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Age Structures and Air Pollution: What Role Does Gender Play?

Struktura wiekowa i zanieczyszczenie powietrza: jaką role odgrywa płeć?

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Abstract

We investigate the influence of age structure and gender on air pollution, dividing the age structure into four groups and use CO_2 emissions as a measure of air pollution, which can be separated into four categories to obtain more complete findings, then employing panel cointegration techniques and panel-based error correction models. The data are collected from 29 OECD and 40 non-OECD countries in the period 1990-2014. For case of total CO_2 emissions, younger (people under 30) and older people (people 65 and above) emit less than people in the intermediate age group, but the impact of age group on CO_2 emissions is different when looking at CO_2 emissions from coal, gas, and oil. While we take gender into account, the causality between age structure and CO_2 emissions becomes significant, especially for the relationship between population and total CO_2 emissions in OECD and non-OECD countries. We also note that more people who are aged 15-29 increase total CO_2 emissions in OECD countries and more people who are aged 30-44 decrease CO_2 emissions from coal in non-OECD countries. Our findings suggest that an energy and environmental policy should consider both age structure and gender effects on environmental issues.

Key words: age structure; gender; carbon emissions; panel cointegration; panel causality

Streszczenie

Artykuł przedstawia wyniki badań odnoszących się do wpływu zmiennych struktury wiekowej i płci na zanieczyszczenia powietrza, wyróżniając cztery grupy wiekowe i wykorzystując poziom emisji CO_2 jako wskaźnik zanieczyszczeń powietrza, który można podzielić na 4 kategorie, a następnie wykorzystaliśmy techniki kointegracji paneli i oparte na panelach modele korekcji błędów. Dane zebrano z 29 krajów należących do OECD i 40 spoza tej organizacji, obejmują one lata 1990-2014. W przypadku całkowitej emisji CO_2 okazało się, że osoby młodsze (poniżej 30 roku życia) oraz starsze (powyżej 65 roku życia) odpowiedzialne są za mniejszą emisję niż osoby w wieku średnim, przy czym występują różnice odnoszące się do poszczególnych grup wiekowych w odniesieniu do emisji CO_2 z różnych źródeł: węgla, gazu i ropy. Biorąc pod uwagę płeć, zależność pomiędzy strukturą wiekową a emisjami CO_2 okazuje się być znaczącą, szczególnie w aspekcie relacji pomiędzy populacją a całkowitą emisją CO_2. Zauważyliśmy ponadto, że osoby w wieku 15-29 z krajów OECD bardziej przyczyniają się do wzrostu całkowitej emisji CO_2, a w przypadku krajów nie należących do OECD osoby w wieku 30-44 bardziej odpowiedzialne są za obniżenie emisji CO_2 z węgla. Przeprowadzone badania umożliwiają postawienie hipotezy, według której polityka energetyczna i środowiskowa w kontekście zagadnień odnoszących się do środowiska powinna uwzględniać zarówno strukturę wieku jak i płci.

Słowa kluczowe: struktura wiekowa, płeć, emisja ditlenku węgla, kointegracja paneli, przyczynowość panelu

1. Introduction

Energy consumption derives from energy demand in all sectors of life. A long-run relationship has been confirmed among energy consumption, CO_2 emissions, and economic growth (Khobai and Le Roux, 2017). The literature suggests that people's age could affect emission-relevant consumption patterns (Menz and Welsch, 2012). Many studies have drawn attention to the relationship among population age, environmental preferences, and environmental quality. In this sense, the demographic aspect is a main factor that affects environmental problems (Wang, et al., 2017). How a population influences energy consumption and carbon emissions has attracted widespread attention.

The literature has increasingly focused on energy consumption and carbon emissions from socio-economic aspects. Population growth is widely seen as a major driving factor for the increase of CO_2 emissions, but the impacts of different age group populations on CO_2emissions are complex. The age composition may affect energy consumption and CO_2 emissions through per capita economic activity. Some studies found that a higher percentage of young people in a population lead to more CO_2 emissions, young people are more inclined to participate in sports and outdoor activities, and they are more educated and seem to actively participate in environmental legislative and regulatory processes. Farzin and Bond (2006) has indicated that a greater share of young people (aged under 15 years) emits more CO_2 emissions. Liddle (2011) confirmed that the age structure follows a U-shaped pattern with residential electricity consumption; a higher share of youngest and oldest cohorts leads to more electricity consumption. Some researchers noted that CO_2 emissions increase with a higher share of older people, they confirm that the willingness towards environmental protection declines with age growth (Israel and Levinson, 2004;Torgler, et al., 2008), mainly because the old are more likely to use energy less efficiently when they live alone and have a lower acceptance of *green taxes* and charitable donations (Rehdanz, 2007), a higher percentage of older people implies greater CO_2 emissions (Liddle and Lung, 2010; Menz and Welsch, 2012).

