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Econometric Assessment Of The Relationship Between Air Pollution And Asthma

Hava Kirliliği ile Astım Arasındaki İlişkinin Ekonometrik Değerlendirilmesi

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ABSTRACT

Background: This study was carried out to determine the impact of Non-methane volatile organic compounds (NMVOC) on the disease of Asthma.

Methods: In the analysis, the relationship between NMVOC and disease of asthma was analyzed by using panel data method. In the analyzes; the Least Squares Method, unit root tests, cointegration tests and FMOLS-DOLS tests were used. 15 countries were determined for this study that have regular data between 1990-2018 about NMVOC. These countries were Canada, Czech Republic, Denmark, Finland, France, Greece, Iceland, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Sweden, and Turkey. As the disease; Disability-Adjusted Life Years (DALYs) of asthma was calculated per capita and included in the analysis.

Results: Significant relationships were found between NMVOC and disease of asthma in the study. A long-term relationship has been identified between the disease of asthma and NMVOC. The regression analysis revealed that the 1-unit increase in NMVOC created an increase of 0.0000375-0.0000413 units on the burden of disease of asthma.

Conclusions: The empirical evidence revealed that NMVOC has increased the disease of Asthma.

Key Words: Disability-Adjusted Life Year, Asthma, NMVOC, Econometric Analysis.

ÖZET

Amaç : Bu çalışma, metan olmayan uçucu organik bileşiklerin (NMVOC) Astım hastalığı üzerindeki etkisini belirlemek için yapılmıştır.

Yöntemler: Analizde, NMVOC ile astım hastalığı arasındaki ilişki panel veri yöntemi ile analiz edilmiştir. Analizlerde; En Küçük Kareler Yöntemi, birim kök testleri, eşbütünleşme testleri ve FMOLS-DOLS testleri kullanılmıştır. Bu çalışma için 1990-2018 yılları arasında NMVOC ile ilgili düzenli verisi olan 15 ülke belirlendi. Bu ülkeler Kanada, Çek Cumhuriyeti, Danimarka, Finlandiya, Fransa, Yunanistan, İzlanda, İrlanda, İtalya, Hollanda, Norveç, Polonya, Portekiz, İsveç ve Türkiye idi. Astım verileri ise global hastalık yükü verilerinden alınmıştır. Astım hastalığına ait Engelliliğe Ayarlanmış Yaşam Yılları (DALY) kişibaşı hesaplanarak analizlere dahil edilmiştir.

Bulgular: Çalışmada NMVOC ile astım hastalığı arasında anlamlı ilişkiler bulundu. Astım hastalığı ile NMVOC arasında uzun süreli bir ilişki tespit edilmiştir. Regresyon analizi, NMVOC'daki 1 birimlik artışın astım hastalığı üzerinde 0.0000375-0.0000413 birimlik bir artış yarattığını ortaya koydu. Yani NMVOC'daki 1 birimlik artışın Astım hastalığına ait Engelliliğe Ayarlanmış yüzbin Yaşam Yılının 3,7 ile 4,1'inden sorumlu olduğu şeklinde de yorumlanabilir.

Sonuçlar: Ampirik kanıtlar, NMVOC'nin Astım hastalıklarını arttırdığını ortaya koydu

Anahtar Kelimeler: Engelliliğe Ayarlanmış Yaşam Yılları, Astım, NMVOC, Ekonometrik Analiz

1. INTRODUCTION

Air pollutants can be formed as a result of the combustion process in general, as well as from many different sources. The sources including motor vehicles and industry are the biggest sources of air pollutants. Main air pollutants; Carbon Monoxide (CO), Ozone (O3), Sulfur Dioxide (SO2), Particulate Matter, Benzene (C6H6), Nitrogen Oxides (NOx), Volatile Organic Compounds (VOCs), and Non-Methane volatile organic compounds (NMVOCs) are the main air pollutants.

