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Air Pollution and Internal Migration: Evidence from Iranian Household Survey

Abstract

The purpose of this study is to examine the impact of air pollution (measured by satellite data of Aerosol Optical Depth (AOD)) on net outmigration. Using data from the 2011 and 2016 *National Population and Housing Censuses* for 31 provinces of Iran and applying a panel fixed effects estimation method, our results show that AOD has a positive and significant impact on net outmigration. We also find that higher levels of economic activities in provinces discourage outmigration.

JEL-Codes: Q530, R230.

Keywords: air pollution, migration, Iran.

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1. Introduction

Air pollution in Iran has attracted international attention. The Reuters (May 12, 2016) reports about “Iranian, Indian cities ranked worst for air pollution”. According to VOA news, at the end of 2019 the air pollution reached its critical levels in several major urban areas in Iran, forcing the government to shut down schools and universities for weeks (VOA, 2019). This media coverage reflects the significant challenges of air pollution and its harmful impacts on Iranian citizens.

According to the 2018 Environmental Performance Index (EPI, 2018), Iran was ranked 167 out of 180 countries in terms of air pollution (measured by sulfur oxides (SOX) and nitrogen oxides (NOX)). Es'haq Jahangiri (Iranian First Vice President) notes that the environmental issue is one of the top four most important problems of the country (Radiofarda, 2017). The key sources of air pollution in Iran are transportation, extensive use of fossil fuels, outdated urban fleets of gasoline and diesel vehicles, industrial sources within and close to the city boundaries and natural dust (Hosseini & Shahbazi, 2016).

Diseases associated with air pollution kill about 35,000 people every year in Iran, according to an official at the Environmental Protection Organization (Darvish, 2017). In addition, several studies in Iran have shown that air pollution has harmful impacts on the physical health (e.g. causing asthma, respiratory illness, cardiovascular disease, cancer) and mental health (e.g. causing anxiety and depression) of citizens, reduces labor productivity and students' academic performance (Amanzadeh et al.,

2019; Birjandi & Yousefi, 2017; Neisi et al., 2016; Ghorani-Azam et al., 2016; Hosseini & Shahbazi, 2016). One aspect of the air pollution that is yet to be examined is whether air pollution explains migration behavior across provinces of Iran.

While the air pollution has been one of the important national issues in recent years, the pollution level in Iran varies widely with some provinces like *Sistan and Baluchestan* (located in the southeast of the country) and *Khuzestan* (located in the southwest) are affected significantly. By contrast, northern provinces such as *Mazandaran* and *Gilan* have been facing less severe pollution. Therefore, the considerable cross-sectional variation in air pollution offers an interesting context to test the relationship between air pollution and migration across provinces of Iran.

Over the period of 2006-2016, approximately 9 million Iranians (approximately 11% of the population) left their habitual residence and moved to a new location (mostly within the border of Iran). This raises the question of whether air pollution has pushed away residents from their habitual residences.

The purpose of this study is to examine the impact of air pollution on domestic migration using data from the 2011 and 2016 *National Population and Housing Censuses* for 31 provinces of Iran. While some studies have tested the relationship between air pollution and actual migration (as well as intention to migrate) in China and the US (e.g. Qin & Zhu, 2018; Lu et al., 2018; Chen et al., 2017; Hsieh & Liu, 1983; Kahn, 2002; Cebula & Vedder 1973; Levine et al., 2019), to the best of our knowledge, little is

known about the pollution–internal migration nexus in one of the most polluted regions of the world, the Middle East (Gholipour & Farzanegan, 2018).

In this study, we utilize satellite-based air pollution data from major cities of each province and match them with the migration data (obtained from *2011 and 2016 National Population and Housing Censuses*) to analyze the relationship between air pollution and migration across provinces of Iran. We find that air pollution is one of the key drivers of internal migration across provinces of Iran over the past decade.

The article proceeds as follows: the second section reviews previous studies and develops the hypothesis. The third section describes the data and variables and explains the estimation method; the fourth section presents the findings; and the fifth section concludes the article.

2. Previous studies and hypothesis

Existing studies have shown that air pollution triggers residences' avoidance behavior (e.g. avoiding outdoor activities), defensive expenditure (e.g. spending on air purifiers and facemasks), and migration as coping strategies (Lu, 2020). In terms of migration, several studies find that residents in polluted locations tend to show greater interest in emigration. For example, Qin and Zhu (2018) show that Chinese residents more often search for the word "emigration" on online search engines when the level of air pollution rises by a significant amount. Their study uses data from 153 major Chinese cities in 2014. Likewise, Lu et al. (2018), using survey data collected in 2015, find a positive and strong relationship between smog risk perception (including perceptions

of physical and mental health risk) and migration intention among skilled workers in the Jing-Jin-Ji region of China. Chen et al. (2017) also show that air pollution has a significant impact on changes in inflows and outflows of migration in Chinese counties over 1996-2010 period.