Different from these two opinions, An inverted U-shaped relationship between age composition and CO_2 emissions is presented in some studies. Shi (2003) confirmed that a higher ratio of working-age people increases CO_2 emissions and that in developing countries the impact of demographic change on CO_2 emissions is much more obvious than that in developed countries. The inverted U-shape between the two variables was confirmed in the transport sector in OECD countries (Liddle, 2011; Okada, 2012), the working-age group may exert more influence on CO_2 emissions. Jorgenson, et al. (2010) also concluded that, in less developed countries, a higher share of adult urban population (aged 15-64 years) increases energy consumption, whereas people living in urban slum conditions exert a negative effect on it. From the discussion above, inconsistency still exists among the literature on the relationship between age structure and CO_2 emissions.

Gender as a major explanation for individual differences has become more important to study environmental issues (Nightingale, 2006). For the gender-environments issue, theories propose different views to explain the nexus. Women are considered closer to nature and men are closer to culture (Griffin, 2016). Women tend to understand and are concerned about the benefits to environmental protection from their unique perspective. In addition, men's and women's work practices play an important role in environmental protection and women have unique environmental knowledge (Nightingale, 2006). Building upon the two above, another theory argues that their role as subsistence providers promote women to master some knowledge about natural resources to guarantee their household survival (Rocheleau et al., 1996a). From the discussion above, women express greater environmental concern and pro-environmental behavior than men do (Boeve-de Pauw, et al., 2014).

Several previous works focusing on the gender-environment nexus focused on certain ages groups. Early research studies, gender differences in adult cohorts (Schahn and Holzer, 1990), while over the next few years gender differences among children and young adult cohorts also received wide attention (Zelezny, et al., 2000; Goldman, et al., 2006). Gender roles have been widely used to explain gender difference in some of the literature on environmental issues (Zelezny, et al., 2000). However, previous studies explored the effect of population and gender difference factors on CO_2 emissions separately. This observation raises an important question: how does gender with regard to environmental concern influence the relationship between age composition and carbon emissions?

This study fills this academic gap in several ways. First, we examine the role of gender between age structure and CO_2 emissions using the latest panel data covering 69 countries from 1990 to 2014. The main contribution of this research is that we consider both age structure and gender in environment concerns. Second, we focus on the role of gender in regards to the inconsistent conclusion over the relationship between age structure and CO_2emissions by using four series of CO_2 emissions: coal, gas, oil, and the total of them. Third, Given the difference in females' social roles and status, a country's position in the development process also determines the correlation among the variables. Hence, we explore this correlation for different groups of countries, such as OECD and non-OECD nations. Fourth and finally, to overcome the shortcomings of previous studies that mostly used a questionnaire approach and case

Table 1. Panel unit root tests

Variables	LLC	ADF	Variables	LLC	ADF
POP1465	-0.425 (0.335)[b]	-0.356 (0.361)	∆POP1465	-4.667** (0.000)	-4.804** (0.000)
SEXRATIO1465	2.205 (0.986)	0.884 (0.812)	∆SEXRATIO1465	-4.014** (0.000)	-2.374** (0.009)
POP1529	0.486 (0.686)	-0.510 (0.305)	∆POP1529	-6.396** (0.000)	-2.980** (0.001)
SEXRATIO1529	-0.130 (0.448)	-0.146 (0.442)	∆SEXRATIO1529	-2.965** (0.002)	-3.770** (0.000)
POP3044	1.411(0.921)	2.355 (0.991)	∆POP3044	-7.368** (0.000)	-10.671** (0.000)
SEXRATIO3044	7.293 (1.000)	0.114 (0.546)	∆SEXRATIO3044	-5.082** (0.000)	-2.485** (0.007)
POP4564	1.218 (0.888)	1.217 (0.888)	∆POP4564	-8.339** (0.000)	-2.737** (0.003)
SEXRATIO4564	-0.359 (0.360)	1.652 (0.951)	∆SEXRATIO4564	-6.562** (0.000)	-3.691** (0.000)
TOTAL[69][a]	2.876 (0.998)	5.002 (1.000)	∆TOTAL	-26.486** (0.000)	-26.733** (0.000)
COAL[55]	-0.129 (0.449)	-0.577 (0.282)	∆COAL	-27.576** (0.000)	-22.010** (0.000)
GAS[57]	0.926 (0.823)	0.568 (0.715)	∆GAS	-20.417** (0.000)	-17.905** (0.000)
OIL[69]	7.918 (1.000)	1.188 (0.883)	∆OIL	-28.477** (0.000)	-23.459** (0.000)