NMVOCs are a large variety of chemically different compounds, such as benzene, cyclohexane, 1,1,1-trichloroethane, acetone, formaldehyde or ethanol. There are several sources of anthropogenic NMVOCs emissions, including industrial processes, fossil fuel combustion, biomass combustion, traffic emissions, and solvent use (Li et al., 2015). Emissions from solvent use in China; growth faster than transportation and combustion emissions, and personal care products have been evaluated as an important and rapidly rising source of NMVOC, which is probably underestimated (Mo et al. 2021). Air pollutants have generally known or suspected harmful effects on human and environmental health.The types of health effects suffered by the most common pollutants at high levels are (meridianclinic, 2021; https://uk-air.defra.gov.uk/air-pollution);

- ✓ Nitrogen Dioxide, Sulphur Dioxide, Ozone irritate the airways of the lungs, increasing the symptoms of those suffering from lung diseases,

- ✓ Particles can be carried deep into the lungs where they can cause inflammation and a worsening of heart and lung diseases,
- ✓ Carbon Monoxide prevents the uptake of oxygen by the blood and this can lead to a significant reduction in the supply of oxygen to the heart, particularly in people suffering from heart disease,
- ✓ Some NMVOCs like benzene also have a direct impact on human health. For example, benzene and 1,3-butadiene are both identified carcinogens in the literature (Khalade et al. 2010; naei. 2021; Steinmaus et al. 2008). Or in a study suggests that increased exposure to benzene may impair respiratory health (asthma, lung function, and pulmonary infections) in children (Ferrero et al. 2014). Another study revealed that exposure to ambient air pollution at an early age might increased the risk of respiratory tract infections in infants (Aguilera et al. 2013).

Non-methane volatile organic compounds are generally known to cause damages to human health. From this perspectivein this study it is aimed to reveal that the NMVOC effects on the respiratory system. Asthma is evaluated as an indicator of respiratory systems health. Hypotheses -to find an answer to the question that given above- determined in the study were established as follows.

H_1: NMVOC has increased the disease of asthma.

2. MATERIALS AND METHODS

In the analysis, the relationship between NMVOC and disease of asthma was analyzed by panel data method. The analyzes were carried out in the fourth main stage. In the 1th stage, descriptive information about the variables was given and the significance test of the model was done with the Least Squares Method (LS). In the second stage, in order to determine the stationary degrees of the series, unit root tests were applied to the series; in the third stage, the lag length of the model was determined and the last section the relationship of cointegration and estimation of variables coefficients by Dynamic Least Square (DOLS) and Fully Modified Ordinary Least Square (FMOLS) Tests were done.

2.1. Variables

In this study, Disability-Adjusted Life Years (DALYs) of Asthma as the dependent variables; on the other hand, NMVOC was taken into account as the independent variable (Figure 1).

Figure 1: Descriptive of Variables

Variables	Measure	Source	Abbreviation
Non-methane volatile organic compounds	Kilograms per capita	https://stats.oecd.org/	NMVOC
Disability-Adjusted Life Years (DALYs) of Asthma	Per capita	https://gbdx.org/	ASTHMA

15 countries were determined for this study that have regular data between 1990-2018 about NMVOC. These countries were Canada, Czech Republic, Denmark, Finland, France, Greece, Iceland, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Sweden, Turkey. Disability-Adjusted Life Years (DALYs) of asthma were calculated per capita between 1990-2018 and included in the analysis.

2.2. Statistical Analysis

The statistical analysis was performed using Eviews 10 Statistics program (Eviews 10, IHS Global Inc., 4521 Campus Drive, #336, Irvine, CA 92612).

2.3.Ethical Issues/Statement

There were no ethical issues. All data in this paper was publicly available.

3. EMPIRICAL RESULTS

The mean of ASTHMA was 0.003273 ± 0.001135 (min: 0.001310; max: 0.006648); the mean of NMVOC 31.17571 ± 19.94741 (min: 9.151; max: 110.3040). A graphical view of the variables of the model was presented in Chart 1.

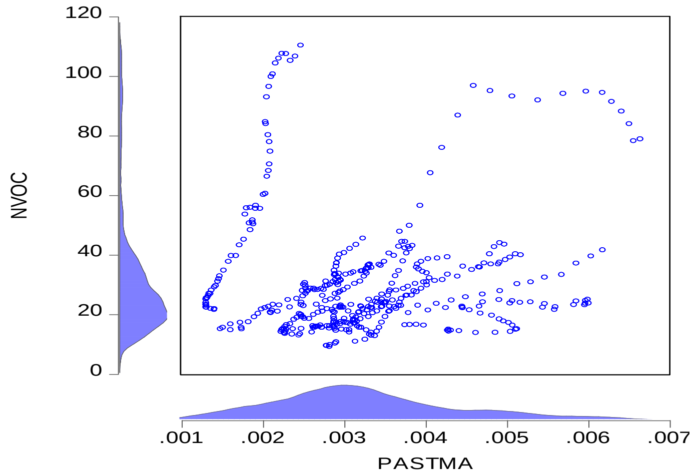

Chart 1: Graphical representation of NMVOC and Asthma data

The econometric model of the study

The equation for defining the econometric model was established as follows:

*ASTHMA= C(1)*NMVOC + C(2)*

*ASTHMA= 4.09E-05*NMVOC + 0.001997*

In table 1, in the established model, the value of R and R^2 is 79%, so it could be accepted that the explanation power of the model was good. At the same time, the relationship between the dependent variable and the independent variables was found to be significant (*p* <0.0000).

