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Valuation of External Effects of Air Pollution Due to Urban Transportation Network - Case study: Isfahan

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Abstract

Most populous cities in the world are currently facing the air pollution problem, and Iran is no exception. Since one of the most important sources of air pollution is mobile sources, this paper tries to estimate the health effects and economic costs of $PM_{2.5}$ concentration emitted by transportation in the urban network of Isfahan during 2018-2019. In this regard, for more detail, we estimate the concentration of pollution caused by vehicles by using the results of the Generalized Additive Model (GAM). We also calculate the spatial distribution of pollution in Isfahan using ArcGIS. Then, the health impacts of air pollution caused by motor vehicles are assessed using the AirQ$^+$. Damages and economic costs of these health impacts are finally estimated by value of a statistical life and mortality rate approach. The results indicate that the mean concentrations for 2018 is 31.03 µg/m3. Using the results of Generalized Additive Model based on the shares obtained for traffic in the five areas studied in Isfahan, the concentration of PM2.5 pollution caused by urban traffic is 4.94 µg/m3. In general, 607 (95%Coeffecient Interval: 404-789) premature deaths in adults in 2018 can be attributed to PM2.5 pollution in Isfahan, among which 150 premature deaths are because of PM2.5 pollution caused by motor vehicles .Using the value of a statistical life approach, the estimated total annual economic cost of traffic pollution in 2018 is USD 57.9 million and 304 billion IRR per year using compensation payment (mortality cost).

Keyword: Economic Valuation, AirQ$^+$ Model, Value of Statistical Life, Road Transport, Generalized additive model.

JEL Classification: I11, O18, Q51, C14.

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1. Introduction

Most populous cities in the world are currently facing the air pollution problem, and Isfahan is no exception. Air pollution in many megacities of Iran has reached a dangerous level so that the $PM_{2.5}$ concentration in metropolises is three times the national standard and most of this contamination originates from cars and industry (Arfaeinia, Kermani, Aghaei, Bahrami Asl, & Karimzadeh, 2014; Heger & Sarraf, 2018). Isfahan is the second most polluted city in Iran and its pollution is a leading cause of many diseases and deaths along with economic problems every year (EPO, 2020). Traffic parameter, as key factor that play a very important role in $PM_{2.5}$ pollutant emitted should be included as an important variable in air pollution modeling (Karimi, Soffianian, Mirghaffari, & Soltani, 2016; Zarabi, Mohammadi, & Abdollahi, 2010).

Since one of the most important sources of air pollution is mobile sources, this paper tries to estimate the health effects and economic costs of $PM_{2.5}$ concentration emitted by the urban transportation network of Isfahan during 2018-2019. So In this study, we focus on the health endpoints assessment caused by the emission of motor vehicles pollutants in Isfahan.

2. Background

Numerous studies have been conducted on the valuation of economic costs associated with transportation-related air pollution (Jakubiak-Lasocka, Lasocki, Siekmeier, & Chłopek, 2014; Requia, Higgins, Adams, Mohamed, & Koutrakis, 2018). Tischer examined the time-space patterns of traffic-related air pollution for various pollutants in Brazil, and estimated the economic damage of traffic-related air pollution (Tischer, Fountas, Polette, & Rye, 2019). In another study, the PM10 pollution due to road transport was calculated, and health effects and economic costs due to pollution in the transport sector were estimated by combining engineering approach and air quality models (Guo, Cheng, Chen, Zhou, & Wang, 2010). In Iran, studies assessed valuation of environmental effects (Ghorani-Azam, Riahi-Zanjani, & Balali-Mood, 2016), as well as the economic burden and health effects of air pollution (Abedi et al., 2020; Bayat et al., 2019; Brajer, Hall, & Rahmatian, 2012; Hadei et al., 2020; Karimzadegan, Rahmatian, Farhud, & Yunesian, 2008). However, all of them concentrated on air pollution from all sources. The present study is to our knowledge the first such attempt concerning Isfahan.

3. Methods

Research method is explained in three steps: a. Definition of the study area b. Estimation of health effects of air pollution caused by motor vehicles c. Quantification of the economic costs of those effects.