Notes: Δ denotes first differences. ** indicates that the estimated parameters are significant at the 5% level.
[a] The values in[]parentheses denote sample size; [b] The values in ( ) parentheses denote p-value.

studies that investigated the relationship between gender and environmental concern (Boeve-de Pauw, et al., 2014; Xiao and McCright, 2015; Chan et al., 2016), we develop and estimate an econometric model to look at the relationship among the three variables. This study provides cross-section and time-series panel data analyses and examines the relationship between age structure, gender, and CO_2 emissions using the panel cointegration approach as well as vector error correction model (VECM).

2. Empirical results and discussions

2.1. Model and econometric methodology

We estimate the panel cointegrated relationships among age structure, gender, and CO_2 emissions. Based on Pedroni's (1999) method of the panel cointegration test, we estimate the following equations with two variables and three variables separately:

$$CO_{2_{it}} = \alpha_i + \delta_i t + \beta_i POP_{it} + v_{it}\text{ , } i=1,\dots, N,\ t=1,\dots, T \quad (1)$$

$$CO_{2_{it}} = \alpha_i + \delta_i t + \beta_i POP_{it} + \eta_i SEXRATIO_{it} + v_{it}\text{ , } i=1,\dots, N,\ t=1,\ \dots,\ T \quad (2)$$

In this model, the observable variables CO_2, POP, and SEXRATIO have dimensions (N*T) × 1 and (N*T)×M. The sample countries include i=1,…, N members; the number of observations over time is expressed by t =1,…, T; the number of regression variables is expressed by M; εit is the residual; CO_2 represents the dependent variable, including CO_2 emissions from burning coal (COAL), gas (GAS), oil (OIL), and their total (TOTAL). POP represents the percentages of population in the countries and is proxied by people aged less than 15 years and aged 65 and above (POP1465), people aged 15-29 (POP1529), people aged 30-44 (POP3044), and people aged 45-64 (POP4564). SEXRATIO denotes the ratio of females to males and is proxied by SEXRATIO1465, SEXRATIO1529, SEXRATIO3044, and SEXRATIO4564.

Panel cointegration analysis is conducted by four stages. First, the panel unit root should be tested to examine if there exists a unit root for the variables. Second, as Pedroni (2004) mentioned, we examine the cointegration relationship between age structure, gender, and CO_2 emissions. Third, we use the fully-modified OLS (FMOLS) methods to estimate the parameters of the panel cointegration vector (Pedroni, 2000). Finally, we use a panel VECM to test the statistical causality hypothesis.

2.2. Data and the empirical results

These estimations are for the period 1990-2014 and cover 69 countries, including 29 OECD countries and 40 non-OECD countries. The data of CO_2 emissions come from the International Energy Agency (IEA). This paper uses three types of fossil fuels, coal, gas, and oil, and the CO_2 emissions data come from burning these fossil fuels as well as their total. Based on the four dependent variables (TOTAL, COAL, GAS, and OIL), the data we collect include separate samples of 69, 55, 57, and 69. Data of age structure and sex ratio collected from the World Development Indicators (WDI). Age group data come from the percentages of people aged under 15 years plus those aged 65 and older, and those aged 15-29,

