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AIR POLLUTION AND MIGRATION IN EUROPEAN CITIES

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ABSTRACT

This article aims to provide new and robust evidence of the effect of air pollution on migration at the level of 70 European cities in the period 2004–2019. We use factor and regression analysis and panel data conducted from Eurobarometer, Eurostat, national statistical offices, and the European Environment Agency. We set a unique approach to examine human migration as we look for a connection between the perceived quality of air of city inhabitants and net migration. The results show that both perceived quality of air and objectively measured pollution can be considered as migration factors. Moreover, we examined that, in general, Eastern European cities attract more migrants than Western European cities and that seaside cities lose more inhabitants due to migration than inland cities, but these differences are not connected to air pollution and thus can be contributed to other non-observed factors.

KEY WORDS

air pollution, migration, European cities, panel regression, factor analysis

JEL CODES

O15, Q53

1 INTRODUCTION

Human migration and its determinants are a widely researched phenomenon. It can be considered as a specific act of human behavior. A certain act of human behavior is a result of the realized intention to perform that behavior. The intention is influenced by the individual's attitude toward the behavior, subjective norms (external expectations) and subjective assessment of the difficulty of performing this behavior, called perceived behavioral control (Ajzen, 1991). This is the so-called "Theory of Planned Behavior", which Gödri and Feleky (2017) applied to the field of migration.

Behavioral theories dealing with human behavior say that an individual, who decides to migrate or not, considers the advantages and disadvantages of realizing migration, external expectations, and the difficulty of realizing migration. But what are the specific factors that influence these parts of a person's decision-making process? Over time, various migration theories have been developed and pointed to the importance of certain factors/determinants, or their groups. Most of them have dealt with the economic factors of migration. Neoclassical macroeconomic theory postulates that people migrate abroad for higher wages. The neoclassical microeconomic theory argues that potential migrants consider the probability of finding a job, the expected level of earnings, and the cost of migration (Massey et al., 1993).

Other theoretical approaches turned attention away from the individual's decision-making. According to the "New Economics of Migration", the decision to migrate is a decision of a group of people (family) and migration arises because of risk diversification. According to the "Dual Labor Market Theory", migration is caused by the demand for foreign labor in receiving economies. Migrants fill job positions mainly in the secondary labor market, where there are generally worse working conditions (Massey et al., 1993).

These (and other) economic theories deal with the economic causes of migration. However, there may be other groups of factors that can cause migration. According to the so-called "Push and Pull Theory", there are factors that "push" a migrant from their place of residence, and, on the other hand, factors that "pull" the migrant to the new destination. In addition to economic factors, these are social and political factors, but also factors related to the state of the environment (Bansak et al., 2021). It is obvious that the level of air pollution can be considered as one of the environmental factors of migration.

Air pollution represents a significant health risk responsible for approximately 400 thousand premature deaths in Europe (EEA, 2019a) and 3.3 mil. premature deaths worldwide (Lelieveld et al., 2015). The perception of health risks resulting from living in an area with air pollution, as well as the problems and diseases already caused by the air pollution, appear to be a significant factor explaining migration from the polluted area (DeGolyer, 2008).

It turns out that air pollution can be a "push" factor for international migration (Xu and Sylwester, 2016) as well as internal migration (Šulák, 2019). Some studies deal with the issue of air pollution and migration on the level of certain cities (DeGolyer, 2008). It turns out that air pollution does not affect all population groups in the same way (Balcar and Šulák, 2020), and thus there are population groups with a greater tendency to migrate due to air pollution.

Based on the literature review (see Chapter 2), we identified research gap regarding the number of studies investigating the relationship between air pollution and migration is significantly lower in the European context. At the same time, most studies focus on migration at the level of provinces, counties, regions or districts, while relatively few works deal with this relationship at the level of cities.

The aim of this paper is to provide new and robust evidence of the effect of air pollution on migration at the level of European cities, thereby contributing to closing the identified research gap. Additionally, we explore if there is a difference in effect of air pollution on migration in capital cities compared to other cities, Eastern European cities compared to Western European cities and seaside cities compared to inland cities.

The literature review will be presented in the following chapter. Chapter 3 presents a description of the used data and methodology. Chapter 4 presents the results and their discussion. The final chapter is a conclusion including suggestions and recommendations for policy makers.

