensive and needs advanced technologies, which are far beyond the government's capacity in this situation. On the flip side, the governors have been going to mitigate the adverse ramifications while managing the economy of energy under sanction, and from the mentioned methods, they selected so-called wet FGD because SO_x is slightly more controversial than NO_x.

Conclusion

Finding the roots of air pollution in Tehran is neither simple nor clear. Data related to that is vague as well as limited. In addition, despite some views trying to make a link between sanctions and this problem, rival hypotheses make it difficult to accept these claims. For these, we planned a program to diminish the challenges and survey the main hypothesis, which emphasizes the direct correlation between international sanctions and the degradation of air quality in the capital city of Iran. In addition, due to technical obstacles, we pointed out that Iran's COE could indicate the sanctions' effect better than other variables.

In terms of descriptive statistics, our findings were not able to confirm a meaningful relationship between COE and toxic gases. Among them, only $PM_{2.5}$ in 2019 accompanied COE since both were at the lowest levels. The result is very similar to special days.

1. Flue Gas Desulfurization

Only in 2003 were COE and VUD simultaneously at their highest levels. In addition, in 2019, COE and VUD are the lowest, while GD is the highest.

However, based on descriptive statistics, the relation between AQI and rival hypotheses- TP, GCC, and GEF- seemed more controversial, as the only overlapping point is in 2022, when AQI and TP are at their highest levels.

According to the inferential statistics, among all variables and sub-variables, only carbon dioxide, nitrogen dioxide, and sulphur dioxide can be linked with sanctions or the level of Iran’s crude oil export.

In other words, there is a very strong yet indirect correlation between sanctions and carbon dioxide (-.۹۱۶)□ □ □□□□□g and direct correlation between sanctions and nitrogen dioxide (.718); and a strong and indirect correlation between sanctions and the level of sulphur dioxide in Tehran (-.۶۸۷). □□□□□□□tably, in terms of regression, none of the variables have the same conditions, and therefore, the regression model was not meaningful.

The results revealed that while sanctions go up, CO and SO_2 diminish, and vice versa. However, while sanctions exacerbate, NO_2 increases, and vice versa. We assumed that by using some methods and applying standards, the country could manage the amount of CO and SO_2, whereas, due to the need for mazut to maintain the economy of energy, NO_2 has increased. Nevertheless, the last sentence could be seen as just a hypothesis needing further research.

Conflicts of Interest Statement

Manuscript title: Sanction's Contribution to Air Pollution

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Author's name	**Author's signature**	**Date**
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