Table 1: Results of Panel Least Squares

Dependent Variable	Independent Variable	Coefficient	Prob.	R^2	Adjusted R^2	F-Statistic	Prob(F-statistic)
ASTHMA	**NMVOC**	4.09E-05	0.0000	0.79	0.79	110.6676	0.0000*
	C	0.001997	0.0000				
Hausmann Test Results: 0.0007 ; *receive significance at level 1%. Fixed Effects Model used.							

In Chart 2, actual values for variables are shown in red, and the estimated values are displayed in green. Actual and fitted values are close to each other; indicates that the estimation values are in compliance with the actual values. The graph below shows this compatibility. Again, the values indicated by blue indicate residual values (Chart 2).

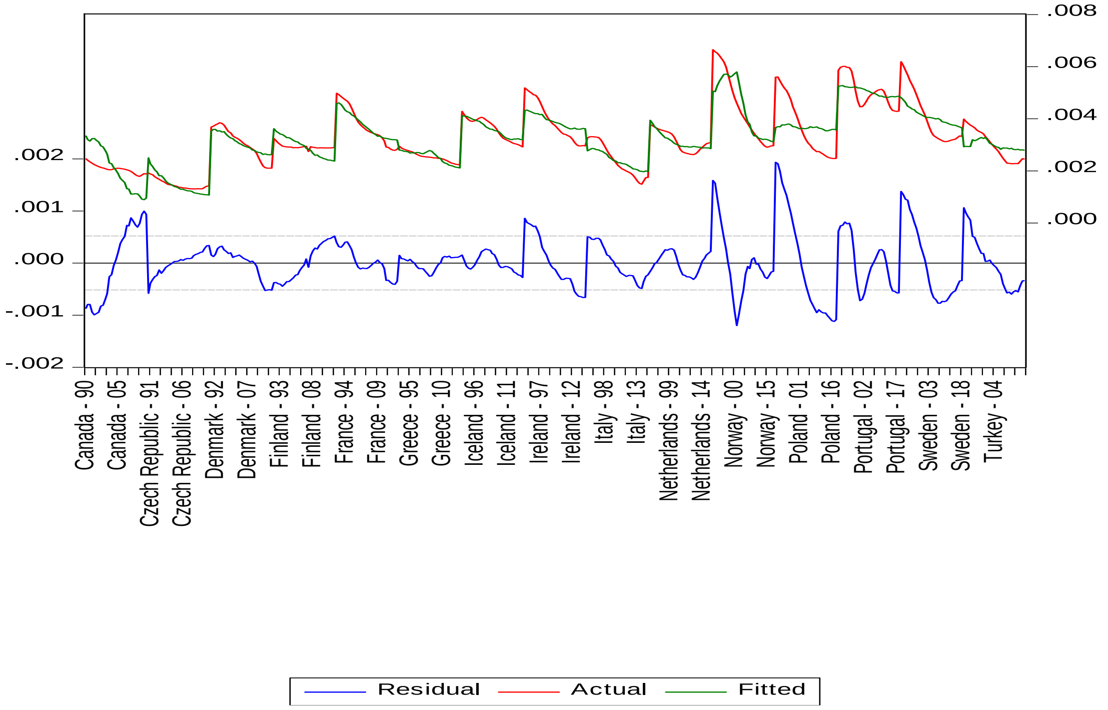

Chart 2: Actual-Fitted-Residual Values of Variables

In table 2 section A, five different panel unit root tests results were shown. These were Im et al., Levin et al., Breitung t-stat, ADF Fisher Chi-square and PP Fisher Chi-square tests. The null hypothesis of all these tests indicates the existence of a unit root, while the alternative hypotheses express its absence. According to table 2 section A, the stationarity of the series was determined at the level.

In cointegration analysis, the first assumption is to use all the series were stationary same level, then the second assumption that should be known is to determine the lag length. For this reason, the VAR model was developed for the lengths of the series and the equations were estimated.

In table 2 section B, the maximum length of the series SC test were found in the 2nd length and HQ, FPE and AIC tests were found in the 4th length.