2 LITERATURE REVIEW

Migration is one of the most examined phenomena due to its effect on development of both origin and destination regions, their labor market, social structure, public finance etc. Originally, the empirical studies focused mainly of economic determinants of migration, such as differences in standard of living, wages or unemployment (Mayda, 2010; Pytliková, 2006; Harris and Todaro, 1970; Sjaastad, 1962). At the present, high attention is paid to environmental factors, such as climate change (Cai et al., 2016; Feng et al., 2012), natural disasters (Koubi et al., 2016; Gray and Mueller, 2012) and environmental degradation (Alscher, 2011; Gray, 2011), due to their negative impact on productivity in agriculture leading to migration. Finally, many studies focus on environmental pollution showing its significant effect on migration at international (Xu and Sylwester, 2016), regional (Li et al., 2020) and municipal (Balcar and Šulák, 2020) level. As the impact of pollution on migration represents our main interest, the following paragraphs focus exclusively on this topic.

The air pollution is usually approximated by individual pollutants, with negative effect on human health. The particulate matters (PM_{10} and $PM_{2.5}$), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2) are the most often used. Less often, it is possible to find studies using e.g. benzo(a)pyrene (BaP), ozone (O_3), carbon monoxide (NO) and other less often published substances. All these pollutants are connected with health related issues, such as cardiovascular diseases (PM, SO_2, O_3), irritation of eyes, nose and throat, breathing problems (PM, NO_2, O_3, BaP), lung cancer (PM, BaP), headache and anxiety (SO_2), chronic obstructive pulmonary disease (PM), asthma and reduced lung function (NO_2), and negative impact on the central nervous system (PM), liver, spleen and blood (NO_2) and the reproductive system (PM); for more information see e.g. Sicard et al. (2021), or EEA (2019a). As these pollutants capture only specific type of air pollution, pollution indexes (e.g. Air Quality Index) or other alternative approaches (e.g. Aerosol Optical Dept used in Farzanegan et al., 2023) are used to provide complex information on pollution. The last approach to air pollution approximation is its subjective assessment, such as air quality satisfaction (Rizzo, 2018), perceived impact on one's life (Rüttenauer and Best, 2020), health of children (Chu et al., 2017), or health risk perception (Lu et al., 2018). Although the subjective measures are often questioned in empirical literature, Balcar and Šulák (2020) provided evidence on correlation between air quality perception and the concentration of particular pollutants.

Although we can find evidence on the impact of air pollution on international migration, e.g. migration from low- and middle-income countries to OECD countries (Xu and Sylwester, 2016), the majority of studies investigate the effect of air pollution on internal migration. The most often, we can find studies from China and other developing countries, as they often belong among countries with the most polluted air (World Air Quality Index, 2021). For instance, Chen et al. (2022) showed that 10% increase of pollutant $PM_{2.5}$ leads to degrease of population through migration by 2.8% in Chinese counties. Moreover, they proved that decrease of pollution has lower effect on in-migration that increase of pollution on out-migration. Studies focused on migration of parents with children can be also noted, as having children can increase the importance of pollution for migration behavior. Chu et al. (2017) revealed that the odds of out-migration from Wuhan district are 6 times higher for parents aware of air quality. Li et al. (2020) showed that the increase of $PM_{2.5}$ by 1 $\mu g/m^3$ in destination region decreases the probability of settling down of parents with children and buying a house by 5.2%. However, there is evidence on pollution-driven migration also from other developing countries. For example, Farzanegan et al. (2023) examined the relationship between air pollution, approximated by aerosol optical dept (AOD), and the net out-migration between Iranian regions. They show that the increase of AOD is connected with the increase of the net out-migration from the region.