In the US context, Hsieh and Liu (1983) provide evidence that the achievement of better quality of social life and pursuance of better environmental quality are the dominant factors in explaining the interregional migration in the long-run and short-run, respectively. Kahn (2002) shows that reduction in smog problems in the Los Angeles (due to Clean Air Act regulation) and consequently higher quality of life fostered migration flows towards the city. Gawande et al. (2000) find that closeness to hazardous waste sites in the US is a contributing factor in the migration decisions of individuals whose income is higher than a certain level. In a recent study in the US, using information on the career paths of executives at all S&P 1500 firms, Levine et al. (2019) find that air pollution has a positive impact on the migration of highly-valued employees from firms that are geographically close to polluting plants. They also find that executive departures have adverse effects on corporate stock prices. Cebula and Vedder (1973) did not find a strong impact of air pollution on migration within the US metropolitan statistical areas over the 1960-1968 period. Similarly, Hunter (1998) show that US counties which pose high levels of environmental hazards (such as air and water pollution, hazardous waste and superfund sites) do not lose residents at rates greater than those without such hazards. She also finds that counties characterized by high levels of environmental risk have lower in-migration rates than counties with

less hazards. At the international level, Xu and Sylwester (2016) show that immigration to OECD countries from other countries are affected by air pollution in the source countries.

The main argument of the above-mentioned studies is that locations' environmental quality (as an important component of quality of life) plays a role in shaping individuals and households' internal and international migration decisions (Kahn, 2002; Hunter, 2005). This argument is closely related to the theoretical work of Wolpert (1966) which was among the first studies that explain the relationship between non-economic variable (environmental quality) and migration behavior. More specifically, Wolpert (1996) argues that migration is a response to stress experienced from the current residential location, with residential "stressors" including environmental dis-amenities such as pollution, congestion and crime. Wolpert's model suggests that these "stressors" bring about "strain" which may lead to consideration of residential alternatives (Hunter, 2005).

To the best of our knowledge, there is a lack of an empirical examination on the effect of air pollution on internal migration in Iran. There are different factors which are contributing to domestic outmigration in Iran such as economic deprivation, unemployment, and climate change which has shown its effects in the way of frequent droughts, flooding, and sand storms. Understanding internal migration patterns and the role of environmental quality in its development are important for policymakers. The recent nationwide protests in response to increased gasoline prices in Iran showed a major participation of people from the vicinity of larger cities. In these areas around

11 million poor Iranians live without access to many urban amenities (Sinaiee, 2019).

There are a variety of factors that may lead to an expansion of the population around major urban areas in Iran. We contribute to the literature by examining the extent that the economic and environmental issues are fueling the internal outmigration, expanding the slum population in Iran.

Based on our review of the literature and stylized facts of Iran, the main hypothesis is as follows:

Hypothesis: Provinces with higher degrees of air pollution are experiencing a higher level of net outmigration, *ceteris paribus*.

3. Data and estimation method

Data

We use data for 31 provinces in Iran for two years, 2011 and 2016, in which the *National Population and Housing Censuses* are conducted and available.

Dependent variable

The dependent variable of the study is the net outmigration ratio (Gawande et al., 2000). It is defined as the population leaving two major cities of a province net of new arrivals divided by population of major cities. We collected data for the number of inflows and outflows of migration from two major cities of each province of Iran which are available at the 2011 and 2016 *National Population and Housing Censuses*

(conducted by the Statistical Centre of Iran¹). The choice of the 2011 and 2016 censuses for the analysis is based on the availability of inflows and outflows of migration data. We focus on two major cities because the majority of economic activities of each province occur in these cities and data on Aerosol Optical Depth (AOD) are also available for major cities. We total the number of migrations of two major cities as a measure of migration in each province. Figure 1 shows the location of each sample city on Iran's map.

