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The Impact of Air Quality on Population Migration

Wpływ jakości powietrza na migracje ludności

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Abstract

Based on annual panel data of OECD countries from 1995 to 2014, this paper analyzes the impact of air quality (including per capita CO_2, PM2.5, and SO emissions) on the immigrant population through a panel fixed-effect model, while employing control factors such as GDP, unemployment rate, and education level. Overall, we provide evidence that air quality is a key determinant of immigration in the selected countries, and in particular the host country's emissions have a negative impact on immigrants. Greater emissions imply fewer immigrants, while fewer emissions denote more immigrants. Our findings provide countries with a way to more accurately estimate migrant inflow and offer an idea for OECD members on how to attract immigrants via an improvement in environmental quality.

Key words: immigration, air quality, emissions, OECD
JEL Codes: F22, Q53, C23

Streszczenie

Na podstawie rocznych danych panelowych krajów OECD za lata 1995-2014 w niniejszym artykule dokonano analizy wpływu jakości powietrza (w tym CO_2 per capita, emisje PM2,5 i emisje SO) na populację imigrantów za pomocą panelu, biorąc pod uwagę czynniki, takie jak PKB, stopa bezrobocia i poziom wykształcenia. Dostarczamy dowodów, że jakość powietrza jest kluczowym czynnikiem determinującym migrację w wybranych krajach, a emisje z kraju przyjmującego mają negatywny wpływ na imigrantów. Większe emisje oznaczają mniej imigrantów, a mniej emisji oznacza więcej imigrantów. Nasze ustalenia pomogą poszczególnym krajom na dokładniejsze oszacowanie napływu migrantów, a zarazem wskazują członkom OECD, że poprzez poprawę jakości środowiska można przyciągnąć więcej emigrantów.

Słowa kluczowe: imigracja, jakość powietrza, emisje, OECD

1. Introduction

With the publishing of *The Silent Spring* (Carson, 1962), environmental issues for the first time became the focus of attention throughout society. While studies on environment and population mainly reflect the relationship between environment and population size, pollution and mortality, population and economy (Lamsal et al., 2013; Ghanem, 2018), few papers look at the correlation between environment and population mobility.

Our research contributes to this strand of the literature in several aspects. In the beginning, we first investigate the potential relationship between air quality and immigration, thus enriching the research on immigration and expanding the area of research concerning the environment. The second contribution is that we analyze the impact of air quality on immigration in some OECD countries (since most of the selected sample countries are developed countries, it can be regarded as the relationship in developed countries). Moreover, the samples we use consist of updated panel data covering 24 countries between 1995 to 2014, instead of focusing on one country or a small number of countries. Finally, we also test the impact of air quality on immigration in the sample countries at different time periods, among geographically densely distributed sample countries, and under the intervention of different political parties, thus proving the robustness of the model.

Our hypothesis is that air pollution has a negative impact on immigrants, which may come from the following two channels. The first channel of effect is through the industrial structure and income channel. For developed countries and some developing countries, higher air quality often represents a greater level of industrial structure (Huang, 2009; Mi et al., 2015). Many studies in the literature have showed a stable relationship between industrial structure and economic development (Gan et al., 2011; Zhang et al., 2014). Countries with a reasonable industrial structure tend to have a higher level of economic development and higher per capita income, which lead to positive immigration inflows.

The second channel of effect is health factors. A large amount of literature has indicated that air pollution poses a great threat to health, and people's health needs are usually one of the main factors to be considered when choosing migration destinations (Khereis et al., 2017; Zheng et al., 2019). Therefore, air pollution affects people's preferences for making migration decisions in a way that threatens human health, thus affecting immigrant inflows.

Some recent papers have discussed the relationship between environment and migration, but in their discussions, migration often seems to be defined as a problem or a threat. Myers (2002) estimated that until 1995, about 25 million people worldwide were displaced by environmental changes. This figure was subsequently cited in *the Stern Review on the Economics of Climate Change* (2007) and adopted by many campaigns and advocacy groups. According to the push-pull theory of population migration, we believe that if environmental refugees are *pushed* by their own harsh environment, then natural migration is *pulled* by the two channels assumed in this paper.

