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The Mitigating Role of Renewable Energy Sources on the Welfare Cost of Air Pollution in APEC Countries

APEC Ülkelerinde Yenilenebilir Enerji Kaynaklarının Hava Kirliliğinin Refah Maliyetlerini Azaltıcı Rolü

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Abstract: The main purpose of this study is to determine the possible long run impacts of renewable energy supply on the welfare cost of premature deaths caused by air pollution in the Asia-Pacific Economic Cooperation (APEC) countries during 1990-2016 by using dynamic panel data techniques. The long run elasticity results showed that the increasing supply of renewable energy sources reduces the welfare cost of air pollution. Empirical findings revealed that clean energy should not just seen as a sustainable energy source but also considered as an efficient way to struggle with possible negative externalities of pollution.

Keywords: Air Pollution, The APEC Countries, Dynamic Panel Data, Renewable Energy, Welfare Cost.

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Öz: Bu çalışmanın ana amacı 1990-2016 yılları süresince Asya-Pasifik Ekonomik İşbirliği (APEC) ülkelerinde yenilenebilir enerji arzının hava kirliliği kaynaklı erken ölümlerin refah maliyetleri üzerindeki uzun dönemli etkilerini dinamik panel veri teknikleri kullanarak incelemektir. Uzun dönem esneklik sonuçları yenilenebilir enerji kaynakları arzındaki artışların hava kirliliğinin refah maliyetlerini azalttığını ortaya koymuştur. Uygulama sonuçları, yenilenebilir enerjinin sadece sürdürülebilir bir enerji kaynağı olarak görülmemesi, aynı zamanda kirliliğin muhtemel dışsallıkları ile baş etmenin etkin bir yolu olarak da değerlendirilmesi gerektiğini ortaya çıkarmıştır.

Anahtar Kelimeler: Hava Kirliliği, APEC Ülkeleri, Dinamik Panel Veri, Yenilenebilir Enerji, Refah Maliyeti.

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1. Introduction

As widely discussed in the literature, economic growth usually defines as an important indicator of welfare (Clarke and Islam, 2005). However, it is inevitable to confront with significant negative externalities of growth process that both threatens environmental quality and human health (Yaduma et al., 2013). Therefore, the rapid depletion of country' natural resources to support economic growth is one of the important source of environmental pollution related externalities (Goodland and Ledec, 1987). In this regard, especially air pollution creates serious externalities. The World Health Organization (WHO) declared air pollution as the most important environmental risk factor that threatens human health. The WHO (2020a) stated that seven million people die every day from the air pollution related diseases such as stroke, heart disease, lung cancer, chronic obstructive pulmonary diseases and respiratory infections. Such serious health consequences of environmental deterioration have been encouraged researchers to explain and investigate the possible costs of air pollution.

Ogden (1966) described air pollution as a social issue that needs to be explain in the framework of welfare economics. Within this approach, well-being concept should not evaluate only with the income per capita level but also should considered with environmental and social sustainability for society (Gowdy, 2005). According to the theoretical perspective of welfare economics, under some specific classical assumptions (for instance non-increasing returns or the absence of externalities etc.) and when the first order (marginal or necessary) and second order conditions ensured, a perfectly competitive market economy will be Pareto optimal (Ng, 2004). This means, in theory, pollution level is going to decrease to the point where marginal benefit and marginal cost are equal. But, in some cases, social marginal benefit gains from an economic transaction could be different from the private marginal benefit of this economic activity due to externalities. Because, the external costs caused from pollution generally ignored by the groups that mutual parts of this direct economic transaction. So, if the market system ignores the external costs then the market equilibrium could not be at Pareto optimum any more. Within this context, air pollution related externalities bring specific costs to society. Therefore, air pollution related externalities could be defined as one of the most important obstacle to reach Pareto optimality (Pigou, 1920; Ogden, 1966). So, the externalities of air pollution could be addressed through this theoretical background. Air pollution causes wide range of externality costs. Especially health damaging consequences of air pollution could be a serious handicap to maintain social optimum (Nam et al., 2010).

Serious health externalities of air pollution bring welfare costs in several ways. One of these ways is link with the resource allocation problem. This fact could explain through the possible health consequences of air pollution. Air pollution creates an increase in medical care demand. So, resources mainly allocate for health production. However, if the pollution level remains unchanged then the desired health status could be achieved without an additional medical care supply. Thus, resources now allocate for more productive activities (Matus et al., 2008). Air pollution related health issues such as reduction in life expectancy and premature deaths is the other way to understand possible welfare burdens of air pollution. In this regard, health related welfare costs of air pollution could described in three types: direct costs, indirect costs and intangible costs. Direct costs consist from the direct health care costs (such as the costs of medicine, hospital facilities, health care workers etc.) and the direct non-health care costs (such as the damage of crops and forests, and materials, informal care etc.). Indirect costs usually states the productivity costs. So, it includes the productivity losses due to morbidity, the decline at working ability and the productivity loss due to deaths. On the other hand, intangible costs describe the non-marketable resources such as the level of pain and suffer of the person and the possible restraining impact of this pain and suffering on living quality (Pervin et al., 2008; Aloi and Tournemaine, 2011).