Table 2. Results of the panel cointegration tests-Full sample

Model: CO_2, POP1465					Model: CO_2, POP1529			
	TOTAL	COAL	GAS	OIL	TOTAL	COAL	GAS	OIL
Panel v-statistic	0.001	-1.014	1.729**	0.186	1.793**	2.043**	1.426*	3.447**
Panel ρ	0.357	-0.320	-0.101	-0.455	-0.233	-2.713**	-0.482	-1.590*
Panel PP	-2.702**	-3.831**	-2.160**	-3.960**	-3.202**	-6.750**	-2.518**	-4.826**
Panel ADF	-3.425**	-2.559**	-2.094**	-4.319**	-3.141**	-6.346**	-2.919**	-4.739**
Group ρ	2.336	2.053	1.787	2.170	1.790	0.203	1.526	1.316
Group PP	-1.877**	-2.786**	-1.584*	-2.776**	-2.521**	-5.481**	-1.692**	-3.575**
Group ADF	-3.230**	-2.376**	-2.080**	-4.461**	-2.450**	-5.670**	-3.044**	-4.538**
Model: CO_2, POP3044					Model: CO_2, POP4564			
	TOTAL	COAL	GAS	OIL	TOTAL	COAL	GAS	OIL
Panel v-statistic	0.734	1.484*	1.941**	1.186	0.694	2.499**	0.737	1.083
Panel ρ	0.068	-1.573*	-1.387*	0.402	-0.481	-3.152**	-1.321*	-0.167
Panel PP-stat	-2.641**	-5.199**	-3.511**	-2.152**	-3.694**	-7.575**	-4.109**	-3.120**
Panel ADF	-2.557**	-4.534**	-3.699**	-2.298**	-3.065**	-6.748**	-4.640**	-3.588**
Group ρ	1.912	1.191	1.231	2.386	1.647	0.013	1.191	2.120
Group PP	-2.593**	-3.635**	-2.029**	-1.681**	-3.427**	-5.872**	-3.082**	-2.122**
Group ADF	-2.914**	-4.243**	-3.336**	-2.17**	-2.347**	-5.999**	-4.042**	-2.986**

Note: The null hypothesis is no cointegration. * and ** indicate that the estimated parameters are significant at the 10% and 5% levels, respectively.

Table 3. Results of the panel cointegration tests-Full sample

Model: CO_2, POP1465, SEXRATIO1465					Model: CO_2, POP1529, SEXRATIO1529			
	TOTAL	COAL	GAS	OIL	TOTAL	COAL	GAS	OIL
Panel v-statistic	0.428	-0.837	0.429	0.076	2.371**	0.433	1.493*	1.759**
Panel ρ	-0.548	-0.281	-0.918	0.548	-0.955	-0.887	-1.141	0.900
Panel PP-stat	-6.491**	-6.047**	-6.272**	-4.705**	-7.120**	-6.908**	-6.071**	-3.936**
Panel ADF	-7.060**	-4.934**	-7.071**	-5.446**	-6.910**	-6.190**	-7.078**	-6.060**
Group ρ	2.035	2.165	0.803	2.839	1.173	1.751	0.832	2.726
Group PP	-5.897**	-5.514**	-6.690**	-4.357**	-7.608**	-6.288**	-6.423**	-4.889**
Group ADF	-6.943**	-4.619**	-7.247**	-6.449**	-7.131**	-6.579**	-7.883**	-7.426**
Model: CO_2, POP3044, SEXRATIO3044					Model: CO_2, POP4564, SEXRATIO4564			
	TOTAL	COAL	GAS	OIL	TOTAL	COAL	GAS	OIL
Panel v-statistic	1.489*	1.335*	1.500*	1.811**	2.058**	2.116**	-0.182	1.996**
Panel ρ	-0.591	-1.655**	-1.815**	0.324	-0.977	-1.358*	-1.003	-0.462
Panel PP-stat	-6.389**	-8.499**	-7.453**	-4.686**	-7.323**	-7.527**	-6.400**	-5.663**
Panel ADF	-6.654**	-8.773**	-7.977**	-6.433**	-7.026**	-7.967**	-6.880**	-5.686**
Group ρ	1.650	1.277	0.866	2.497	1.396	1.498	1.276	2.547
Group PP	-6.472**	-7.346**	-7.023**	-4.569**	-7.809**	-6.286**	-5.753**	-3.992**
Group ADF	-7.244**	-8.820**	-8.931**	-7.476**	-7.428**	-7.669**	-7.850**	-5.488**

Note: The null hypothesis is no cointegration. * and ** indicate that the estimated parameters are significant at the 10% and 5% levels, respectively.