The rest of this research runs as follows. Section 2 reviews the literature on environment and population, summarizes the theoretical perspectives of international migration and environment, and puts forward the hypotheses to be tested. Section 3 introduces the data and empirical methods used in greater detail. The results are discussed in Section 4 and summarized in Section 5.

2. Literature review

Research on the environment and population mainly focuses on the change in population quantity, especially the impact of population size and growth on the environment. The earliest IPAT model proposed by Ehrlich and Holdren (1972) is representative of this field.

Jorgenson and Clark (2010) used panel data from 1960-2005 to examine the temporal stability of the population/ environment relationship, finding that the temporal stability generally holds for both developed countries and less-developed countries. On the basis of previous literature, Harper (2013) discussed the impact of population aging and population migration on the environment and considered that there is an interactive relationship between them.

Some scholars have also studied the impact of environmental changes on population. Kummu and Varis (2010) finding that less than 1/8 of the human population live south of the equator while around 50% of the population dwell within the area between 20°N and 40°N, where also most of the world's development and poverty-related problems are located. Cesur et al. (2016) explored the experimental design provided by Turkey's natural gas expansion and found that air quality improved by the conversion of coal to natural gas, significantly reducing infant mortality.

A few papers have dealt with the relationship between environment and other aspects of population, such as environment and population structure as well as environment and population mobility. Studies on the relationship between environment and population mobility have some limitations, such as the selection and methods of data samples. In order to overcome the limitations of previous studies, we collate the panel data of OECD countries from 1995 to 2014 and use the annual inflow of immigrants to represent the population flow index and employ annual per capita CO2, PM2.5, and SO emissions to represent the air quality index. The fixed effect model allows us to verify the relationship between environment and population flow, which fills the gap in the literature on this issue.

3. Data and methodology

3.1. Data

Compared with traditional cross-sectional data or time series data, panel data increase the degrees of freedom and reduce the collinearity between explanatory variables, thus improving the effectiveness of empirical estimation (Hassan et al., 2011; Dimitrova et al., 2015). Therefore, based on panel data of 24 OECD countries from 1995 to 2014, we analyze the impact of air pollution on the inflows of immigrants. Most data come from the OECD official database and the World Bank's World Development Indicators System. Table 1 gives a detailed description of variables and data sources.

3.1.1. Dependent variable

Following studies such as Hatton and Williamson (2005), we use immigration (inflows of foreign population by Nationality, in tens of thousands of people) as an indicator of population mobility. Normally, the national estimate of this indicator is based on population registration or residence permit data.

Table 1. Definitions of variables and data sources

Variable	Definition	Source
Immigration	Inflows of foreign population by nationality (tens of thousands of people)	OECD official database
CO_2 emissions	Metric tons per capita / year	OECD official database
$PM_{2.5}$ emissions	Metric tons per capita / year	OECD official database
SO emissions	Metric tons per capita / year	OECD official database
Unemployment	Unemployment, total (% of total labor force) (modeled ILO estimate)	World Bank. World Development Indicators
Log (GDP)	GDP per capita (constant 2010 US$)	World Bank. World Development Indicators
Education	Government expenditure on education, total (% of GDP)	World Bank. World Development Indicators
Medical	Numbers of physicians (per 1,000 people)	World Bank. World Development Indicators
Urbanization	Urban population (% of total)	World Bank. World Development Indicators
Political stability	External conflict	ICRG Historical Data by PRS Group

3.1.2. Explanatory variables

Because the purpose of this study is to examine the relationship between air quality and immigration population, we take CO_2, PM2.5, and SO emissions as three key independent variables. Specifically, while the dependent variable is immigration, in order to maintain consistency and comparability of data, CO_2, PM2.5, and SO emissions (metric tons per capita / year) are taken as specific explanatory variables in the model. The following control variables are included in our study.