In this regard, for more detail, we estimate the concentration of pollution caused by motor vehicles by using the results of the Generalized Additive Model (GAM). This is a statistical model that are used to estimate the share of traffic from $PM_{2.5}$ concentrations and to calculate road transport -related air pollution in Isfahan. For this purpose, Generalized Additive Models are used as a flexible statistical model that shows linear and nonlinear relationships between predictors and response variable using non-parametric smoothing functions. In this model, traffic volume, meteorological variables (such as relative humidity, wind speed and direction, temperature, precipitation) and also the spatial variable related to latitude and longitude of pollution monitoring stations were been used. We also calculate the spatial distribution of pollution in Isfahan using ArcGIS software. Then, the health impacts of air pollution caused by motor vehicles are assessed using the $AirQ^{+}$ software. This can estimate long-term natural mortality due to all natural causes and other mortality due to Ischemic heart disease, chronic obstructive pulmonary disease, and Lung cancer. Damages and economic costs of these health impacts are finally estimated by value of a statistical life and mortality rate approach. Value of a statistical life (VSL) is a preferred method, calculated using the willingness to pay and means the willingness to pay of people in the community for the marginal reduction in mortality risk. In the compensation payment method (mortality rate), a fixed amount is set by the government on an annual basis to compensate for the costs of mortality.

4. Results

The results indicate that the mean concentrations for 2018 is 31.03 $\mu g/m^3$. Using the results of Generalized Additive Model based on the shares obtained for traffic in the five areas studied in Isfahan, the concentration of $PM_{2.5}$ pollution caused by urban traffic is 4.94 $\mu g/m^3$.

In general, 607 (95%Coeffecient Interval: 404-789) premature deaths in adults in 2018 can be attributed to PM2.5 pollution in Isfahan, among which 150 premature deaths are because of PM2.5 pollution caused by motor vehicles, i.e.

about 25%. Out of a total of 150 deaths, the number of deaths caused by each factor is 51 (95%Coeffecient Interval: 30-107) cases of Ischemic heart disease (IHD), 3 (95% CI: 2-5) cases of Lung cancer (Rocha et al.), 8 (95% CI: 4-12) cases of chronic obstructive pulmonary disease (COPD). Thus PM2.5 caused by traffic in 2018 accounts for 1.76% of all adult mortality.

Using the value of a statistical life approach, the estimated total annual economic cost of traffic pollution in 2018 is USD 57.9 million and 304 billion IRR per year using compensation payment (mortality cost).

5. Discussion and Conclusions

Among air pollutants, $PM_{2.5}$ pollution has been selected as an indicator because according to assessments, its impacts on health are much higher than other pollutants (McCubbin & Delucchi, 1999; World Bank, 2016). Also, the average $PM_{2.5}$ concentration in Isfahan has been much higher than the average allowed by the world health organization (more than 10 $\mu g/m^3$) over the past several years.

Health effect valuation is an important part of assessing the social costs of air pollution because by implementing cost-benefit analysis, a criterion can be achieved to prioritize pollution control measures and policies can be adapted in accordance with these priorities.

Although the life of individuals cannot be fully valued, the government needs to prioritize measures to prevent these losses, including: improving fuel quality, smoothing the way for the production of vehicles with clean fuel technology, updating emission standards for vehicles, retiring high-emitting and high-consumption vehicles, Implement regular technical inspection programs for in-use vehicles, etc.

References

Ainy, E.; Soori, H.; Ganjali, M.; Le, H. & Baghfalaki, T., (2014). "Estimating cost of road traffic injuries in Iran using willingness to pay (WTP) method". *PLoS One*, No. 9(12), e112721 .

Alberini, A. & Krupnick, A., (2000). "Cost-of-illness and willingness-to-pay estimates of the benefits of improved air quality: evidence from Taiwan". *Land Economics*, No. 1, Pp: 37-53.

Ansari, M. & Ehrampoush, M. H., (2019). "Meteorological correlates and AirQ+ health risk assessment of ambient fine particulate matter in Tehran, Iran". *Environmental research*, No. 170, Pp: 141-150 .

Arfaeinia, H.; Kermani, M.; Aghaei, M.; Bahrami Asl, F. & Karimzadeh, S. (2014). "Comparative investigation of health quality of air in Tehran, Isfahan and Shiraz metropolises in 2011-2012". *Journal of Health in the Field*, No. 1(4), Pp: 37-44 .

Bahrami Asl, F.; Leili, M.; Vaziri, Y.; Arian, S. S.; Cristaldi, A.; Conti, G. O. & Ferrante, M., (2018). "Health impacts quantification of ambient air pollutants using AirQ model approach in Hamadan", *Iran. Environmental research*, No. 161, Pp: 114-121 .

Bayat, R.; Ashrafi, K.; Motlagh, M. S.; Hassanvand, M. S.; Daroudi, R.; Fink, G. & Künzli, N., (2019). "Health impact and related cost of ambient air pollution in Tehran". *Environmental research*, No. 176, Pp: 108547 .

Brajer, V.; Hall, J. & Rahmatian, M., (2012). "Air pollution, its mortality risk, and economic impacts in tehran, iran". *Iranian journal of public health*, No. 41(5), Pp: 31

Burnett, R.T., et al. (2014). "An integrated risk function for estimating the global burden of disease attributable to ambient fine particulate matter exposure". *Environmental health perspectives*, No. 122(4), Pp: 397-403 .