Although developed countries report lower level of pollution and thus less attention is paid to pollution-driven migration there, we can mention at least some empirical studies on this topic. Cebula and Vedder (1973) represent one of the early studies on pollution-driven migration in the US. This study found no statistically significant relationship between pollution and migration between metropolitan areas. Later studies (Kim, 2019; Hsieh and Liu, 1983; Bozzo et al., 1979), on the other hand, confirmed the relationship between environmental quality and migration. Kim (2019), for example, shows that increase of number of polluted days ($AQI > 150$) by 10 decrease the immigration to more polluted county in California by 1–2 pp, while has no effect on its out-migration. Evidence for European countries is even more rare. Rüttenauer and Best (2020) provide evidence that increase of perceived impact of air pollution on one's life by one level (measured on 5-point scale) leads to 5.8% higher probability of out-migration for individuals with average income, and its effect on out-migration grows with increasing income. Germani et al. (2021) examined the relationship between different air pollutants (NO_x, CO and PM_{10}) and regional migration in Italy and found out that the migration was negatively corelated with air pollution. Evidence for the Czech Republic brings mixed results. Fidrmuc and Huber (2007) found no statistically significant relationship between air pollution in Czech districts (approximated by PM_{10}, SO_2 and NO_x) and migration intention, while Šulák (2019), who focused on real migration behavior in the most polluted districts, found out that 1% increase of SO_2 and NO_x is connected with 2.5‰ increase of out-migration.

Although reviewed studies provide robust picture on the importance of air quality for regional migration, whereas this effect is more pronounced for highly educated individuals (see studies on this topic, e.g. Wang and Wu, 2021; Liu et al., 2021; Levine et al., 2020; Lu et al., 2018; Rizzo, 2018), application of these results for specific conditions of large cities can be questioned. For instance, Guo et al. (2022) show that the effects of air pollution on migration in Chinese cities are stronger among lower-educated people. Unfortunately, the number of studies focused on city level is very limited, especially in European context. In China, temporary workers have 15.1% lower probability of settling down in a city with Air Quality Index higher by 100 points (Liu and Yu, 2020). Qin and Zhu (2018) used alternative approach focused on online searching “emigration” as an approximation of intended out-migration from polluted city. They found out that increase of Air Quality Index by 100 points increase searching of “emigration” by 2.3–4.8% next day. It can be noted that higher absolute level of pollution leads to progressive increase of “emigration” searching. Cui et al. (2019) examined mobility of individuals, approximated by location of their smartphones, in case of rapid increase of air pollution. They revealed that increase of Air Quality Index by 100 points leads to increase of out-migration from cities by 49.6% and this effect was significant even 7 days after the pollution increase. Use of $PM_{2.5}$ brings similar results. The survey in Hong Kong (DeGolyer, 2008) reveals that air pollution causes health problems to inhabitants, increases work absence, premature death and outflow of highly qualified labor work. DeGolyer (2008) reports that 8% of inhabitants of the city plan or consider out-migration, and further 12 % do not exclude this option. This share reaches 30–40% for individuals with university and postgraduate education. For evidence from Europe, we can mention two studies from the Czech Republic. Mikula and Pytliková (2020) focused on change in out-migration connected with powerplant desulfurization. They show that the desulfurization led to 27% decrease in out-migration in the most polluted municipalities compared to less polluted ones. Balcar and Šulák (2020) investigated the relationship between satisfaction with air quality as well as different pollutants ($PM_{2.5}$, PM_{10}, NO_2 and BaP) and migration intentions in industrial city of Ostrava. They found that air pollution increased migration intentions, although they had different impact on different migration strategies.

This review shows that air pollution represents an important determinant of migration on both international and intranational levels. The review also shows that individual authors use several approaches to approximate air pollution as an independent variable and migration as a dependent variable, and that a relatively larger portion of studies focus on explaining the impact of air pollution on migration in relatively more polluted areas. Studies from China play a dominant role, whereas the evidence for developed countries with generally lower levels of pollution is empirically poorer. Additionally, the research on the level of cities as regional centers is insufficient. Most studies focus on bigger territorial units as provinces or regions.

The results of the literature review are reflected in the stated aim of the paper and research questions provided in the next section of this paper. The following paragraphs are focused on overcoming these shortcomings by providing evidence on the influence of air pollution on net migration in European cities.

3 DATA AND METHODOLOGY

We use dataset which combines three different types of information: satisfaction with air quality and other areas of life in European cities from Eurobarometer surveys, objective data on air pollution published by European Environment Agency, and data on population and migration from Eurostat and national statistical offices.