Unemployment: On the basis of previous studies (Mete, 2007), we use unemployment rate indicators to reflect the employment situation of the labor force in various countries.

Per capita GDP: GDP usually reflects the overall level of a country's economic development (Boubtane et al., 2013; Vargas-Silva, 2017). we use the logarithmic form of per capita GDP (constant 2010 US$) to evaluate the economic growth of various countries.

Education: Improvement in education level, especially higher education, helps reduce labor exports and increase labor imports (Lewer and berg, 2008; Jackson, 2015). Due to data availability, we choose the proportion of government investment in education to GDP to reflect the level of education.

Medical: Sundquist (2001) and Moreno et al (2016) pointed out that an important driver of international migration is the level of health care in the target country of immigration. Therefore, following Cebula (2010) and others, we use the number of physicians per one thousand people as an indicator of the medical level of a country or region.

Urbanization: Some scholars believe that urbanization increases the attraction of migrants (Vij, 2012). Therefore, on the basis of these studies, we use the proportion of urban population to total population to reflect the urbanization rate.

Political stability: Through the research of some scholars (Essuman-Johnson, 2006), We believe that individuals tend to have a more stable political environment when making immigration decisions. This paper uses the external conflict index for a period of time to measure the stability of a regime.

3.2. Descriptive statistics

Table 2 gives the descriptive statistics of the variables. We can see that the mean value of Immigration is 16.068, the standard deviation is 24.786, the minimum value is 0.925, and the maximum value is 134.253, indicating that all sample countries are inflow countries, and the migration gap between countries is very large. The explanatory variables are CO_2, PM2.5, and SO Emissions. The mean values of these variables are 9.652, 0.006, and 0.026, the standard deviations are 4.486, 0.010, and 0.041, the minimum values are 3.538, 0.00008, and 0.0001, and the maximum values are 24.824, 0.062, and 0.264, respectively. This shows that although the air pollution emissions of OECD member countries are generally low, the internal differences are still not low.

Figure 1 shows the trend of migrant inflows from 1995 to 2014. Except for the Slovak Republic, the annual migration of residents in most sample countries has been on the rise since 1995, peaking around 2006 to 2008 and then declining in some countries. In 2014, the overall annual migration of residents is still greater than that in 1995, which shows that the sample countries have a sustained attraction for migrants.

Figure 2 shows the trend of total immigration and total CO2, PM2.5, and SO emissions in all sample countries from 1995 to 2014. We can see that the to-