Considering the possible externality costs of pollution, researchers have been suggested several solutions to sustain Pareto optimality. In this regard, Coase (1960) recommended the improvement property rights that ensure the pollutant party to make internalize the externality. Thus, negative externalities may not cause market failure, especially where the property rights defined well and the bargaining process are costless. However, usually it is hard to accuse one specific individual or firm for externalities such as global warming. Even if this accusation problem assumed to be solved, the property rights provide a significant power to a party over all others. Thereby, negotiations for Coase solution could breakdown. Besides, free rider problem could be an obstacle on Coase solution, too (Gruber, 2016). In case where Coasian solution is quite insufficient, governments lean to some alternatives such as taxes, subsidies or regulations to overcome negative externalities of pollution. Pigou (1947) is the first researcher who develops a taxation framework to internalize negative externalities. Pigovian taxes load pollution related negative externalities to the parties whose are responsible from it. But, Pigovian taxes could also cause an increase in market prices due to the addition of environmental cost of fossil fuels on to the energy prices (Meneteau et al., 2003; Ciarreta et al., 2011). Considering this fact, green energy sources provide an alternative for households and firms to overcome increased costs due to rising energy prices. Besides, green energy sources ensure a clean alternative for production. Thus, dramatic consequences of negative externalities such as global warming, climate change, air pollution etc. could be prevented or at least restrained through renewable energy technologies (e.g. Dincer, 2000; Cansino et al., 2010).

In the existing literature, many researchers already indicated the potential role of renewable energy sources to reduce air pollution and improve the health status. These studies could help to understand the feature of clean energy to decrease negative externalities of air pollution in terms of health. However, possible welfare cost of air pollution related health consequences is also a very crucial issue that needs to be addressed. In this regard, recently, some researchers investigated the role of clean energy to decrease health expenditures. But, it is usually difficult to determine how much of the health expenditures are caused by the health externalities induced by air pollution. Therefore, with this way, it may hard to measure the effect of renewable energy sources on reducing the welfare cost of health externalities of air pollution. Considering this fact, this study aims to make a contribution to the existing literature by using a more specified indicator of health related welfare cost while revealing the reducing role of renewable energy sources on welfare cost of air pollution.

In this study, welfare cost of air pollution measured by the welfare cost of premature deaths caused by the ambient particulate matter for few reasons. Initially, compared to other pollutants such ozone (O3), nitrogen dioxide (NO2), sulphur dioxide (SO2) etc., the health risks due to the particulate matter especially being well recorded (The WHO, 2020b). Secondly, the public health is facing with serious consequences due to the ambient particulate matter. For instance, intensive and chronic exposures of particles both increase the risk of lung cancer and cardiovascular and respiratory diseases (The WHO, 2018). Third, welfare cost of premature deaths caused by air pollution creates the majority of total social costs occurred from environmental related health risks (The Organisation for Economic Co-operation and Development (OECD), 2019). By considering these reasons, the welfare cost of premature deaths due to the ambient particulate matter is preferred as an indicator of the welfare cost of air pollution in this study. Thus, the reducing impact of clean energy on welfare cost of air pollution could be determined more efficiently. In this regard, authors wish to provide more reliable results for policy makers by using this relatively specific indicator of welfare cost of air pollution. Concordantly, this study aimed to investigate the long run impacts of clean energy sources on welfare cost of premature deaths caused by the ambient particulate matter in the APEC countries during 1990-2016 by using dynamic panel data techniques.

Table 1: The APEC Countries' Global Share in GDP, in Renewable Energy Supply, in Trade Volume and in The Welfare Cost of Premature Deaths caused by Ambient Particulate Matter

Year	The share of welfare cost of premature deaths caused by ambient particulate matter (%)	The share of GDP (%)	The share of renewable energy supply (%)	The share of trade volume (%)
1990	48,36	51,67	45,53	31,45
1991	47,81	51,69	45,50	30,79
1992	47,05	51,89	45,41	30,94
1993	48,53	52,25	44,99	31,75
1994	48,04	52,43	44,35	32,47
1995	47,32	52,47	44,49	33,01
1996	46,43	52,79	44,26	33,49
1997	47,81	52,95	43,65	33,55
1998	45,56	52,79	43,06	32,68
1999	48,89	53,14	42,82	33,11
2000	49,42	53,27	42,77	33,26
2001	50,05	53,24	41,54	32,32
2002	50,78	53,44	41,17	32,53
2003	51,60	53,72	40,38	32,78
2004	51,57	53,75	39,97	33,42
2005	52,22	53,91	39,41	33,46
2006	51,74	53,85	39,30	33,01
2007	51,62	53,80	38,21	32,86
2008	52,08	53,79	37,67	32,85
2009	52,19	54,09	37,11	32,53
2010	52,50	54,32	36,43	33,24
2011	53,08	54,39	36,43	33,35
2012	53,77	54,95	36,73	33,70
2013	53,84	55,28	37,22	33,78
2014	53,73	55,47	37,93	33,94
2015	53,02	55,71	37,77	33,59
2016	52,60	55,87	38,02	33,31
Average	50,43	53,59	40,82	32,86