Table 4. Panel FMOLS estimates and panel causality tests: CO_2 vs. POP

OECD								
Dependent variable	POP1465[a]	λ[b]	POP1529	λ	POP3044	λ	POP4564	λ
ΔTOTAL	-0.51**	-3.54**	-0.06**	-2.89**	0.27**	-3.80**	0.36 **	-0.88
ΔCOAL	-0.30**	-4.59**	0.17**	-4.50**	0.04**	-4.59**	-0.10 **	-5.09**
ΔGAS	-0.05**	-2.62**	-0.15**	-1.20	0.09**	-1.69*	0.08**	-1.42
ΔOIL	-0.16**	-1.62	0.05**	-1.41	0.14**	-2.16**	-0.09**	-1.70*
Non-OECD								
Dependent variable	POP1465	λ	POP1529	λ	POP3044	λ	POP4564	λ
ΔTOTAL	-0.06**	-2.06**	-0.06**	-1.72*	0.10**	-2.50**	0.25**	-1.43
ΔCOAL	-0.00**	-4.01**	-0.03	-0.58	0.03*	-2.97**	0.05**	-0.95
ΔGAS	-0.01**	-1.04	-0.01**	-1.09	0.08**	-0.99	0.18**	-0.82
ΔOIL	-0.03**	-1.53	-0.03**	-1.48	0.03**	-1.66*	0.09**	-1.36
Full Sample								
Dependent variable	POP1465	λ	POP1529	λ	POP3044	λ	POP4564	λ
ΔTOTAL	-0.25**	-3.77**	-0.01**	-2.68**	0.17**	-5.63**	0.11**	-2.933**
ΔCOAL	-0.17**	-5.94**	0.08*	-5.23**	0.04**	-6.663**	-0.03	-6.123**
ΔGAS	-0.03**	-1.58	-0.08**	-1.38	0.08**	-2.253**	0.13**	-1.30
ΔOIL	-0.08**	-2.61**	0.01	-2.23**	0.07**	-3.503**	0.01**	-2.29**

Note: ** (*) indicates statistical significance at the 5% (10%) level.
[a] Panel FMOLS estimates results are the same with the other sample test results.
[b] λ indicates the long-run cointegrated relationship of the cointegrated process in VECM is the same as the other sample test results.

30-44, and 45-64. SEXRATIO is measured as the ratio of females to males in the population, and are calculated from the female and male population data of each age group.

2.2.1. Results of panel unit root tests and panel cointegration tests

Table 1 reports the findings of the full sample panel unit root tests. We use Levin–Lin–Chu (LLC) and panel ADF tests to examine whether each variable has a panel unit root. The results indicate that POP and SEXRATIO in each group and TOTAL, COAL, GAS and OIL have a unit root in level. On the contrary, the first-differences test results indicating that all variables follow the I(1) processes. We further examine if population, sex ratio, and CO_2 emissions have long-run relationships. Results of the full sample panel cointegration tests are presented in Table 2 and Table 3. The test results imply the existence of a long-run cointegration relationship among variables in the sample countries.

As the cointegration relationship is confirmed in sample countries, we further estimate the parameters of the panel cointegration vector in both the subsamples and full sample. Table 4 shows the panel estimate results for the model that contains the variables of CO_2 and POP when TOTAL, COAL, GAS, and OIL are the dependent variable. The full sample results indicate that for TOTAL the coefficients of POP1465 and POP1529 are significantly negative; conversely, the coefficients of POP3044 and POP4564 are significantly positive, implying that increasing POP1465 and POP1529 will consistently decrease total CO_2 emissions. For COAL, increasing POP1465 will consistently decrease CO_2 emissions; conversely, increasing POP1529 and POP3044 will consistently it. For GAS, the result is similar to TOTAL while OIL, increasing POP1465 will consistently decrease CO_2 emissions; conversely, increasing POP3044 and POP4564 will consistently increase it.

Table 5 exhibits the panel FMOLS results when the variable SEXRATIO is added. The results indicate that for TOTAL the coefficients of POP1465 and POP1529 are significantly negative; the coefficients of POP3044 and POP4564 are estimated to be the opposite, which are similar to the results shown in Table 4. Specifically, for COAL, only increasing POP1465 will consistently decrease COAL, while increasing POP1529, POP3044 and POP4564 will consistently increase it. For GAS, the results are similar to TOTAL. For OIL, the results illustrate that POP1465 negative impacts on OIL while POP3044 and have positive impacts on it.

In Table 4 the panel FMOLS results of TOTAL and GAS in the OECD countries are consistent with the full sample test results. For COAL and OIL, the results indicate that increasing POP1465 and POP4564 will consistently decrease COAL and OIL. The test results in non-OECD countries seem more consistent for different categories of CO_2 emissions. From the test results, except for the non-significant result for COAL of age group POP1529, increasing POP1465 and POP1529 will consistently decrease CO_2 emissions, while those for POP3044 and POP4564 run conversly.