Satisfaction of inhabitants of large European cities with environment and other areas of urban life were measured by Eurobarometer *'Quality of Life in European Cities'*, conducted by European Commission, DG Regional and urban policy, in years 2004 (Eurobarometer no. 156), 2006 (EB 194), 2009 (EB 277), 2012 (EB 366), 2015 (EB 419) and 2019. The surveys were performed in approximately 80 European cities (the number of cities varies in different years), where 500 individuals (15+ years old) were interviewed in each city (300 individuals in 2004 survey, 700 individuals in 2019 survey). As the data are weighted, the sample for each city is representative according to the population structure of the country (European Commission, 2020, 2016, 2013, 2010, 2007; Eurostat, 2021a). Thus, we set a unique approach to examine human migration as we look for a connection between the perceived quality of air of city inhabitants and net migration.

The air quality is approximated by annual mean concentration of particulate matters (PM_{10} and $PM_{2.5}$), benzo(a)pyrene (BaP), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2) provided by the European Environment Agency (EEA, 2021). Data from background measurement stations were used, as they measure pollution levels that 'are representative of the average exposure of the general population or vegetation' (EEA, 2019b, pp. 11). In the case of more measurement stations in one city, the mean of measured values was used. Because data on all pollutants were not available for some cities, the number of cities differ in models.

As data on city-level migration were not available at Eurostat (Eurostat, 2021b) or within all national statistical offices, net migration is approximated here as the annual change of population ($\mathrm{pop}_t - \mathrm{pop}_{t-1}$) adjusted for natural change (births − deaths); net migration per 1000 inhabitants is used as a dependent variable.

We use the panel data for 70 cities[1] from 24 countries in the period 2004–2019 to address our main research questions:

RQ_1: *Is there any statistically significant relationship between air pollution and migration in European cities?*

RQ_2: *Does this relationship differ in case of capital cities, Eastern Europe cities and seaside cities, compared to others?*

Although the level of pollution in EU is generally lower than in other parts of the world, we aim to determine if air pollution can be considered a determinant of EU city migration.

According to the results of the Hausmann and the Breusch-Pagan Lagrange multiplier test, the relationship between migration and air pollution is performed by a panel regression with random effects. The multicollinearity tests were also made to eliminate possible interdependence between explanatory variables (see Appendix 1).

In Equation 1, the net migration per 1000 inhabitants (M) in the city i and time t represents a dependent variable, which is explained by set of explanatory variables: air pollution (P), public services (CTY), labor market (L), and dummy variable for a country (C); see Equation 1, where βs are regression coefficients. The model was set according to the stated aim of the paper, results

[1] Aalborg, Amsterdam, Antwerp, Barcelona, Belfast, Berlin, Białystok, Bologna, Bordeaux, Braga, Bratislava, Brussels, Budapest, Bucharest, Burgas, Cardiff, Cluj, Copenhagen, Dortmund, Essen, Gdansk, Geneva, Glasgow, Gratz, Groningen, Hamburg, Helsinki, Košice, Krakow, Leipzig, Ljubljana, Lille, Lisbon, London, Lutych, Luxembourg, Madrid, Malaga, Malmö, Manchester, Marseille, Miskolc, Munich, Naples, Newcastle, Oslo, Ostrava, Oulu, Oviedo, Paris, Palermo, Piatra Neamț, Prague, Reykjavik, Rennes, Riga, Rome, Rostock, Rotterdam, Sofia, Stockholm, Strasbourg, Tallinn, Turin, Verona, Vienna, Vilnius, Warsaw, Zagreb, Zurich.

of run tests, and data availability.

$$\mathrm{M}_{it} = \beta_0 + \beta_1 \cdot \mathrm{P}_{it} + \beta_2 \cdot \mathrm{CTY}_{it} + \beta_3 \cdot \mathrm{L}_{it} + \beta_4 \cdot \mathrm{C}_{it} + u_{it} \tag{1}$$

Independent (explanatory) variable P (air pollution) varies across models with multiple particles and substances representing the air pollution. It expresses overall[2] satisfaction with air quality (model 1.1), high[3] satisfaction with air quality (model 1.2), overall dissatisfaction with air quality (model 1.3), and high dissatisfaction with air quality[4] (model 1.4). Other models work with objectively measured pollution – with the level of pollutants PM_{10} (model 1.5), $PM_{2.5}$ (model 1.6), SO_2 (model 1.7), NO_2 (model 1.8) and BaP (model 1.9). In the case of subjectively assessed satisfaction with air quality, a positive regression coefficient is expected, because it can be assumed that higher satisfaction with air pollution (presumably lower air pollution) is positively connected with migration (models 1.1 and 1.2). In case of subjectively assessed dissatisfaction with air quality, or objective-measured pollution, a negative regression coefficient is expected (models 1.3–1.9). It can be assumed that higher dissatisfaction with air quality or higher pollution is negatively connected with migration.