Note: The statistics are calculated by author's. Percentage values are estimated through the OECD statistics and the United States Department for Agriculture (USDA) database.

The APEC countries panel is preferred as the sample of this study for few reasons. At first, especially South East Asia and Western Pacific regions suffer from air pollution related premature deaths. As given in Table 1, the share of the APEC countries on global welfare cost of premature deaths caused by the ambient particulate matter estimated as approximately 50% during 1990-2016. This statistics reveal the high importance of air pollution induced welfare cost for the APEC sample. Secondly, the APEC economies play a vital role on global production. As seen in Table 1, the APEC countries produced approximately 54% of the world GDP during 1990-2016. As a third reason, the trade volume of the APEC countries shows a considerable importance for global production also. As given in Table 1, the share of the APEC countries on global trade volume estimated as approximately 33% during 1990-2016. Fourth, the APEC countries are important suppliers of clean energy worldwide. As presented in Table 1, the APEC countries provided approximately 41% of the global renewable energy supply. All these facts verify that the APEC countries panel is the proper sample to examine the possible mitigating impact of renewable energy sources on air pollution related welfare cost. In addition, according to the literature review, the potential of renewable energy to reduce welfare cost of pollution specifically for the APEC countries seen as a gap that needs to be filled. Therefore, this study also aimed to make a contribution to the existing literature by investigating the mitigating impact of clean energy on health related welfare cost caused by air pollution for the APEC countries.

This study designed as follows. Section two contains a brief summary of related literature. Section three explains the econometrical model while section four defines the dataset and the empirical methods adopted. Section five presents the empirical results and discussions. And the last section includes concluding remarks, policy implications and suggestions.

2. The Literature Review

In the literature, many researchers investigated the possible cost of air pollution in terms of health status or medical care expenditures. While some researchers focused on the increasing impact of air pollution on health expenditures, some others leaned on to the possible welfare cost of air pollution. Both types of studies summarized in this section. Initially, the researches that aim to determine the possible impact of air pollution on health expenditures are discussed. The majority of the empirical findings of existing literature (e.g. Narayan and Narayan, 2008; Yahaya et al., 2016; Badamassi et al., 2017; Yazdi and Khanalizadeh, 2017; Hao et al., 2018; Yang and Zhang, 2018; Zeng and He, 2019; Apergis et al., 2020; Nasreen, 2021) support the view that air pollution increases health expenditures. Still, empirical results of some studies showed a negative relationship between air pollution and health spendings (e.g. Gangadharan and Valenzuela, 2001; Zaidi and Saidi, 2018) while some others' findings reached mixed implications (e.g. Badulescu et al., 2019; Usman et al., 2019). Besides, some studies also revealed the uni-directional causality running from CO2 emissions to health expenditures (e.g. Chaabouni et al., 2016; Wang et al., 2019). Futhermore, existing literature also contains studies that could not reach any statistically significant relationship among health expenditures and air pollution (e.g. Qureshi et al., 2015).

On the other hand, some researchers in the existing literature investigated the possible welfare cost of worsening health status due to environmental pollution. As understood from the empirical investigations (e.g. Zhang et al., 2007; Nam et al., 2010; Matus et al., 2012; Chen and He, 2014; Owusu and Sarkodie, 2020), air pollution loads significant welfare costs to the economies through worsening health condition of individuals.

Considering the possible health related externalities of air pollution, renewable energy sources are recommended as an efficient source to achieve sustainable development goals in the literature (Kaygusuz, 2002). Therefore, the remedial role of clean energy sources both on environment and thus the health status, attracts academic world' attention. Recently, some researchers examined the possible impacts of renewable energy sources on medical care expenditures in the framework of sustainable development. In this regard, Çetin (2018), Shahzad et al. (2020) and Ullah et al. (2021) revealed the reducing impact of renewable energy sources consumption on health care expenditures. On the other hand, Apergis et al. (2018) and Sasmaz et al. (2021) have found uni-directional causality runs from renewable energy consumption to health care spendings while Khan et al. (2019) reached bi-directional causality among the clean energy and health expenditures. As a result, the empirical results of the existing literature imply the crucial role of clean energy to decrease health expenditures mostly induced by air pollution, due to improving health status of society.