Table 5 Panel FMOLS and panel causality tests results: CO_2, POP and SEXRATIO

OECD												
Dependent variable	POP1465[a]	SEXRATIO1465[a]	λ^b	POP1529[a]	SEXRATIO1529[a]	λ^b	POP3044[a]	SEXRATIO3044[a]	λ^b	POP4564[a]	SEXRATIO456[a]	λ^b
ΔTOTAL	-0.60**	28.10**	-2.61**	0.23**	36.62	-2.86**	0.21**	-28.27**	-3.50**	0.00**	-1.80**	-3.57**
ΔCOAL	-0.28**	24.23**	-4.61**	0.22**	16.98	-4.76**	0.04 **	-27.43**	-4.41**	0.02	16.10**	-5.03**
ΔGAS	-0.11**	-6.65**	-2.10**	-0.14**	-4.08**	-1.056	0.05**	-7.39**	-1.65*	0.04**	-14.95**	-1.39
ΔOIL	-0.22**	11.07**	-1.25	0.16**	25.41	-1.41	0.11**	5.37**	-2.09**	-0.07**	-3.00**	-1.80*

Non-OECD												
Dependent variable	POP1465	SEXRATIO1465	λ	POP1529	SEXRATIO1529	λ	POP3044	SEXRATIO3044	λ	POP4564	SEXRATIO4564	λ
ΔTOTAL	-0.10**	14.01	-2.46**	-0.12**	-7.84**	-3.36**	0.05**	1.15**	-4.68**	0.17**	8.15	-4.22**
ΔCOAL	-0.04**	3.46**	-1.09	-0.04**	-1.01**	-0.94	-0.05**	-11.36**	-3.30**	-0.02**	8.91**	-0.84
ΔGAS	-0.04**	7.32	-1.29	-0.07**	-4.48**	-2.51**	0.10**	-3.61*	-3.34**	0.15**	-4.64**	-3.22**
ΔOIL	-0.05**	5.47	-1.58	-0.05**	-3.65**	-1.76*	0.02**	-3.45**	-2.16**	0.08	6.03	-2.39**

Full Sample												
Dependent variable	POP1465[a]	SEXRATIO1465	λ^b	POP1529	SEXRATIO1529	λ	POP3044	SEXRATIO3044	λ	POP4564	SEXRATIO4564	λ
ΔTOTAL	-0.31**	19.93**	-3.85**	-0.02**	-10.85**	-4.01**	0.12**	11.21**	-6.45**	0.10**	-3.97**	-4.82**
ΔCOAL	-0.17**	14.41**	-5.21**	0.10**	-8.48**	-5.53**	0.00**	-9.09**	-6.65**	0.00**	12.70**	-6.10**
ΔGAS	-0.07**	0.21**	-2.16**	-0.10**	-4.28**	-3.31**	0.07**	5.53**	-4.820**	0.09**	-7.53**	-3.86**
ΔOIL	-0.12**	7.83**	-2.77**	0.04	-8.56	-2.40**	0.06**	0.25**	-3.68**	0.01	-2.23	-2.93**

Note: ** (*) indicates statistical significance at the 5% (10%) level.

[a] The same as Table 4; [b] the same as Table 4.

The test results in Table 5 show that there are some differences when we take SEXRATIO into account. In OECD countries, the results of GAS and OIL are consistent with the results shown in Table 4, but for COAL the coefficient of age group POP4564 is insignificant. For TOTAL, the result indicate that increasing POP1529 will consistently raise total CO_2 emissions. In non-OECD countries, the results of TOTAL and GAS are consistent with the results shown in Table 4, but for OIL the coefficient of age group POP4564 is insignificant. For COAL, the result indicate that when we consider the role of SEXRATIO, increasing the population will consistently raise CO_2 emissions. Based on the result of the panel FMOLS estimate, POP, SEXRATIO, and CO_2 emissions exhibit long-run relationships.

2.2.2. Panel causality test results

When the long-run cointegrated relationships among these variables are confirmed, we further implement the causality tests using VECM to estimate the causalities among POP, SEXRATIO, and CO_2 emissions.

$$\Delta CO_{2_{it}} = \theta_{1i} + \lambda_1 \varepsilon_{it-1} + \sum_k \theta_{11k} \Delta CO_{2\,it-k} + \sum_k \theta_{12k} \Delta POP_{it-k} + u_{1it} \quad (3)$$

$$\Delta CO_{2_{it}} = \theta_{2i} + \lambda_1 \varepsilon_{it-1} + \sum_k \theta_{21k} \Delta CO_{2\,it-k} + \sum_k \theta_{22k} \Delta POP_{it-k} + \sum_k \theta_{23k} \Delta SEXRATIO_{it-k} + u_{2it} \quad (4)$$

Here, the variables in the models are defined above. Based on these models, we test the significance of the coefficients of dependent CO_2 emissions (TOTAL, COAL, GAS, and OIL) in equations (3), and (4) to examine the directions of causation. We test in equations (3) and (4) for long-run causality to investigate whether there exists causality among CO_2, POP, and SEXRATIO. The estimator in Table 4 and Table 5 presents the panel causality test results among variables. In the full sample test in table 4, for TOTAL, the evidence shows that higher POP1465 and POP1529 contribute to a decline of CO_2 emissions, however, higher POP3044 and POP4564 lead to greater CO_2 emissions in the long run. One possible reason is that, young people (aged less than 20) and old people (aged 65 and above) exhibit higher preferences for air quality (Menz and Welsch, 2010; Zhang, et al., 2018). Compared to working-age people, young people are not at their working age and older people past their peak working years consume fewer energy (Hasimoglu and Aksakal, 2015).