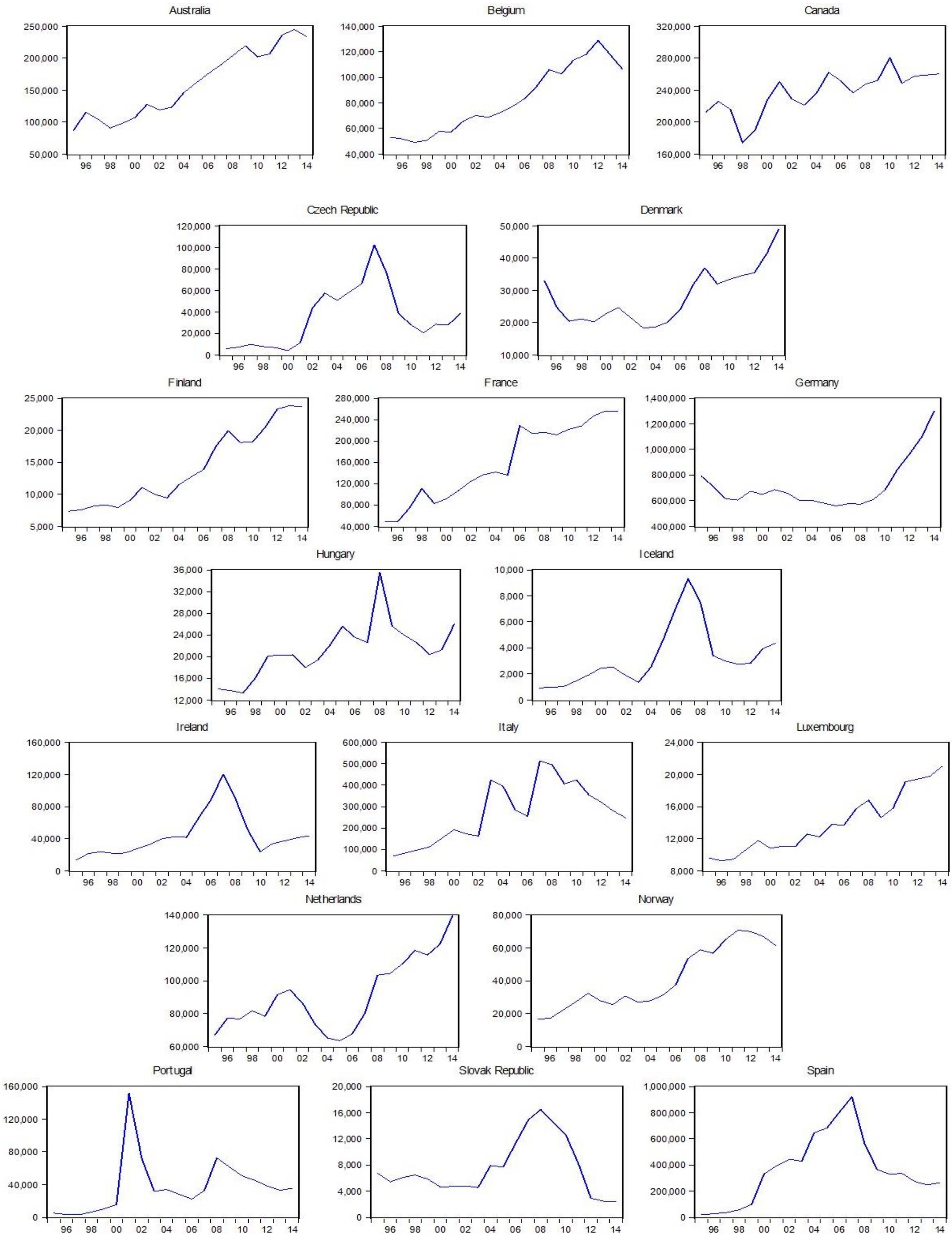

Figure 1. Plots of *IM* for OECD countries, 1995-2014, part I

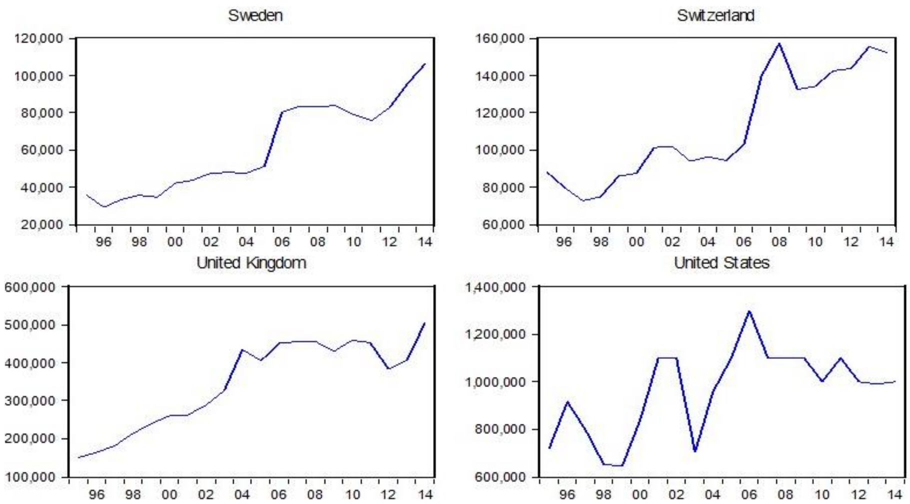

Figure 1. Plots of *IM* for OECD countries, 1995-2014, part II

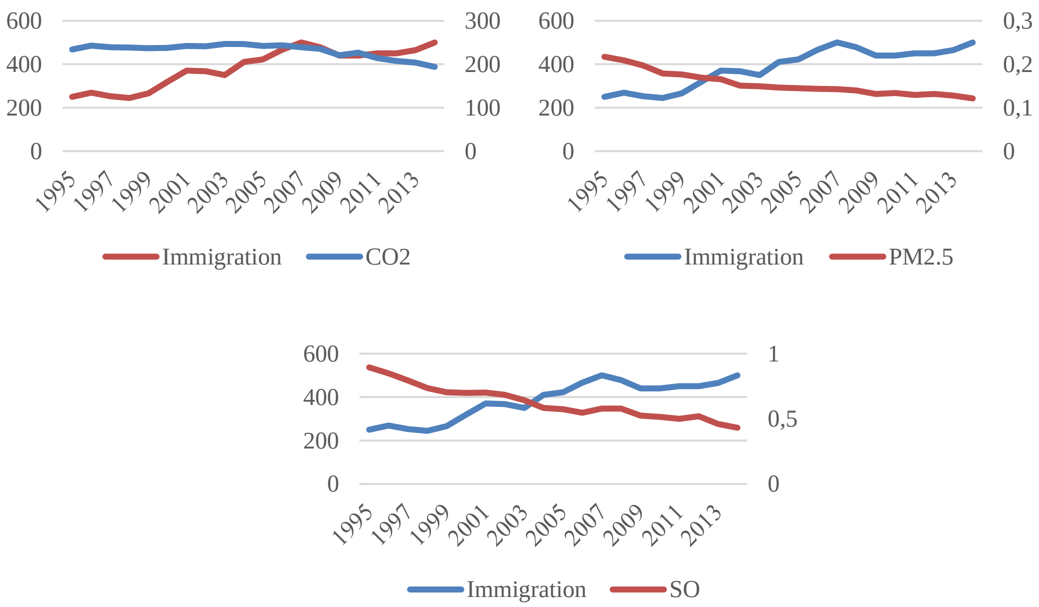

Figure 2. Trend of Migrant Population and Emission

Table 2. Descriptive statistics of the model's variables

Variable	Observations	Mean	Std. Dev	Min	Max
Immigration	480	16.068	24.786	0.092	134.253
CO_2 emissions	480	9.652	4.486	3.538	24.824
$PM_{2.5}$emissions	480	0.006	0.010	0.00008	0.062
SO emissions	480	0.026	0.041	0.0001	0.264
Unemployment	480	7.532	3.871	1.8	26.090
Log (GDP)	480	10.481	0.587	8.925	11.625
Education	480	5.305	1.151	2.973	8.559
Medical	480	3.149	0.684	1.2	4.857
Urbanization	480	77.740	10.526	51.109	97.833
Political stability	480	10.642	1.352	4.380	12

tal immigration trend of 24 OECD countries in this period is rising, while the emissions of CO_2, PM2.5, and SO are decreasing in this period. We thus can make the hypothesis that there is a negative correlation between them in our sample countries.

3.3. Empirical methodology
Owing to the main purpose of our study is to investigate the impacts of air quality in a country on the inflows of immigration population by nationality and considering the huge difference of the various variables, we take the natural logarithm of GDP in the actual estimation process. Therefore, the panel data model is:

$$IM_{i,t} = \alpha_0 + \alpha_1 EM_{i,t} + \gamma Z_{i,t} + \mu_i + \nu_i + \varepsilon_{i,t} \quad (1)$$

In equation (2), IM stands for immigration, which measures the number of immigrants. EM, including $CO_2, PM_{2.5},$ and SO emissions, respectively, are the main independent variables. Z is a vector that affects the control variables of immigration, μ_i and ν_i are fixed effect variables of time and region, respectively, and $\varepsilon_{i,t}$ is the error term.