3. Empirical Model

The empirical model of this study constructed based on the general theoretical approaches and the studies in the empirical literature. The main regression equation stated as below;

$$WFC_{it} = \beta_1 RGDP_{it} + \beta_2 TRADE_{it} + \beta_3 RES_{it} + \varepsilon_{it} \quad (1)$$

where i=1,2,…,N denotes the cross sections and t=1,2,…,T represents the time period. Besides, the WFC is the welfare cost of premature deaths caused by ambient particulate matter, RGDP is the real gross domestic product and used as a proxy for economic growth, TRADE is the trade openness and RES is the renewable energy sources supply.

As already mentioned, the welfare cost of air pollution related premature deaths declared as responsible from the majority of total social costs caused from environmental related health risks (The OECD, 2019). Therefore, in this study, the possible negative externalities due to the air pollution measured by the welfare cost of premature deaths caused by ambient particulate matter by following Owusu and Sakordie (2020). Besides, the RES is included in to the empirical model to reveal the mitigating role of renewable energy supply on air pollution induced welfare cost by following the claims in the existing literature.

Furthermore, two commonly preferred control variables are also included in to the empirical model both to avoid from biased results caused from omitted variable and to consider other possible socio-economic indicators that may have an important influence on air pollution. The first control variable is real GDP. The possible impacts of increasing economic activity on environmental quality being discussed usually based on the EKC hypothesis in the literature (e.g. Grossman and Krueger, 1991; Selden and Song, 1994). According to the EKC hypothesis, environmental deterioration increases faster than income in the first stages of economic development. During this period, economies intensely focused to produce enough amount of goods and services and to create new job opportunities for individuals. Thereby, rapid growth in economic activity causes an excessive consumption of natural resources. As a consequence of this intense natural sources depletion, environmental pollution level increases. However, in earlier stages of economic growth, individuals do not have enough wealth to pay negative externality costs and they usually ignore the possible adverse outcomes of environmental degradation. But, in further stages, environmental pollution level decreases due to both accelerated economic growth and increased social awareness of environmental quality. This inverted U-shaped relationship known as the EKC in the literature (Dinda, 2004). On the other hand, some researchers (e.g. Shahbaz and Lean, 2012; Wang et al., 2020) also asserted that increased welfare of individuals stimulates the demand for luxury goods like cars, TV sets, refrigerators, computers etc. which triggers the need of energy consumption. So, increased living standards could adversely affect the environmental quality. Considering this possible impacts of economic growth on air pollution, RGDP is included in to the empirical model. Besides, trade openness is the other control variable of the empirical model because many researchers (e.g. Copeland and Taylor, 2004; Cetin and Bakirtas, 2020) states the significant role of trade openness on environmental quality. Trade liberalization could either have negative or positive consequences on environment. For instance, increasing trade liberalization could ensure to flow global investments to pollution restraint implementation and also enables the transfer of cleaner production technologies from developed to developing economies. Although, trade openness increases the volume of traded goods and this means increasing production, rising construction and industrial units. Thus, energy demand also increases to reach desired production level. So, the rapid depletion of energy sources may lead to dramatic environmental problems such as air and water pollution (Baek et al., 2009; Shahbaz et al., 2017).

4. Data and Methodology

4.1. Data

Welfare cost of premature deaths caused by ambient particulate matter (millions US$, constant 2010 US$) is obtained from the OECD statistics. Real GDP is collected from the United States Department of Agriculture database (billions US$, constant 2010 US$). Trade openness which means exports plus imports (both measured as constant 2010 US$) is provided from the world development indicators of World Bank. Renewable energy supply (thousand tonne of oil equilevant) is taken from the OECD statistics. Annualized series covers the period from 1990-2016. The APEC panel preferred as the proper sample in the empirical analysis. The APEC defined as a regional premier forum established in 1989, to enhance economic growth, cooperation, trade and investment of Asia-Pacific region. This forum has 21 member economies (The United States Department of State, 2019; The APEC, 2020). However because of the data availability issue, 17 of the APEC countries (whose are Australia, Canada, China, Chile, Japan, Korea, New Zealand, USA, Mexico, Indonesia, Malaysia, Peru, The Philippines, Russia, Singapore, Thailand, Vietnam) are included in to the empirical model. Unfortunately, Brunei Darussalam, Hong Kong, Papua New Guinea and Chinese Taipei are excluded due to the missing data. On the other hand, all series transformed into their natural logarithm forms to obtain elasticity values.

Both descriptive statistics and Pairwise correlation matrix results are given in Table 2. According to the panel A of Table 2, high standard deviation results may imply the possible heterogeneity among the APEC economies. Considering this fact, Delta tests are employed to check heterogeneous coefficients in empirical analysis.