Menz and Welsch (2012) raised a different opinion and claimed that people in the intermediate age group emit less emissions than younger and older people. This difference is probably because their sample spans the period 1960-2005, whereas the people in that group have become old in our sample. Moreover, they pointed out that for the general public in that period, people were unaware of the danger of CO_2 emissions on the environment, and that older people emit less today than they did in the past. For different sources of CO_2 emissions, higher POP1465 contributes to a drop in CO_2 emissions; conversely, higher POP1529 and POP3044 lead to greater CO_2 emissions from COAL. For GAS, higher POP3044 contributes to increased CO_2 emissions. For OIL, higher POP1465 contributes to a decline in CO_2 emissions, but the POP3044 and POP4564 effects are the reverse.

We note that the CO_2 emissions from different fuel combustions mainly come from different age groups. One reason may be that most CO_2 emissions of each sector that directly relate to people's lives are derived from different fuel combustion. About 65.5% of coal is primarily used for the generation of electricity and commercial heat (IEA Statistics, 2017); with the quick pace of life, people's sleeping times are being shortened, which may lead to increasing electricity consumption of intermediate age groups, and the age trend is getting younger. According to IEA's investigation, the largest contribution to the increase in oil product demand comes from motor gasoline. In private travel, compared to young and older cohorts, people of the intermediate age groups tend to travel more, (Menz and Welsch, 2012).

In Table 5, for TOTAL the evidence shows that greater POP1465 and POP1529 decrease CO_2 emissions, however, greater POP3044 and POP4564 lead to increased CO_2 emissions in the long run, and the same goes for GAS. For GAS, the long-run causality between population and CO_2 emissions becomes more significant when adding the variable SEXRATIO. For COAL, the results indicate that greater POP1465 contributes to lower CO_2 emissions, conversely, other groups contribute to increase CO_2 emissions. Different from the test results of TOTAL, POP1529 increases CO_2 emissions from coal; one important reason may be that, young childless couples, young single people (aged under 30), tenants in social or private housing with one or two rooms (smaller than 70 m^2) representing high electricity consumers(Lévy and Belaïd, 2018), residential electricity consumption is the main application of coal combustion (IEA statistics, 2017). pointed out that. For OIL, higher POP1465 contributes to lower CO_2 emissions, but higher POP3044 increases CO_2 emissions.

The OECD and non-OECD results in Table 4 and Table 5 show the panel cointegration test and long-run cointegrated relationship for the sub-samples. From the analysis of the results of OECD and non-OECD countries in table 4, we notice two obvious differences between them. First, the causality of population and CO_2 emissions from gas combustion is not confirmed in non-OECD countries, probably because the reasons for gas causing CO_2 emissions are seemingly complex. Second, the groups of people that produce CO_2 emissions by coal consumption in OECD countries are younger than those in non-OECD countries, probably because mostly young people are working in informal sectors or in the agriculture sector in developing countries (Djankov and Ramalho, 2009; Choudhry, et al., 2012). This work pattern may consume less fuel compared to developed countries (Das, et al., 2014).

Compare to Table 4, the results in Table 5 indicate that when SEXRATIO added in the model, some relationships between population and CO_2 emissions become clearer. For TOTAL in both OECD and non-OECD countries, higher POP4564 contributes to greater CO_2 emissions. It is worth noting that a higher share of people aged 15 to 29 in OECD countries emits more CO_2 emissions when we take gender into account. A possible reason may be that in OECD countries, young women participate in more economic activities than non-OECD countries (Gaddis and Klasen, 2014). For COAL, the coefficient of POP4564 is statistically not significant, indicating that the relationship between POP4564 and CO_2 emissions needs more research in OECD countries. For GAS, in non-OECD countries, larger POP1529 decreases CO_2 emissions, while POP3044 and POP4564 increase CO_2 emissions. For OIL, the results are the same as Table 4 in OECD countries. In non-OECD countries, except for POP3044, higher POP1529 also decreases CO_2 emissions.