4. Empirical results

4.1. The panel fixed-effect model
Tables 3, 4, and 5 list the results of the three different emissions' effects on immigration in the fixed effect model from the panel data, respectively. In the process of regression analysis, we incorporate control variables into the model respectively.

First, in Table 3, The estimation results confirm that the coefficient of CO_2 *emissions* is negative and significant at the 10% level regardless of adding any control variables, proving that immigration rises under lower CO_2 *emissions* and declines under higher CO_2 *emissions*. In some sense, this confirms the view that population is related to CO_2 *emissions* (Jane et al., 2009; Jiang and Hardee, 2011). Interestingly, unlike population size, which has a positive impact on CO_2 *emissions*, CO_2 *emissions* have a negative impact on mobile populations. This result validates the previous hypothesis about the influence of environment on industrial structure and income channels.[1]

Table 4 and Table 5 are consistent with Table 3, and so we add the same control variables in order. Table 4 shows that the coefficient of $PM_{2.5}$ *emissions* is negative and significant at the 1% level regardless of adding any control variables, proving that $PM_{2.5}$ *emissions* have a strong negative impact on immigration; with an increase of $PM_{2.5}$ *emissions*, the migrant population is significantly reduced. This result confirms another channel for environmental impact migration, as the environment affects the decision over immigration by influencing people's health.[2]

The results listed in Table 5 are similar to those in Table 4, we speculate that the similarity of the results may be due to the similarity between $PM_{2.5}$ and SO in some sources (coal and oil burning) and per capita emissions.

In terms of control variables, by observing the estimated results of Tables 3, 4, and 5, we find that the coefficients of all control variables, including *unemployment*, *GDP*, *education*, *medical*, *urbanization*, and *political stability* are significant at the 5% level. Among them, *unemployment* has a negative impact on *immigrants*, which is consistent with the results of Mete (2007); *GDP* has a positive impact on *immigrants*, which is consistent with the results of Boubtane et al., (2013) and Vargas-Silva (2017). Moreover, *education* has a positive impact on *immigrants*, which is consistent with the results of Lewer and berg (2008) and Jackson (2016). *Medical* treatment has a positive impact on *immigrants*, which is consistent with the results of Sundquist (2001) and Moreno et al (2016). *Urbanization* has a positive impact on *immigrants*, which is consistent with the results of Vij (2012). Finally, because the *political stability* index we choose is a negative indicator, the results show that *political stability* has a negative impact on *immigration*, which is consistent with Essuman-Johnson (2006).

4.2. Robustness
To further check the robustness of the results, we use three different sub-samples in Table 6; the sub-samples of the 10-year window (1998-2007) in all samples, OECD European member countries, and non-right-wing party countries. First, we chose 1998-2007 because this decade was the time when the Tokyo Protocol came into force and greenhouse gas emissions became the legal obligation of developed countries. Therefore, we believe that these 10 years can better reflect the air quality changes in the samples of OECD countries. Second, we select all sample countries in Europe as sub-samples to test whether there are different impacts between environment and immigration in countries with high geographic densities. Neumayer (2003) made an empirical analysis of the party system and pollution level in 21 OECD countries, presenting results show the non-right-wing political system has a positive impact on the corresponding countries' environment. Therefore, we choose non-right-wing party countries as sample subsets to examine the model's robustness.[3]

The results of these three different subsamples appear in columns (1)/(2)/(3), columns (4)/(5)/(6), and columns (7)/(8)/(9) of Table 6, respectively. It can be seen that the sub-sample results of the 10-year window in columns (1), (2), and (3) show that all explanatory variables are significant at least at the 10% level. It can be roughly explained during the 10-year period that the immigrant population of the sample countries decreases with the increase of emissions. The results in columns (4), (5), and (6) of the sub-sample countries in Europe are consistent with those

[1] The first channel's details are on page 3.
[2] The second channel's details are on page 3.
[3] The non-right-wing party countries defined in this paper are those in which the left-wing party or the neutral party has been in power for more than half of the time from 1995 to 2014.