Burnett, R.; Chen, H.; Szyszkowicz, M.; Fann, N.; Hubbell, B.; Pope, C. A.; . . . Weichenthal, S., (2018). "Global estimates of mortality associated with long-term exposure to outdoor fine particulate matter". *Proceedings of the National Academy of Sciences*, No. 115(38), Pp: 9592-95 .

Burnett, R. T.; Pope III, C. A.; Ezzati, M.; Olives, C.; Lim, S. S.; Mehta, S.; . . . Brauer, M., (2014). "An integrated risk function for estimating the global burden of disease attributable to ambient fine particulate matter exposure". *Environmental health perspectives*, No. 122(4), Pp: 397-403 .

Cravioto, J.; Yamasue, E.; Okumura, H. & Ishihara, K. N., (2013). "Road transport externalities in Mexico: Estimates and international comparisons". *Transport policy*, No. 30, Pp: 63-76 .

De Marco, A.; Amoatey, P.; Khaniabadi, Y. O.; Sicard, P. & Hopke, P. K.; (2018). "Mortality and morbidity for cardiopulmonary diseases attributed to PM2.5 exposure in the metropolis of Rome, Italy". *European Journal of Internal Medicine*, No. 57, Pp: 49-57 .

Dehghan, A.; Khanjani, N.; Bahrampour, A.; Goudarzi, G. & Yunesian, M., (2018). "The relation between air pollution and respiratory deaths in Tehran, Iran-using generalized additive models". *BMC pulmonary medicine*, No. 18(1), Pp: 49 .

Guo, X.; Cheng, S.; Chen, D.; Zhou, Y. & Wang, H., (2010). "Estimation of economic costs of particulate air pollution from road transport in China". *Atmospheric Environment*, No. 44(28), Pp: 3369-3377 .

Gustafsson, M.; Lindén, J.; Tang, L.; Forsberg, B.; Orru, H.; Åström, S. & Sjöberg, K. (2018). "Quantification of population exposure to NO2, PM2.5 and PM10 and estimated health impacts". *IVL Swedish Environmental Research Institute Ltd.*

Hajizadeh, Y.; Jafari, N.; Mohammadi, A.; Momtaz, S. M.; Fanaei, F. & Abdolahnejad, A., (2020). "Concentrations and mortality due to short-and long-term exposure to PM 2.5 in a megacity of Iran (2014–2019)". *Environmental Science and Pollution Research*, Pp: 1-11 .

Han, F.; Lu, X.; Xiao, C.; Chang, M. & Huang, K., (2019). "Estimation of Health Effects and Economic Losses from Ambient Air Pollution in Undeveloped Areas: Evidence from Guangxi, China". *International journal of environmental research and public health*, No. 16(15), Pp: 2707 .

Hanemann, W. M. (1994). "Valuing the environment through contingent valuation". *Journal of economic perspectives*, No. 8(4), Pp: 19-43 .

Heger, M. & Sarraf, M., (2018). "Air pollution in Tehran: health costs, sources, and policies". *Environment and Natural Resources Global Practice Discussion Paper,* No. 6, https://openknowledge.worldbank.org/handle/10986/29909 License: CC BY 3.0 IGO.

Héroux, M.-E., et al., (2015). "Quantifying the health impacts of ambient air pollutants: recommendations of a WHO/Europe project". *International journal of public health*, No. 60(5): Pp: 619-627.

Janjani, H.; Hassanvand, M. S.; Kashani, H. & Yunesian, M., (2020). "Characterizing Multiple Air Pollutant Indices Based on Their Effects on the Mortality in Tehran, Iran during 2012–2017". *Sustainable Cities and Society*, No. 59, Pp: 102222 .

Karimi, A.; Shirmardi, M.; Hadei, M.; Birgani, Y. T.; Neisi, A.; Takdastan, A. & Goudarzi, G., (2019). "Concentrations and health effects of short-and long-term exposure to PM2. 5, NO2, and O3 in ambient air of Ahvaz city, Iran (2014–2017)". *Ecotoxicology and Environmental Safety*, No. 180, Pp: 542-548 .

Karimi, H.; Soffianian, A.; Mirghaffari, N. & Soltani, S., (2016). "Determining air pollution potential using geographic information systems and multi-criteria evaluation: A case study in isfahan province in Iran". *Environmental Processes*, No. 3(1), Pp: 229-246 .

Karimzadegan, H.; Rahmatian, M.; Farhud, D. & Yunesian, M., (2008). "Economic Valuation of Air Pollution Health Impacts in the Tehran Area, Iran". *Iranian journal of public health*, No. 37(1), Pp: 20-30 .