Table 2: Descriptive Statistics and Pairwise Correlation Matrix

Panel A: Descriptive statistics				
	WFC	RGDP	TRADE	RES
Mean	85584,77	1750,088	5.53E+11	33442,57
Maximum	1229389	16972,35	5.15E+12	266484,6
Minimum	1348,523	29,45847	2.17E+09	35,06000
Standart-deviation	167431,5	3306,652	8.31E+11	54368,44
Observations	459	459	459	459
Panel B: Pairwise correlation matrix				
Variables	lnWFC	lnRGDP	lnTRADE	lnRES
lnWFC	1,00			
lnRGDP	0,92	1,00		
lnTRADE	0,43	0,55	1,00	
lnRES	0,59	0,55	-0,04	1,00

Even though the correlation matrix presents some pioneer information about the possible interactions among the series, still more advanced techniques needs to be used to avoid from biased results caused by problems like existence of a unit root or cross section dependency. Therefore, the econometric methods adopted in this study are explained in the next section.

4.2. Methodology

As a first step of empirical analysis, the possible unit root existence needs to be checked with panel unit root tests. However, the first generation panel unit root tests assume the cross-sectional independence along the series (Pesaran, 2007). If individual series are cross sectionally dependent, this could cause seriously biased results (Hoechle, 2007). By considering this issue, cross sectional dependence needs to be investigated initially to decide whether the first or the second generation panel unit root test has to be employed. The cross sectional dependence (CD) test that developed by Pesaran (2004) is adopted in this study. This CD test relies on the pairwise correlation coefficients (ϱ̂_ij) average.

If the null hypothesis of cross sectional independence across the series is rejected, then the second generation panel unit root test would be the appropriate technique to check unit root existence in individual series. Because the second generation test loosen the first generations tests' restriction assumption of cross sectional independence (Baltagi & Pesaran, 2007). In this study, one of the most popular second generation panel unit root test that developed by Pesaran (2007) is employed to check the unit root existence. Pesaran (2007) introduced a cross-sectionally augmented Dickey Fuller (CADF) unit root test where the standard ADF regressions augmented with the cross section averages of lagged levels and the first differences of each series. Thus, the possible cross section dependence could be eliminated (Baltagi and Pesaran, 2007).

If all series are I(1) in unit root process, the co-integration relationship among the variables should be determined with the second generation panel co-integration tests which eliminates the cross section dependence. Therefore, Westerlund (2007) panel co-integration test is applied in the empirical analysis. Westerlund panel co-integration test is based on an error-correction model and by this way it aimed to mitigate the possible impact of cross section dependence. Westerlund panel co-integration test provides both better size accuracy and higher power compared to residual-based co-integration tests of Pedroni (2004). In addition, Westerlund panel co-integration test presents two type of statistics. Two of them declared as group statistics (Gt and Ga) while the other two introduced as panel statistics (Pt and Pa). It is assumed that both statistics distributed normally. If cross sectional dependence exists along the series, the null hypothesis of no cointegration in panel groups or individual cross sections could be check by obtaining robust critical values through bootstrapping in Westerlund panel co-integration test. On the other hand, the co-integration relationship among the variables also examined with a residual based test that developed by Westerlund (2005). He derived a pair of variance ratio test statistics for the null hypothesis of no co-integration. The variance ratio test does not necessitate any modelling or adaptation for serial correlation.

After a long run relationship among the series is found, the long run elasticity results could be investigated by dynamic panel data estimators. However, the possible slope heterogeneity needs to be investigated to choose proper method. Therefore, the slope homogeneity test that developed by Pesaran and Yamagata (2008) adopted in this study. The slope homogeneity test is based on two models and compares them. The first model called restricted and it is the weighted fixed effects estimator that imposes slope homogeneity. The second model called unrestricted and it is the cross-sectional unit specific OLS regression model. The slope homogeneity test relies on the difference of two models and if the test statistics gains large values, then the null hypothesis of slope homogeneity could be rejected (Berdsvendsen and Ditzen, 2020). Thereafter, the direction of the long term interactions among lnWC, lnRGDP, lnTRADE and lnRES is investigated by using the DOLS and the FMOLS estimators. The pooled DOLS estimator defined as the OLS that estimates an augmented co-integrating regression equation given as below.

$$y_{it} = a_i + x_{it}'\beta + \sum_{j=-q}^{q} c_{ij}\Delta X_{it+j} + \dot{v}_{it} \tag{2}$$

where $\dot{v}_{it} = v_{it} + \sum_{|j|>q} c_{ij}\varepsilon_{it+j}$ and q is the choosen number of leads/lags for the model (Kao and Chiang, 1999). The pooled version of the FMOLS estimator is the basic extended version of the Phillips and Hansen's (1990) estimator and developed by Phillips and Moon (1999). Both the DOLS and the FMOLS estimators provide less biased results compared to the panel OLS method. The autocorrelation correction is the main difference between two techniques. In this regard, the FMOLS eliminates serial correlation problem with the help of Newey-West approaches while the DOLS allows to adding more many lagged and lead variables to overcome possible serial correlation (Nasir et al., 2019).