Pedroni and Kao tests were applied to determine the long-term cointegration relationship between the variables. The series were taken into the analysis the same sequence integration I(0).

C section in Table 2 showed there were 2 cointegrating equations at the 0.05 level between the series. According the Pedroni test; within dimension test statistics; in no deterministic trend model, eight of the four tests were significance at 1-5%level; and deterministic intercept and trend model two of the eight tests were at 1-5% significance level. In the between dimension test statistics; no deterministic trend model, one of the three tests were found to be at 5% significance level and none of the three tests in the deterministic and trend model were found to be significant (Table 2 section D). In Kao test; automatic lag length selection based on AIC with a max lag of 2nd and results was found significance at 1% (Table 2 section E).

Table 2: Panel Tests Results

A. Unit Root Tests

			LLC	Breitung t-stat	Im et al.	ADF	PP
NMVOC	Level	İnvidual Effects	0.0000*	-	0.0253**	0.0002*	0.0000*
		İnvidual Effects-Trends	0.0747***	0.9990	0.9503	0.3965	0.0000*
		None	0.0000*	-	-	0.0000*	0.0000*
	1.diff.	İnvidual Effects	0.0016*	-	0.0000*	0.0000*	0.0000*
		İnvidual Effects-Trends	0.0300**	0.0005*	0.0001*	0.0003*	0.0000*
		None	0.0000*	-	-	0.0000*	0.0000*
ASTHMA	Level	İnvidual Effects	0.0000*	-	0.0005*	0.0001*	0.0004*
		İnvidual Effects-Trends	0.0012*	0.9581	0.0231**	0.0005*	0.6686
		None	0.0000*	-	-	0.0000*	0.0000*
	1.diff.	Invidual Effects	0.0018*	-	0.0000*	0.0000*	0.0006*
		Invidual Effects-Trends	0.0081**	0.0141**	0.0000*	0.0000*	0.0000*
		None	0.0000*	-	-	0.0000*	0.0000*

* , **, *** significance at 1%, 5%, 10% level respectively.

B. VAR Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	432.3265	NA	0.000223	-2.732232	-2.708406	-2.722713
1	2014.756	3134.718	9.91e-09	-12.75401	-12.68253	-12.72545
2	2205.494	375.4201	3.03e-09	-13.93964	-13.82051*	-13.89205
3	2212.218	13.14866	2.98e-09	-13.95694	-13.79016	-13.89030
4	2222.168	19.33285	2.87e-09*	-13.99472*	-13.78029	-13.90905*
5	2223.086	1.771204	2.92e-09	-13.97515	-13.71307	-13.87044
6	2229.033	11.40358	2.89e-09	-13.98751	-13.67778	-13.86376
7	2230.896	3.548110	2.93e-09	-13.97394	-13.61656	-13.83115

* indicates lag order selected by the criterion: [1] LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion. Roots of Characteristic Polynomial; 0.96-0.48

C. Cointegration Test Results				
Unrestricted Cointegration Rank Test (Trace)	Eigenvalue	**Trace Statistic**	**0.05 Critical Value**	**Prob**
No deterministic trend - Lags interval (in first differences): 1 to 4 (Trace test indicates 2 cointegrating eqn(s) at the 0.05)				
None*	0.175134	96.27161	20.26184	0.0000*
At most 1	0.072151	26.95910	9.164546	0.0000*
Linear deterministic trend - Lags interval (in first differences): 1 to 4 (Trace test indicates 2 cointegrating eqn(s) at the 0.05 level)				
None*	0.134516	78.40791	15.49471	0.0000*
At most 1*	0.070709	26.40001	3.841466	0.0000*
JB Normality test: 0.013**; VAR Residual Serial Correlation LM Tests: 0.9011; VAR Residual Heteroskedasticity Tests: 0.6945; VAR satisfies the stability condition between 0.225647 - 0.897363; *, ** significance level at 1%, 5%; respectively				