Table 3. Estimation results: panel fixed effect model (CO_2 emissions)

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
CO_2emissions	-1.602*** (0.000)	-0.955** (0.018)	-0.789* (0.054)	-0.858** (0.034)	-0.815** (0.042)	-0.721* (0.070)
Unemployment	-1.595*** (0.000)	-1.289*** (0.000)	-1.346*** (0.000)	-1.703*** (0.000)	-1.532*** (0.000)	-1.555*** (0.000)
log(GDP)		0.178*** (0.000)	0.162*** (0.000)	0.113*** (0.004)	0.063 (0.119)	0.021 (0.622)
Education			1.829** (0.027)	1.554* (0.059)	1.184 (0.149)	1.407* (0.084)
Medical				3.735*** (0.002)	2.332* (0.061)	2.307* (0.062)
Urbanization					0.873*** (0.001)	0.784*** (0.002)
Political stability						-1.582*** (0.002)
Constant	0.435*** (0.000)	-1.519*** (0.000)	-1.463*** (0.000)	-1.041** (0.011)	-1.130*** (0.005)	-0.461 (0.308)
F-test (p-value)	44.86***	40.00***	31.49***	27.66***	25.61***	23.84***
R^2	0.165	0.209	0.218	0.235	0.255	0.271
Observation	480	480	480	480	480	480

Notes: The values in parentheses denote the standard errors. *indicates significance at 10%. ** indicates significance at 5%. ***indicates significance at 1%.

Table 4. Estimation results: panel fixed effect model ($PM_{2.5}$ emissions）

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
$PM_{2.5}$emissions	-1.099*** (0.000)	-0.701*** (0.001)	-0.797*** (0.000)	-0.761*** (0.000)	-0.691*** (0.001)	-0.698*** (0.001)
Unemployment	-1.436*** (0.000)	-1.252*** (0.000)	-1.385*** (0.000)	-1.379*** (0.00)	-1.533*** (0.000)	-1.573*** (0.000)
log(GDP)		0.133*** (0.001)	0.0955** (0.021)	0.056 (0.129)	0.017 (0.700)	-0.031 (0.503)
Education			2.545*** (0.002)	2.301*** (0.005)	1..905** (0.019)	2.107*** (0.009)
Medical				3.351*** (0.005)	2.084* (0.092)	2.076* (0.089)
Urbanization					0.806*** (0.001)	0.711*** (0.005)
Political stabi-lity						-1.665*** (0.001)
Constant	0.340*** (0.000)	-1.099** (0.011)	-0.819* (0.061)	-0.506 (0.25)	-0.652 (0.142)	-0.098 (0.842)
F-test (p-value)	56.20***	42.03***	34.61***	29.74***	27.00***	25.32***
R^2	0.199	0.218	0.235	0.248	0.265	0.283
Observation	480	480	480	480	480	480

Notes: same as Table 3.

of the sub-sample countries in the 10-year window. All explanatory variables are significant at least at the 10% level. For the results of the sub-sample of non-right-wing party countries shown in columns (7), (8), and (9), the explanatory variables except CO_2 are significant at least at the 5% level, and the coefficient symbols are consistent with the results of the first two sub-samples. This means that the model has passed three robustness tests, solved the endogenous problem of the model, and confirmed our important conclusion again that the immigrant population of OECD sample countries is affected by the air quality of the host country.

We note that the CO_2 emission results of the three sub-sample countries deviate from those of the whole sample. The positive coefficients in columns (1) and (4) mean that CO_2 emissions have a positive impact on immigrants, while column (7) shows that there is no sufficient reason to believe that CO_2 emissions are related to immigrants. We speculate that the reasons for this result may be the insufficient sample size or the fact that CO_2 emissions do not have a significant impact on human health and do not attract much attention from immigration. The detailed reasons are not discussed in this paper and need to be further studied.