Krewski, D.; Burnett, R. T.; Goldberg, M. S.; Hoover, K.; Siemiatycki, J.; Jerrett, M.; . . . White, W. (2000). "Reanalysis oft the Harvard Six Cities Study and the American Cancer Society Study of particulate air pollution and mortality". *Health Effects Institut, Cambridge, MA* .

Krewski, D.; Jerrett, M.; Burnett, R. T.; Ma, R.; Hughes, E.; Shi, Y.; . . . Calle, E. E., (2009). "Extended follow-up and spatial analysis of the American Cancer Society study linking particulate air pollution and mortality". *Health Effects Institute Boston, MA*.

Künzli, N.; Medina, S.; Kaiser, R.; Quenel, P.; Horak Jr, F. & Studnicka, M., (2001). "Assessment of deaths attributable to air pollution: should we use risk estimates based on time series or on cohort studies?" *American journal of epidemiology*, No. 153(11), Pp: 1050-1055 .

Liu, W.; Xu, Z. & Yang, T., (2018). "Health effects of air pollution in China". *International journal of environmental research and public health*, No. 15(7), Pp: 1471 .

McCubbin, D. R. & Delucchi, M. A., (1999). "The health costs of motor-vehicle-related air pollution". *Journal of Transport Economics and Policy*, No. 33(3), Pp: 253-286 .

Meisner, C.; Gjorgjev, D. & Tozija, F., (2015). "Estimating health impacts and economic costs of air pollution in the Republic of Macedonia". *South Eastern European Journal of Public Health (SEEJPH)*. No. 4.

Menz, T. & Welsch, H., (2010). "Population aging and environmental preferences in OECD countries: The case of air pollution". *Ecological Economics*, No. 69(12), Pp: 2582-2589 .

Miri, M.; Aval, H. E.; Ehrampoush, M. H.; Mohammadi, A.; Toolabi, A.; Nikonahad, A., . . . Abdollahnejad, A., (2017). "Human health impact assessment of exposure to particulate matter: an AirQ software modeling". *Environmental Science and Pollution Research*, No. 24(19), Pp: 16513-16519 .

Mohamadnejad, N.; Assari Arani, A.; Keshavarz Haddad, G. & Faraji Dizaji, S., (2020). "Statistical Value of Life and Health Capital in Iran". *2Quarterly Journal of Economic Research and Policies*, No. 27(92), Pp: 197-225 .

Narain, U. & Sall, C., (2016). "Methodology for valuing the health impacts of air pollution: discussion of challenges and proposed solutions". *World Bank Report*.

Omidi, Y.; Goudarzi, G.; Heidari, A. M. & Daryanoosh, S. M., (2016). "Health impact assessment of short-term exposure to NO2 in Kermanshah, Iran using AirQ model". *Environ. health eng. manag.*, No. 3(2), Pp: 91-97.

Pařil, V. & Tóthová, D., (2020). "Assessment of the burden on population due to transport-related air pollution: The Czech core motorway network". *Journal of Cleaner Production*, No. 275, Pp: 123111 .

Pascal, M.; Corso, M. & Ung, A., (2011) "Guidelines for assessing the health impacts of air pollution in European cities". *Aphekom project*. Work package 5 .

Quah, E. & Boon, T. L., (2003). "The economic cost of particulate air pollution on health in Singapore". *Journal of Asian Economics*, No. 14(1), Pp: 73-90 .

Shahbazi, H. & Khoddam, N., (2020). "Tehran Air and Sound Quality Report in 2019". Report. Retrieved from https://hshahbazi.ir/fa

Soleimani, M. & Amini, N., (2017). "Source identification and apportionment of air pollutants in Iran". *Journal of Air Pollution and Health*, No. 2(1), Pp: 57-72.

Tischer, V. Fountas, G.; Polette, M. & Rye, T., (2019). "Environmental and economic assessment of traffic-related air pollution using aggregate spatial information: A case study of Balneário Camboriú, Brazil". *Journal of Transport & Health*, No. 14, Pp: 100592 .

World Bank (2016). "The cost of air pollution: strengthening the economic case for action. Washington". *World Bank Group* .

World Bank web site, (2020a). "GDP per capita (current US$) - OECD members".

World Bank web site, (2020b). "GDP per capita (current US$) - Iran, Islamic Rep".

World Health Organization (2018). "AirQ^{+}: Software tool for health risk assessment of air pollution".

Zarabi, A.; Mohammadi, J. & Abdollahi, A., (2010). "Investigation and evaluation of fixed and mobile sources in air pollution in Isfahan". *Iranian Journal of Geography*, No. 2(1), Pp: 1-18.