On the other hand, the pooled mean group (PMG) and the dynamic common correlated effects (DCCE) estimators are also adopted in the empirical analysis of this study for robustness check. Pesaran et al. (1997, 1999) developed the PMG estimator that based on pooling and averaging of the slope coefficients. The PMG is an intermediate estimator that enables intercepts, short run coefficients and error variances differ across panel groups. However it provides equal long run coefficients across all panel groups. The PMG estimator is determined with ARDL(p,q,q...,q) model like stated as below.

$$y_{it} = \sum_{j=1}^{p} \gamma_{ij} y_{i,t-j} + \sum_{j=0}^{q} \delta_{ij}' x_{i,t-j} + \mu_i + \varepsilon_{it} \tag{3}$$

where x_it (kx1) is the vector of regressors for group i, μ_i is the fixed effects, γ_ij are the lagged dependent variables coefficients and δ_ij are (kx1) coefficient vectors. Equation 3 is re-designed by assuming all variables have a long run relationship and ε_it is I(0) for all cross section. This new form is presented as in equation 4.

$$\Delta y_{it} = \varphi_i y_{it-1} + \beta_i' x_{it} + \sum_{j=1}^{p-1} \gamma_{ij}^{*} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta_{ij}^{*\prime} \Delta x_{i,t-j} + \mu_i + \varepsilon_{it} \tag{4}$$

where $i = 1,2, \dots., N$, $t = 1,2, \dots, T$, $\varphi_i = -1(1 - \sum_{j=1}^{p} \gamma_{ij})$, $\beta_i = \sum_{j=0}^{q} \delta_{ij}$, $\gamma_{ij}^{*} = -\sum_{m=j+1}^{p} \gamma_{im}$, $j = 1,2, \dots, p-1$ and $\delta_{ij}^{*} = -\sum_{m=j+1}^{q} \delta_{im}$, $j = 1,2, \dots, q-1$. The error correction term (φ_i) defines the speed of convergence. If φ_i is significant and takes a negative sign, this implies a long run relationship between the variables.

However the long run findings of the PMG estimator could suffer from the issue of cross-section dependency and possible endogeneity along the series because PMG estimator does not consider both of these issues. Therefore, the dynamic common correlated effects (DCCE) estimators which is introduced by Chudik and Pesaran (2015) is also employed for the robustness check. This brand new estimator allows homogenous and heterogeneous long run slopes, dynamic common correlated effects and it also considers cross section dependency trough the inclusion of cross-sectional means and lags. In addition, DCCE estimator command that proposed by Ditzen (2018) consider the endogeneity among the series to avoid from biased results.

5. Empirical Results and Discussion

The CD test results are given in panel A of Table 3. As seen from the results, the null hypothesis of cross sectional independence rejected for all series at 1% level of significance. Corresponding to that, the second generation panel unit root test is adopted to check unit root existence.

Table 3: Cross Sectional Dependence, Panel Unit Root and Slope Homogeneity Tests Results

Variables	lnWFC	lnRGDP	lnTRADE	lnRES
Panel A: CD test results				
CD test statistics	49,730	57,399	58,128	30,429
Prob. value	0,000	0,000	0,000	0,000
Panel B: CADF test results				
CADF test statistics (level)	-2,182	0,775	0,815	-0,313
Prob. value	0,985	0,781	0,793	0,377
CADF test statistics (first difference)	-4,908	-3,215	-4,440	-7,143
Prob. value	0,000	0,001	0,000	0,000
Panel C: Slope Homogeneity test results				
	Statistics		Prob. value	
$\bar{\Delta}$ test	-0.024		0,981	
$\bar{\Delta}$ adj.	-0.044		0,965	

Note: CADF panel unit root tests are estimated for 1 lag and with deterministic trend by using "pescadf" command which is developed by Lewandowski (2006). Slope homogeneity test is determined with "xthst" command which is developed by Bersvendsen and Ditzen (2020). Slope homogeneity test is employed by adding cross-sectional averages with 3 lags to eliminate cross section dependence.

The CADF test results are presented in panel B of Table 3. According to the findings, all series are stationary on their first difference which means all series are I(1). Besides, the possible slope homogeneity is investigated with Delta tests and the results are presented in panel C of Table 3. As seen in Table 3, the null hypothesis of Delta tests could not rejected. This finding implies that slope coefficients are homogeneous. Therefore, the homogeneous dynamic panel data estimator is employed to obtain long run elasticity results. But before that, the co-integration relationship among the series is examined with two tests.