2.3. Policy implications

Based on the empirical results above, we can draw some policy implications about the relationship between population age structure and CO_2 emissions as well as the influence of a country's sex ratio on that relationship. The results indicate that total CO_2 emissions mainly come from working-aged (between 30 and 64) people. Countries should implement various carbon policies to promote low carbon technological innovation in the manufacturing industry in the production process (Kang, et al., 2018). The *green travel* behavior characterized by travel modes that take up low energy (Yang, et al., 2017). Governments should offer convenient and green modes of transportation to promote *green travel*. Countries with a younger population may provide a plentiful labor force for production and operating activities in the future and should offer education and publicity to deepen the environmental awareness and green consumption pattern. The population aging of countries to some extent decreases CO_2 emissions, but the aging process implies reduced labor supply (Wei, et al., 2018). As such, countries with population aging should take action to improve energy use efficiency, such as developing new technology (Fathabadi, 2015) and improving government efficiency (Chang, et al., 2018).

The impact of age structure on CO_2 emissions is heterogeneous across countries of different position in the development process as well as sources of CO_2 emissions. The energy consumed by people aged between 30 and 64 contributes more to CO_2 emissions in both OECD countries and non-OECD countries, but there exists little difference in age groups when we focus on different sources of CO_2 emissions. In OECD countries, CO_2 emissions from burning coal mainly come from people aged between 15 and 44; from gas mainly from people aged between 30 and 64; and from oil mainly from people aged between 30 and 44. In non-OECD countries, CO_2 emissions from burning coal mainly come from people aged between 30 and 64 and that from oil mainly come from people aged between 30 and 44; the long-run causality between GAS and CO_2 emissions is not significant. The change in population age structure influences the energy consumption structure, and governments should forecast energy consumption and CO_2 emissions dependent upon the change of their country's age structure in order to maximize the effects of an energy optimization policy. Acceleration of the population aging process is more apparent in developed countries than in developing countries (Menz and Welsch, 2012). In OECD countries, renewable energy has helped decrease gas combustion by people heating households, which is one of the main source of gas combustion. Non-OECD countries' coal consumption is far more than OECD countries, and the coal consumption by intermediate age groups (between 30 and 64) is more than other groups. Thus, governments should consider to decrease coal consumption in the electricity sector and replace it by other fuels, such as that used by the iron and steel industry in China and India (IEA statistics, 2017).

When we take SEXRATIO into account, the causality between age structure and CO_2 emissions becomes more significant, especially for long-run causality between POP and GAS. In non-OECD countries, although a higher population aged between 30 and 64 contributes to greater CO_2 emissions, an increase in the ratio of the female population could mitigate the relationship. From IEA Statistics (2017), non-OECD countries have consumed gas more than OECD countries since 2008. Thus, countries suffering from a gender imbalance should attach importance to women's influence on the environment and give them more opportunities to help decrease environmental hazards (Chukwukere and Onyenechere, 2015).

According to the analysis above, we notice that except for the effect of POP3044 from COAL in non-OECD countries in Table 5, increasing the other group of women is unable to decrease CO_2 emissions when we consider the sex ratio. Even though women have an important role in their local environmental protection, the effects of these preferences depend on how they are put into practice. Women's participation in the decision-making process and have higher political status may prove invaluable for addressing climate change(Ergas and York, 2012; Chukwukere and Onyenechere, 2015). Because of the different levels of economic development and gender inequality between OECD and non-OECD countries, women in some countries are underrepresented in the climate change discussion. Governments should listen more to women's suggestions on the environmental problem, and a certain proportion of decision-making positions given to women could guarantee their voices are not ignored. Strengthening the education of women, especially in regards to environmental knowledge, will support the due role that women play in this regard.

4. Conclusion

This paper has tested the effects of age structure on CO_2 emissions and investigated the role of gender in that relationship. We utilize the panel cointegration tests to examine the co-movement and causality among age structure, gender, and CO_2 emissions for 29 OECD countries and 40 non-OECD countries for the period 1990-2014. Generally speaking, we find that younger (less than 30) and older (65 and above) people emit less than people in the intermediate age group in full sample. The difference in CO_2 emissions depends on the age structure of each country.
The results also indicate that the main type of energy consumption causes different results in the relationship between age structure and CO_2 emissions. As countries' energy structure changes in the future, the effect of age structure on CO_2 emissions may change in different periods. Thus, demographic and energy structure changes should be considered together. Our evidence also suggests that gender should be included in the research on the relationship between demographics and CO_2 emissions. For a gender's influence on the environment, studies should consider not only the amount of women, but also their economic and political status in their country. The findings of this study offer some suggestions to governments.

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