Independent variable CTY is the factor that was created by aggregating variables expressing subjective overall satisfaction with other areas of life[5] (public services) in the cities. A positive regression coefficient is assumed for this variable, as an increase in satisfaction with public services should have a positive effect on migration.

The reason for running factor analysis was twofold. First, this approach incorporates as much information as possible while dealing with collinearity between the explanatory variables. Second, it can be assumed that some variables, that express the overall subjective satisfaction with various areas of life in the cities, can be clustered into particular groups, and that behind each group of variables there is a factor that influences the subjective evaluation of the respondents (de Vaus, 2014). According to the results of principal-component factors method (see Appendix 2) one factor for these variables was obtained as following Kaiser criterion (eigenvalue > 1) and explaining the highest amount of variability. Kaiser-Meyer-Olkin test (0.824) confirmed the adequacy of the data for factor analysis.

Independent variable L expresses the portion of respondents agreeing with the opinion that it is easy to find a job in the given cities. A positive regression coefficient is assumed for this variable, as the availability of jobs should have a positive effect on migration.

A dummy variable C is also included in the models to control for country effects. Countries are divided into several groups based on geographic proximity.

4 RESULTS AND DISCUSSION

Tab. 1 contains the results of nine model variants, whose composition was explained in the previous chapter.

Results in Tab. 1 show that both perceived air quality and level of air pollution are statistically significant variables, although there are some exceptions. Specifically, high dissatisfaction with air quality in model 1.4, pollutant SO_2 in model 1.7 and pollutant NO_2 in model 1.8. The regression

[2] "Overall" means the % of respondents who stated they are very and rather/somewhat satisfied (or dissatisfied).

[3] "High" means the % of respondents who stated they are very satisfied (or dissatisfied).

[4] For the surveys conducted in 2004, 2006, and 2009, "overall" refers to the % of respondents who stated they strongly or somewhat agree (or disagree) with the statement that they consider air quality to be a big problem. "High" refers to the % of respondents who strongly agree (or disagree) with this statement.

[5] Public transport, health care services, sports facilities, cultural facilities, green spaces, cleanliness, and personal feeling of safety. For cleanliness (2004–2009) and personal feeling of safety (all surveyed years), data were collected in the same way as for air quality in 2004–2009 – by asking for agreement with a statement.

Tab. 1: Model estimations (dependent variable: the net migration per 1000 inhabitants in year t)

	(1.1)	(1.2)	(1.3)	(1.4)	(1.5)	(1.6)	(1.7)	(1.8)	(1.9)
	Air quality (OS)	**Air quality (HS)**	**Air quality (OD)**	**Air quality (HD)**	**PM_{10}**	**$PM_{2.5}$**	**SO_2**	**NO_2**	**BaP**
Environmental	0.036*	0.075*	−0.039*	−0.033	−0.081**	−0.157**	0.175	−0.092	−0.722*
variables	(0.020)	(0.042)	(0.020)	(0.021)	(0.037)	(0.078)	(0.140)	(0.057)	(0.437)
Public services	0.656	0.791	0.616	0.806	1.394*	1.856	0.888	1.472**	1.691
	(0.633)	(0.625)	(0.638)	(0.661)	(0.789)	(1.145)	(0.852)	(0.748)	(1.202)
Labor market	0.147***	0.152***	0.148***	0.145***	0.126***	0.096***	0.153***	0.150***	0.108**
	(0.025)	(0.025)	(0.025)	(0.024)	(0.025)	(0.035)	(0.033)	(0.027)	(0.044)
Country	yes	yes	yes	yes	yes	yes	yes	yes	yes
Constant	1.382	1.961	4.968	3.810	6.028*	7.671*	1.168	5.931*	5.092
	(2.276)	(2.336)	(3.390)	(3.016)	(3.450)	(4.429)	(2.758)	(3.344)	(3.484)
Overall R^2	0.3718	0.3673	0.3729	0.3661	0.3693	0.3539	0.3677	0.3646	0.4068
Observations	326	326	326	326	277	210	227	288	126
Number of cities	70	70	70	70	68	62	58	68	42