D. Pedroni Panel Cointegration Test					
No Deterministic Trend			**Deterministic Intercept and Trend**		
Within Dimension Test Statistics	**Statistic**	**Weighted Statistic**	**Within Dimension Test Statistics**	**Statistic**	**Weighted Statistic**
Panel v-statistics	-0.789195 (0.7850)	0.641401 (0.2606)	Panel v-statistics	3.380925 (0.0004)*	1.980805 (0.0238)**
Panel rho-statistics	-0.664331 (0.2532)	-0.435500 (0.3316)	Panel rho-statistics	3.427434 (0.9997)	1.669114 (0.9525)
Panel PP-statistics	-2.521741 (0.0058)**	-1.639570 (0.0505)**	Panel PP-statistics	4.354303 (1.0000)	1.111174 (0.8668)
Panel ADF-statistics	-4.407959 (0.0000)*	-2.992667 (0.0014)*	Panel ADF-statistics	2.230303 (0.9871)	1.069528 (0.8576)
Between Dimension Test Statistics					
Group rho-statistics	1.339173 (0.9097)		Group rho-statistics	3.089275 (0.9990)	
Group PP-statistics	-0.346246 (0.3646)		Group PP-statistics	2.695348 (0.9965)	
Group ADF-statistics	-3.111804 (0.0009)*		Group ADF-statistics	0.682231 (0.7525)	
E. Kao Residual Cointegration Test					
t-statistics	-3.264570 (0.0005)*				

Notes: Probability values are in parenthesis. Newey-West automatic bandwidth selection and Bartlett kernel. *, ** 1%, 5% significance level respectively. Since the series were studied at the level and in the pedroni analyzes was made in the 2nd length.The Kao analysis automatic lag length selection based on AIC with a max lag of 2nd.

Panel DOLS and Panel FMOLS tests have been carried out next to estimate various estimators available include "within- and between-group FMOLS and DOLS" estimators (Yorucu and Bahramian, 2015). Among several panel estimators, the FMOLS and DOLS are the most commonly chosen ones. In the next step, in Table 3, the dynamic least square (DOLS) and fully modified ordinary least square (FMOLS) techniques for cointegrated panels were estimated (Table:3).

According to the DOLS coefficient estimation results, NMVOC effective on disease of asthma positively and 1 unit increase in NMVOC at 1 % significance level increased disease of asthma by 0.0000375 unit. According to the FMOLS coefficient estimation results, NMVOC effective on disease of asthma positively and 1 unit increase in NMVOC at 1 % significance level increased disease of asthma by 0.0000413 unit.

Table 3: Panel DOLS and FMOLS Estimations Results

The dependent variable: ASTHMA

	FMOLS		**DOLS**	
	Coefficient	t-Statistic	Coefficient	t-Statistic
NMVOC	4.13E-05 (0.0000)*	10.00647	3.75E-05 (0.0000)*	10.13569
	R : 0.80 R^2 : 0.79 JB Normality test 0.000000		R : 0.85 R^2 : 0.83 JB Normality test 0.000011	

Notes: Probability values are in parenthesis. In the DOLS estimation method, Automatic leads and lags specification (based on AIC criterion. * significance level at 1%.

4. RESULTS

Concentration measurements of Non-methane volatile organic compounds (NVOCs) (Bartzis et al., 2015, Wieck et al., 2018) and effects in terms of secondary ozone (Li et al., 2020, Niu et al., 2017, Yan et al., 2017) were studied in the literature. Non-methane volatile organic compounds are known to cause damages to human health. Exposure to these compounds is primarily with household and personal care products, especially using in an aerosol form. Literature showed that hair sprays, body sprays, air fresheners, body washes, detergents, air fresheners, insecticides are products with high NMVOC concentrations (Bartzis et al. 2015; Kwon et al. 2007; Nourian at al. 2021). In a study provided data suggesting that using personal care products may have an adverse effect on lung function (Dales et al., 2013). In an other study reported that a late asthmatic response and an increase in sputum eosinophils following challenge with inhalation with eugenol in a 30-year-old hairdresser with occupational skin and respiratory symptoms (Quirce et al., 2008). Beside this in a meta-analysis demonstrated that a significant excess in the relative risk (RR) of multiple myeloma (MM) in relation to benzene exposure (PF Infante 2006). Therefore, NMVOCs are associated with disease from asthma to many types of cancer. In this study, the relationship between disease of asthma and NMVOC was tested by using the annual data of the countries for the period 1990-2018 and the following findings were reached;

- ✓ A long-term relationship has been identified between the disease of asthma and NMVOC. This finding that a long-term relationship is important because chronic diseases such as asthma have the characteristics of diseases that develop after a period of time as a result of continuous exposure to the organism's disease agent.
- ✓ The regression analysis revealed that the 1-unit increase in NMVOC created an increase of 0.0000375-0.0000413 units in the disease of asthma. This result can also be interpreted as follows: when there is a 1 unit increase in NMVOC, the per capita asthma disease burden increases by 4 units per hundred thousand.

This work is the first study that deals with the relationship of air pollutants such as NMVOC with health with an econometric model and is thought to contribute to the literature.

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