Table 4 shows the panel co-integration tests results. The error-correction model based Westerlund panel co-integration findings shows that the two of four statistics (Pt and Pa) are statistically significant at 5% and 10% level, respectively. This finding indicates a long run relationship among the variables. As an alternative, the long run variance ratio test statistics of Westerlund panel co-integration test also rejects the null hypothesis of no co-integration at 1% level of significance. This finding also revealed that all panels are co-integrated.

Table 4: Westerlund Panel Cointegration Test and The Variance Ratio Test Results

	Statistics	Prob. value	Robust Prob. Value
G_t	4,970	1,000	0,540
G_a	7,406	1,000	0,170
P_t	4,269	1,000	0,030
P_a	5,626	1,000	0,100
Variance ratio	2,278	0,011	

Note: Westerlund panel cointegration test is employed by using "xtwest" command which is developed by Persyn and Westerlund (2008). The variance ratio test applied by using "xtcointtest westerlund" command. In the process of "xtwest", the optimal lag length is choosed by AIC with a maximum lag length of 3. Width of Bartlett-kernel window set to 3. Number of bootstraps to obtain bootstrapped p-values, which are robust against cross-sectional dependence, set to 100 repetition. The variance ratio test statistic is determined for all panels with "demean" to mitigate the impact of cross section dependence. Both tests are applied with deterministic trend.

Thereafter, the long run elasticity results are determined with the DOLS and the FMOLS techniques. During this process, Delta tests findings take in consideration. The results of the DOLS and the FMOLS analysis are presented in first and second column of Table 5. The long run elasticity results of the DOLS indicate that, lnWFC increases about 0,838% due to a 1% increase in lnRGDP. Likewise, the long run coefficient findings of the FMOLS show that, lnWFC increased by 0,969% due to the 1% increase in lnRGDP. This two findings coherence with the view that economic growth stimulates the demand for big ticket items that induce energy consumption and brings serious welfare costs related to air pollution. Even though economic growth defined as one of the main welfare indicator in the literature, possible negative externalities of growth could bring significant pollution related health costs to society especially in emerging countries (Usman et al., 2019). The APEC countries panel consists mainly from the Asian and the American emerging economies. Therefore, natural resources of the APEC countries are rapidly consumed to satisfy increasing needs of growing population. This intense consumption of natural resources cause serious environmental impacts that brings significant health consequences. Negative impact of economic development on pollution related welfare cost could be explained within this framework.

Table 5: The Long and the Short Run Elasticity Results

	DOLS	FMOLS	PMG	DCCE
ECT			-0,131** (-2,27)	
Long run elasticity results				
lnRGDP	0,838*** (5,41)	0,969*** (8,24)	1,134*** (13,17)	2,022** (2,19)
lnTRADE	0,257*** (2,74)	0,193*** (2,68)	0,093* (1,63)	-1,064 (-1,07)
lnRES	-0,307*** (-5,05)	-0,308*** (-5,38)	-0,131*** (-4,51)	-0,631** (-2,02)
Short run elasticity results				
lnRGDP			0,502** (2,28)	
lnTRADE			-0,004 (-0,08)	
lnRES			-0,136* (1,82)	
Adj. R^2	0,99	0,99		0,90
Obs.	415	442	442	374

Note: ***, ** and * indicates the 1%, 5% and 10% level of significance, respectively. Pooled panel method is used in both the DOLS and the FMOLS estimations. Optimal lag length is choosed by AIC for the DOLS estimator. ARDL(1,1,1,1) model is estimated via the PMG process which depends on "xtpmg" command that proposed by Blackburne and Frank (2007). DCCE estimator is calculated trough "xtdcce2" command which introduced by Ditzen (2018). In the process of DCCE estimation, RGDP defined as endogenous variable. Therefore, the lags of the endogenous variable are included in to the model as an instrument variable to avoid from possible biased results caused from endogeneity problem.

Besides, the long run results of the DOLS and the FMOLS estimators demonstrate the additive impact of trade openness on the welfare cost of air pollution. In this regard, 1% increase in lnTRADE causes 0,257% increase and 0,193% increase in lnWFC, respectively based on the DOLS and the FMOLS results. These findings could be explained with the positive impact of trade liberalization process on welfare increment. Increased welfare of individuals triggers aggregate demand in an economy. So, it is natural to expect that growing demand stimulates industrial production and thereby the usage of natural resources such as fossil energy sources. As it commonly accepted in the literature, overuse of fossil based sources seen as the key factor of air pollution. As mentioned before, air pollution could load serious health related welfare cost to society. Concordantly, growing trade volume increases welfare cost of air pollution through the welfare increment. On the other hand, both the DOLS and the FMOLS long run elasticity results revealed that renewable energy supply has a significant mitigating impact on air pollution related welfare cost. As seen in Table 5, 1% increase in lnRES causes 0,307% decrease and 0,308% decrease in lnWFC, respectively based on the DOLS and the FMOLS results. This could be explained with the remedial role of renewable energy on environment. Increasing supply of clean energy reduces the ambient particulate matter and thereby the welfare cost of premature deaths caused by air pollution. In this regard, renewable energy supply play a crucial role to lowered the welfare cost of premature deaths caused by ambient particulate matter in the APEC economies.