Notes: OS = overall satisfaction, HS = high satisfaction, OD = overall dissatisfaction, HD = high dissatisfaction.
Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

coefficients of variables that represent subjective satisfaction with air quality (models 1.1 and 1.2) are positive, which means that higher satisfaction with the air is associated with a higher net migration. The regression coefficients of variables that represent subjective dissatisfaction with air quality (models 1.3 and 1.4) are, on the other hand, negative, which means that higher dissatisfaction with air pollution is associated with a lower net migration. The results of models with subjectively measured air pollution (1.1–1.3) are fully in line with the assumptions made in Chapter 3.

Results of models 1.5–1.9 show a negative and statistically significant relationship between migration and objectively measured air pollution (except for models 1.7 with pollutant SO_2 and model 1.8 with pollutant NO_2). These findings are also fully in line with our assumptions made in previous chapter. Higher air pollution approximated by the level of pollutants PM_{10}, $PM_{2.5}$ and BaP is connected with lower net migration. Conversely, pollution caused by sulfur and nitrogen oxides is not statistically significant, probably due to them not being and issue in the EU countries, in contrast to $PM_{10}/PM_{2.5}$ which are serious and more easily "observable" issue in the European cities. These results are fully in line with findings in studies which show that pollutants PM_{10} and $PM_{2.5}$ are significant factors of human migration (e.g. Germani et al., 2021; Chen et al., 2022). According to results in Tab. 1, it can be stated that people tend to take environmental factors into account when deciding about their relocation/migration.

The regression coefficients of the factor of overall satisfaction with public services are positive in line with our assumptions, but statistically significant in just two models, at the significance level $p < 0.05$ in model 1.5 and at the significance level $p < 0.1$ in model 1.8. This result means that the higher satisfaction of the residents of the cities with public services is positively associated with net migration. In models that work with subjective satisfaction or dissatisfaction with air quality (models 1.1–1.4), however, the factor variable of public service is not statistically significant at all.

The labor market variable is positive across models and, apart from model 1.9, statistically significant at the significance level of $p < 0.01$ (in case of model 1.9 is $p < 0.05$). This result indicates that there is a positive statistically significant relationship between the perceived availability of job opportunities by the residents of the given cities and net migration.

The results of labor market is fully in line with traditional migration theories, especially with neoclassical theories or the theory of the dual labor market (e.g. Massey et al., 1993), and the empirical research that is devoted to the issue of migration and the labor market conditions (e.g. Mayda, 2010; Pytliková, 2006; Harris and Todaro, 1970; Sjaastad, 1962). Unavailability of jobs (or unemployment) can "push" people from the current place of their residence, available jobs can attract people to the new place of residence. If we assume that the assessment of the state of the labor market in the given cities by the respondents corresponds to the actual state of the labor market, then the positive and statistically significant regression coefficients of the labor market variables in Tab. 1 suggest that available jobs may act as a "pull" factor of migration.

For confirmation of stability of results shown in Tab. 1, we made additional set of estimations with dummy variables represents specific characteristics of cities (see Tab. 2). We explored the significance of the city being capital, Eastern European or seaside. We use these dummies since this information is easily obtainable and because of lack of detailed objective data on cities. This enables us to analyze the significant gravitation power of urban centers as well as the by-the-sea regions, each offering various opportunities for its inhabitants. These characteristics can thus offer additional information to the puzzle of the migration behavior regarding specific environmental traits as well. We paid attention just to the first six model variants (1.1–1.6) because of the statistical insignificance of pollutants SO_2 and NO_2 (models 1.7–1.8) and because of the low number of observations in model 1.9 (pollutant BaP).