5. Conclusion and policy implications

In order to analyze the relationship between the environment and immigrants, we employ panel data of 24 OECD countries from 1995 to 2014, using CO_2,

Table 5. Estimation results: panel fixed effect model (SO emissions)

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
SOemissions	-1.061*** (0.000)	-0.711*** (0.002)	-0.809*** (0.001)	-0.816*** (0.000)	-0.729*** (0.002)	-0.688*** (0.003)
Unemployment	-1.417*** (0.000)	-1.193*** (0.000)	-1.316*** (0.000)	-1.319*** (0.000)	-1.473*** (0.000)	-1.507*** (0.000)
log(GDP)		0.172*** (0.000)	0.140*** (0.000)	0.093** (0.017)	0.052 (0.204)	0.009 (0.833)
Education			2.505*** (0.002)	2.265*** (0.005)	1.872** (0.021)	2.037** (0.011)
Medical				3.636*** (0.002)	2.362* (0.056)	2.345* (0.056)
Urbanization					0.793*** (0.002)	0.710** (0.005)
Political stability						-1.564*** (0.002)
Constant	0.295*** (0.000)	-1.537*** (0.000)	-1.320*** (0.000)	-0.931** (0.018)	-1.043*** (0.008)	-0.368 (0.405)
F-test (p-value)	47.75***	41.53***	34.12***	29.72***	26.91***	24.96***
R^2	0.173	0.215	0.231	0.247	0.264	0.280
Observation	480	480	480	480	480	480

Notes: same as Table 3.

Table 6. Robustness analysis using possible endogeneity concern: ten-year window, restricted data, and partial samples.

	Ten-year dummy (1998-2007)			**Restricted data (EU)**			**Partial samples (non-right parties)**		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CO_2	0.001* (0.070)			0.001*** (0.004)			-0.0004 (0.139)		
PM_{25}		-1.134*** (0.001)			-0.563* (0.069)			-0.473*** (0.005)	
SO			-0.112** (0.020)			-0.042* (0.065)			-0.111** (0.010)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-test (p-value)	7.99*** (0.000)	8.67*** (0.000)	8.20*** (0.000)	10.42*** (0.000)	10.06*** (0.000)	10.07*** (0.000)	8.26*** (0.000)	9.26*** (0.000)	9.06*** (0.000)
R^2	0.378	0.398	0.384	0.447	0.438	0.438	0.194	0.212	0.208
Observations	264	264	264	380	380	380	260	260	260

Notes: same as Table 3. We do not list the results of all the control variables. The table uses *Yes* to represent all the control variables that passed the test.

$PM_{2.5}$, and SO emissions as explanatory variables to express air quality and inflows of immigration population and set up the panel data fixed effect model. The results show for the 24 OECD sample countries that CO_2, $PM_{2.5}$, and SO emissions have a negative impact on immigration. We propose two hypotheses about the reasons for this relationship. First is the channel of industrial structure and income, and second is the channel of health.

Nordheim (2004) forecasted over the next three decades in Europe, the number of people in the 20–29 age band will fall by 20%, while the number in the 50–64 age group will increase by 25%, labor force participation rates may drop to just 1/3 of those of prime age workers. This huge labor gap means strong demand for immigrants, especially skilled migrants, across Europe. In order to attract more immigrants in the future, we suggest countries should pay more attention to improving their environment, because people with a higher quality of talent demand higher environmental requirements.

This paper further uses the sub-sample sets of 10-year window, European countries, and non-right-wing party countries to test the robustness of the model, and the results are almost the same as the whole sample. This proves the robustness of the model and further illustrates the reliability of the relationship between environment and immigration.

Interestingly, we find that the results of the robustness test using sub-sample sets of right-wing party countries denote that we are not sure about the influence of the environment on immigration, meaning that the party system of the sample countries does have an impact on the domestic environment.

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