

## An Estimation on Mortality Cost Through Air Pollution in Isfahan City

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### Introduction

Air pollution is one of the critical challenges in metropolitans around the world. According to World Health Organization (WHO), three millions people die from air pollution annually. In some studies mortality costs by air pollution was estimated. Social cost of air pollution was estimated 28990 billions Rials in Tehran city. The mortality cost by air pollution was estimated about 4.31% of GDP in Singapore. Air pollution was increased the mortality rate by 868 in Manchester city annually in 1992-98, where the social cost was estimated about £572 million.

Recently air pollution has become a serious crisis in Isfahan city in Iran. In this study the mortality cost by air pollution as a social cost was estimated in this metropolitan in 2010-2011. Also mortality rate and long run effect of air pollution were estimated.

### Material and methods

Air pollution has short run and long run effect on the mortality. Air pollution accelerate patient' death and also can shorten life expectancy of other citizens. In most empirical studies only short run effect was investigated using dose response function. In this study, an ARMAX model was used to decompose short run and long run effect of air pollution on the mortality:

$$(1+\theta_1L+\theta_2L^2)(\log(\text{MORT}) - \text{SMOOTH90}[\log(\text{MORT})]) = \alpha + (\beta_1+\beta_2L+\beta_3L^2)\text{AQI} + (\beta_4+\beta_5L+\beta_6L^2)\text{TEMP} + (1+\gamma_1L+\gamma_2L^2)e \quad (1)$$

Where, MORT is daily mortality rate, AQI is air quality index, TEMP is the average of daily temperature and e is an error term. Also seasonality effect of the mortality variable was smoothed with locally weighted least squares smoothing approach with a bandwidth of 90 days. Long run effect of AQI on the mortality rate was calculated as:

$$\text{LRE} = (\beta_1 + \beta_2 + \beta_3) / (1 + \theta_1 + \theta_2) \quad (2)$$

Also, Long run elasticity of the mortality to air pollution was calculated as:

$$\text{LREL} = [(\beta_1 + \beta_2 + \beta_3) / (1 + \theta_1 + \theta_2)] \text{AQI} \quad (3)$$

Where, AQI is the average of daily air quality index in 2010-211. To estimate the social costs of air pollution for  $t=0$ , at first relative risk ratio was calculated:

$$\text{RRR} = \text{Exp}((\beta_1) \times \text{AQI}) \quad (4)$$

Total mortality was then divided by RRR. Difference of this figure with the total mortality yield the mortality in  $t=0$  due to air pollution. For  $t=1$ , the RRR was calculated as:

$$\text{RRR} = \text{Exp}((\beta_2 - \beta_1 \times \theta_1) \times \text{AQI}) \quad (5)$$

By multiplying mortality in  $t=0.1$  by blood money gives the approximate social cost of air pollution.

**Results and discussion**

Data on the daily mortality rate, daily mean temperature, and Air Quality Index (AQI) was taken from Isfahan University of Medical Sciences, Isfahan Metrological Organization and Isfahan Environmental Protection, respectively in 2010-2011. The data are described in Table 1.

**Table 1. Descriptive statistics**

Variables	Mean	Std. dev.	Minimum	Maximum
Mortality(daily rate)	16.45	4.48	1	33
AQI index	95.13	28.6	32	240
Temperature(C)	17.22	9.73	1.20	34.9

For mortality variable the Phillips – Perron tests are able to reject the null hypothesis of unit root. The Phillips – Perron tests statistics was -781.75 for the log(MORT) variable with a five percent critical value of -29.5. The econometric results are reported in Table 2. This model includes one lagged value of AQI and a twice lagged value of temperature. Air pollution had significant effect in the mortality rate (Table 3).

**Table 2. The regression model for the mortality**

Variables	Coefficients	t-statistic	P-value
Intercept	-0.0124	-1.74	0.081
AR(1)	0.6789	5.25	0.000
TEMP(-2)	-0.0005	-2.13	0.033
AQI	0.00059	2.82	0.005
AQI(-1)	-0.00035	-1.68	0.092
MA(1)	-0.6666	-5.07	0.000
Durbin-Watson stats	2.03		
Schwartz criterion	511.30		
F	7.02(0.000)		

Source: Research Findings

**The long run and short run effects of air pollution on the mortality**

The long run effect of air pollution on the mortality was calculated as (2):

$$LRE=(0.00059-0.00035)/(1-0.6789)=0.0013$$

The Wald test showed that the long run and short run effects are significant (Table 3 and 4).

**Table 3. The long run effect of air pollution on the mortality**

Long run effect	X <sup>2</sup> Wald statistic	P-value
0.0013	110446	0.000

Source: Research Findings

**Table 4. The short run effect of air pollution on the mortality**

Short run effect	t- statistic	P-value
0.00059	2.82	0.000

Source: Research Findings

Long run elasticity of the mortality to air pollution was 0.123% that means a 1% increase in air pollution causes 0.123% increase in the daily mortality as presented in Table 5.

**Table 5. The long run elasticity of the mortality with respect to air pollution**

Long run elasticity	X <sup>2</sup> Wald statistic	P-value
0.123	110446	0.000

Source: Research Findings

### The social cost of air pollution

To estimate the annual social costs of air pollution, relative risk ratio (RRR) was calculated as Equ. 4 for  $t=0$ :

$$RRR = \text{Exp}(0.00059 * 95.13) = 1.09146$$

The total mortality (12015) was divided to this figure yield 11008 implying 1007 more deaths. Next to calculate the RRR for  $t=1$ , the lag coefficient was calculated:

$$-0.00035 + (0.00059 * 0.67898) = 0.00005$$

The relative risk ratio was calculated:

$$\text{Exp}(0.00005 * 13.95) = 1.0047$$

Dividing the total mortality (12015) by this figure yields 11958 implying 17 more deaths. Therefore, air pollution has caused 1024 deaths in 2010-11 (annually 512). Multiplying by blood money, the annual mortality cost was estimated 345 billion Rials.

### Conclusions

Air pollution has increased significantly in Isfahan city in recent years. In this study the short-run and long-run impacts of air pollution on the mortality rate was estimated in Isfahan city. For this purpose an ARMAX model was used to approximate the entire distributed lag impacts of changes in the level of air pollution on the mortality rate. Results showed that, annually, air pollution has increased the mortality rate about 8.5%. Accounting for this phenomenon the social cost has 346 billions for the residents of Isfahan. Also a 1% increase in air pollution increase 0.123% daily the mortality rate.

**Keywords:** air pollution, ARMAX model, hospital cost.