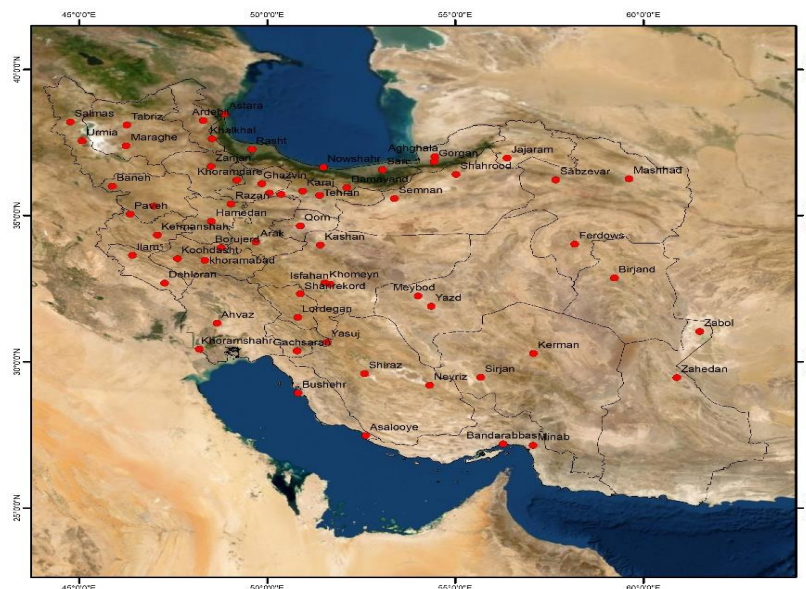


Figure 1. Location of sample cities in Iran's map

Variable of interest

The main explanatory variable of interest is the AOD to measure air pollution. Aerosols are very small solid and liquid particles that are suspended in the atmosphere. The examples of aerosols include dust, sea salts, volcanic ash, smoke

¹ See <https://www.amar.org.ir/english/Population-and-Housing-Censuses>

from wildfires, and pollution from factories. The inhalation of aerosols is often associated with increased morbidity and mortality. The long-run excessive exposures to aerosols lead to higher risks of lung cancer, chronic obstructive pulmonary diseases, and ischaemic heart disease and stroke (Traboulsi et al., 2017).

We use remote sensing data to measure AOD across provinces of Iran. In particular, we employ MODIS (Moderate Resolution Imaging Spectroradiometer) which is a key instrument aboard the Terra (originally known as EOS AM-1) and Aqua (originally known as EOS PM-1) satellites. The Terra MODIS and Aqua MODIS are constantly monitoring the entire Earth's surface. They collect information on global dynamics and processes happening on the land, in the oceans, and in the lower atmosphere.² They measure global aerosol optical depth and optical properties since 2000 (van Donkelaar et al., 2010).

MODIS aerosol products are freely available and are being used in several studies for different purposes. MODIS AOD has shown a good relationship with ground measurements (Mardi et al., 2018; Shi et al., 2019). The source of data to measure AOD in our study of Iranian provinces is NASA Earthdata³. The average AOD values in the study area are illustrated in Figure 2. It shows that the southern part of Iran has suffered more of an impact by air pollution in comparison to the northern part. The main source of AOD in Iran is usually dust storms, except for

² See <https://modis.gsfc.nasa.gov/about/>

³ See <https://earthdata.nasa.gov/>

metropolitan cities like Tehran and Isfahan in which are sources have typically originated from urban activities. The deserts in Iraq, Saudi Arabia, Syria, as well as local soil erosions are the main dust sources of Iran. Therefore, southern and western provinces of Iran have higher AOD than northern provinces. Based on Figure 2, Zahedan, Zabol, Ahvaz, Khorramshahr, and Urmia are the most polluted cities in Iran during the period of our study⁴.