In addition, the PMG and the DCCE estimators are also employed in this study for robustness check of the DOLS and the FMOLS findings. The PMG findings are presented in third column of Table 5. As seen from the table, the error correction term is negative and statistically significant. The existence of the long run relationship between the series is verified with this result. Moreover, the long run coefficients of PMG shows that economic growth and trade openness increases the welfare cost of air pollution. Besides, PMG findings revealed that a 1% increase in renewable energy supply causes 0,131% decrease in the welfare cost of premature deaths caused by ambient particulate matter in the long run. In fact, the PMG findings indicated that this reducing impact of renewable energy sources even valid in the short run. Consequently, both short and long run findings of the PMG estimator supports the important role of clean energy sources to mitigate the negative health externalities of air pollution in APEC economies. Even though the DOLS, the FMOLS and the PMG findings shows similar results in terms of the positive impact of clean energy to reduce welfare cost of air pollution, neither of these estimators consider the possible cross section dependency and endogeneity along the series. In this regard, DCCE estimator is employed to check the long run elasticity findings of other three estimators. The long run elasticity results of DCCE estimator is given in the fourth column of Table 5. According to the findings of DCCE estimator, economic growth has an increasing impact while trade openness hasn't got any statistically significant impact on the welfare cost of air pollution. As seen from DCCE findings, possible disruptive impact of increasing trade volume could not be seen when possible cross section dependency and endogeneity is considered in the estimation. However, the long run results of DCCE clearly revealed the possible decreasing role of renewable energy sources on the welfare cost of premature deaths caused by ambient particulate matter in APEC countries. In the empirical process of this study, the crucial importance of renewable energy sources for sustainable development is strongly supported through the long run elasticity results of the four different panel data estimators.

6. Conclusion

This study aimed to determine the long term impacts of clean energy sources supply on the welfare cost of premature deaths caused by ambient particulate matter in the APEC countries during 1990-2016 by using dynamic panel data techniques. Empirical findings revealed a long run relationship between the welfare cost of premature deaths caused by ambient particulate matter, real GDP, trade openness and renewable energy supply. The long run findings of the three of four panel data estimator adopted in the empirical process indicated that the economic growth and the trade openness have an additive impact on the welfare cost of air pollution in APEC economies. According to this finding, policy makers of the APEC economies should re-consider the possible negative externalities of economic growth and increasing trade volume. The environmental externalities of growth and increasing trade bring health related welfare costs to both individuals and the society. Thus, the APEC economies could be stay far from the social optimum. Considering that, policy makers of the APEC economies should regulate their legal structure by strengthen the environmental laws. By this way, both domestic and foreign producers in the APEC countries will be discouraged to over-pollute due to the legal punishments or the financial penalties. In addition, trade laws also should re-design to prevent from the possible environmental consequences of the products whose are produced with pollutant technologies. Thereby, the producers whose production infrastructure still mainly depends on pollutant technics will be forced to switch their current production technologies with more environmental friendly ones. All these legal regulations introduced to protect environmental quality will also improve the health status of the societies in the APEC countries. So, the possible health related welfare cost of air pollution could be reduced by new legal arrangements on behalf of the environmental quality protection. On the other hand, policy makers of the APEC countries should focused on environmental taxation policies and re-design these policies efficiently. Even though the Pigovian taxes are introduced as the practical way to load the cost of pollution to the party who is responsible from it, still environmental taxes might also disrupt the functioning of the market mechanism by causing an increase in prices. In this regard, policy makers should consider the possible inflationary pressure when they determining the rate of environmental taxes.

In addition, renewable energy sources also suggested as an alternative production way for sustainable development in the existing literature. In this regard, through this study, it is questioned whether renewable energy sources could help to mitigate the health related welfare cost of air pollution. The long run elasticity results of the DOLS, the FMOLS, the PMG and the DCCE estimators showed that the welfare cost of premature deaths caused by ambient particulate matter reduces with an increase at renewable energy supply. This finding supports the view that renewable energy sources improve the public health in the long run. Thereby, the possible welfare cost of air pollution could be decreased with the extensive usage of renewable energy technologies. Concordantly, policy makers of the APEC economies should support the possible innovative investment opportunities intended to develop renewable energy technologies, through the fiscal policies such as tax incentives and subsidies. Besides, monetary authorities and governments should also implement supportive credit arrangements that encourage renewable energy technology usage by the firms in wade range of industries from automotive to chemicals. The share of renewable sources on total energy mix could be increased with these fiscal and monetary based policies. So, the air pollution and thus the welfare cost of premature deaths caused by ambient particulate matter could be prevented.

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