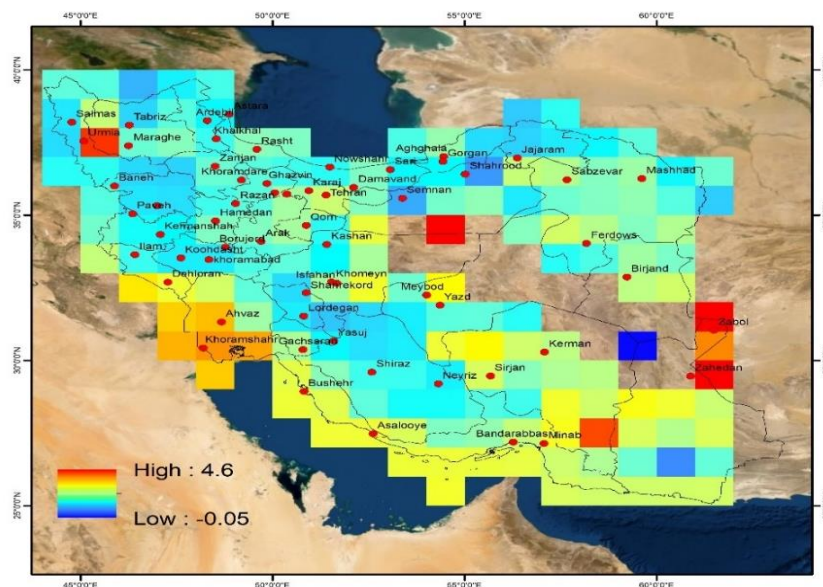


Figure 2. Averaged AOD of cities included in our study over 2007-2016 period

Control variables

In addition to our variable of interest (AOD), we also control for other key determinants of internal net outmigration. The choice of control variables is based on our literature review into the determinants of internal migration and availability of

⁴ We embedded the interactive map and its JavaScript code in Google Earth Engine and it is publicly available: <https://code.earthengine.google.com/31d7026e72b575db9e6d2e33e7769a9a>

data for provinces of Iran. Our control variables include: level of economic activities of the source location (e.g. Docquier & Rapoport, 2012; Hunt, 2006; Xu & Sylwester, 2016); unemployment rate (e.g. Gawande et al., 2000; Karemer et al., 2000; Gallardo-Sejas et al., 2006); availability of medical facilities; and precipitation as proxies for quality amenity and income inequality (e.g. Gallardo-Sejas et al., 2006). Table 1 provides a more detailed description of the variables and data sources.

Estimation method

We apply a panel fixed effects model for estimations⁵. Equation (1) presents the empirical model. The fixed effects account for all time-invariant differences across provinces, such as cultural, traditional or geographical factors which may affect the net migration.

$$\text{EMIGOUT_RATIO}_{it} = \beta_1 \text{AOD}_{it} + \beta_2 X_{it} + v_i + u_{it} \quad (1)$$

where EMIGOUT_RATIO is the number of population leaving two major cities of a province net of new arrivals; AOD is the Aerosol Optical Depth (as a proxy for air pollution); X is a vector that includes the control variables; v_i captures the province-specific effects; $i = 1, \dots, n$ denotes the province; $t = 1, \dots, t$ denotes the time period; β_s are coefficients; and u_{it} is an error term.

⁵ We employed a Hausman (1978) test to compare the fixed and random effects estimates of coefficients. The χ^2 statistic of the test was significant at the 5% level, indicating that fixed effects are appropriate for our models.

Table 1. Description of variables

Notation	Variables	Definition	Data source	Transformation
EMIGOUT_RATIO	net outmigration ratio	Outgoing migration minus incoming migration in two major cities of province divided by population of two major cities of provinces.	Statistical Centre of Iran & Authors' calculation 2011 and 2016 Iranian Population and Housing Censuses	
AOD	Air pollution	It is the average of Aerosol Optical Depth (AOD) for two major cities in each province. For 2011, we use the average of AOD for the period of 2007-2011. For 2016, we use the average of AOD for the period of 2012-2016.	NASA Earthdata	
GDPC	Economic activities	Real gross domestic product per capita. For 2011, we use the average of real GDP per capita for the period of 2007-2011. For 2016, we use the average of real GDP per capita for the period of 2012-2016.	Statistical Centre of Iran	Logarithm
UNEM	Unemployment	Unemployment rate (among population above 10 years old). For 2011, we use the average of unemployment rate for the period of 2007-2011. For 2016, we use the average unemployment rate for the period of 2012-2016.	Statistical Centre of Iran	
HOSPITAL_POP	Medical facilities	Number of active hospital beds divided by population (in million)	Statistical Centre of Iran & Authors' calculation	
RAIN	Average monthly rainfall (millilitre)	For 2011, we use the average of monthly rainfall for the period of 2007-2011. For 2016, we use the average of monthly rainfall for the period of 2012-2016.	The Iran Meteorological Organization	Logarithm
GINI	GINI coefficient	2011 and 2015	Statistical Centre of Iran	

Table 2. Descriptive statistics (before transformation)

	EMIGOUT_RATIO	AOD	GDPC	UNEM	HOSPITAL_POP	RAIN	GINI
Mean	-0.004	0.261	67,708.860	11.635	36.281	305.273	0.320
Maximum	0.061	0.409	222,141.500	19.300	120.661	1,317.180	0.400
Minimum	-0.082	0.163	25,941.560	7.940	4.065	42.820	0.250
Std. Dev.	0.029	0.054	37,290.100	2.587	20.738	239.672	0.034
Observations	62	62	62	62	62	62	62

4. Results

The results of panel fixed effects regressions are presented in Table 3. In each estimation, we include AOD along with other possible determinants of net outmigration. Regardless of which control variables we include in the model, the results indicate that AOD has the expected positive association with EMIGOUT_RATIO and is statistically significant across most specifications. This result supports our hypothesis that provinces with higher levels of air pollution are experiencing more net outmigration. In addition, this finding is consistent with Qin and Zhu (2018), Lu et al. (2018) and Chen et al. (2017) who all show that there is a positive relationship between pollution and actual migration or intention to migrate in China. Our finding also lends support to the theoretical work of Wolpert (1996) which argues that migration is a response to residential stressors such as pollution and traffic congestion.

Among the control variables, the only statistically significant driver of net outmigration is real GDP per capita. Higher levels of income per capita as a measure of economic and business opportunities in source locations is reducing the net outmigration. This finding is consistent with earlier findings in the literature (e.g. Docquier & Rapoport, 2012; Hunt, 2006; Xu & Sylwester 2016). Our regression results also show that medical facilities and precipitation level do not play important roles in net outmigration over the period of study as the coefficients of *hospital facility* and *precipitation* are not significant (see columns 5, 6 and 7 of Table 3).

Model 7 in Table 4 includes all control variables besides our main variable of interest (AOD). The positive association between higher levels of air pollution and outmigration is robust in this general specification. More specifically, the semi-elasticity of EMIGOUT_RATIO with respect to AOD index indicate that when AOD index increases by one unit, EMIGOUT_RATIO increases by approximately 100(0.34) = 34% (see column 7 of Table 3). For instance, while the annual mean AOD of *Khorramshahr* (in *Khuzestan* province) and *Zabol* (in *Sistan and Baluchestan* province) increased from 0.36 and 0.29 in the year 2011 to 0.43 and 0.35 in the year 2016 respectively, their outmigration also increased from 7,905 to 9,872 and from 16,534 to 21,772, respectively. In contrast, for *Nowshahr* (in *Mazandaran* province), while the annual mean AOD was stable around 0.20 between 2011 and 2016, the outmigration was just slightly changed from 6,445 to 6,619, which is consistent with AOD changes.

Table 3. Panel fixed effects regressions

Dependent variable: EMIGOUT_RATIO							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
AOD index	0.237** (2.37)	0.311*** (2.81)	0.247** (2.63)	0.213 (1.62)	0.268*** (2.76)	0.245** (2.48)	0.346** (2.31)
Log of GDP per capita		-0.046*** (-2.89)					-0.046*** (-2.90)
Unemployment			-0.002 (-1.16)				-0.002 (-1.35)
Gini index				0.043 (0.54)			-0.016 (-0.19)
Hospital facility					0.001 (1.61)		0.0002 (0.44)
Log of precipitation						0.016 (0.92)	0.013 (1.24)
Observations	62	62	62	62	62	62	62
R-sq	0.16	0.32	0.20	0.17	0.19	0.19	0.40

Notes: The asterisks *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively. t-statistics are presented in parentheses.

5. Conclusion

In this study, we examine the impact of air pollution using Aerosol Optical Depth index on domestic net outmigration in Iran. Employing panel data of 31 provinces over two periods, 2011 and 2016, our findings suggest that higher levels of air pollution in recent years significantly increase the level of net outmigration from affected provinces. This increasing effect is robust while controlling for other economic and social drivers of internal migration and province fixed effects. Among the control variable, we find that higher levels of income per capita as a measure of economic activities and market size discourages internal outmigration in provinces of Iran.

Internal migration from regions with a degrading environment to other provinces may increase the social and economic burden on the management of receiving regions, increasing informal settlements and marginalization. A destination province like *Tehran* would be impacted by job loss, discrimination/ racism due to not behaving like locals, social/civil pressure by suffering from the excessive use due to more people than it was designed to take, breakdown of culture and traditions due to the diversity, as well as increasing the risk of a contagious disease outbreak. Furthermore, they might be highly vulnerable to outmigration in the near future due to an unsustainable increase in population. In contrast, the home province of *Khuzestan* can be affected by the loss of skilled labor, an insufficient population for investors and social problems by separating dependents.

Our finding shows that policymakers may control the forced internal migration by focusing more on environmental projects and addressing the factors that are contributing to degradation of air quality (particularly within two of the most polluted provinces of Iran, *Khuzestan* and *Sistan and Baluchestan*).

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