Tab. 2 adds proof about the robustness of our results as well as underlining the differences among the various types of cities (eastern European/seaside). Estimations show that Eastern European cities on average attract more people compared to western cities. Possibly due to regional centers in Eastern Europe offer significantly higher quality of life compared to smaller towns and villages. The differences between regional centers and smaller municipalities and their quality of life are probably smaller in the Western Europe. Furthermore, seaside cities attract less people in comparison with the rest of the sample. Possible explanation may be extensive level of tourism or cargo shipping and related consequences. We also assessed the city being capital which proved insignificant regarding migration behavior in comparison to the rest of the sample. On the other hand, Tab. 5 in the Annex shows interactions between environmental variables and dummy variables which are statistically insignificant, which means that differences described above occur due to other than environmental factors.

5 CONCLUSION

Air pollution has a negative impact on human health (EEA, 2019a). In the literature on migration and air pollution is air pollution usually approximated by the level of particulate matter (PM) (e.g. Germani et al., 2021; Chen et al., 2022), sulfur dioxide (SO_2) (e.g. Wang and Wu, 2021; Mikula and Pytliková, 2020), nitrogen dioxide (NO_2) (e.g. Balcar and Šulák, 2020; Šulák, 2019) and benzo(a)pyrene (BaP) (e.g. Balcar and Šulák, 2020). Exposure to these pollutants can cause a range of health complications, illnesses, and it can ultimately lead to premature death (EEA, 2019a). Thus, air pollution is a widely examined factor of human migration, but less attention is paid to investigating this phenomenon in Europe than in Asia or the USA. Although the level of pollution in the EU is generally lower than in other parts of the world, we aimed to determine if air pollution can be considered a determinant of EU city migration.

According to the stated aim of the paper, we addressed the two research questions:

RQ_1: *Is there any statistically significant relationship between air pollution and migration in European cities?*

The results of the paper show that both perceived and objectively measured air quality can be considered as an input into migration decisions. Higher satisfaction with air quality of city residents attracts more inhabitants, while higher objectively measured pollution causes higher emigration or lower immigration.

Tab. 2: Estimations of basic models with dummy variables

	(1.1)	(1.2)	(1.3)	(1.4)	(1.5)	(1.6)
	Air quality (OS)	**Air quality (HS)**	**Air quality (OD)**	**Air quality (HD)**	**PM_{10}**	**$PM_{2.5}$**
Environmental variables	0.036*	0.075*	−0.039*	−0.033	−0.081**	−0.157**
	(0.020)	(0.042)	(0.020)	(0.021)	(0.037)	(0.078)
			Models with dummy variables			
	(1.1.1)	(1.2.1)	(1.3.1)	(1.4.1)	(1.5.1)	(1.6.1)
Environmental variables	0.033	0.061	−0.036*	−0.031	−0.074**	−0.136*
	(0.020)	(0.043)	(0.020)	(0.021)	(0.037)	(0.081)
Dummy "East"	5.518*	5.228	5.501*	5.844**	5.566**	6.568
	(2.924)	(3.449)	(2.935)	(2.793)	(2.828)	(4.577)
Country	yes	yes	yes	yes	yes	yes
Observations	326	326	326	326	277	210
Overall R^2	0.3884	0.3830	0.3894	0.3846	0.3875	0.3698
	(1.1.3)	(1.2.3)	(1.3.3)	(1.4.3)	(1.5.3)	(1.6.3)
Environmental variables	0.039*	0.084*	−0.042**	−0.036*	−0.072**	−0.143*
	(0.021)	(0.045)	(0.021)	(0.021)	(0.036)	(0.074)
Dummy "Capital City"	1.604	1.606	1.629	1.476	1.775	2.323
	(1.071)	(1.101)	(1.068)	(1.068)	(1.215)	(1.618)
Country	yes	yes	yes	yes	yes	yes
Observations	326	326	326	326	277	210
Overall R^2	0.3834	0.3784	0.3848	0.3766	0.3815	0.3682
	(1.1.5)	(1.2.5)	(1.3.5)	(1.4.5)	(1.5.5)	(1.6.5)
Environmental variables	0.040**	0.086**	−0.043**	−0.038*	−0.102***	−0.177**
	(0.020)	(0.040)	(0.020)	(0.021)	(0.037)	(0.077)
Dummy "Seaside City"	−2.327***	−2.369***	−2.343***	−2.236***	−2.650***	−2.516**
	(0.795)	(0.762)	(0.797)	(0.823)	(1.017)	(1.100)
Country	yes	yes	yes	yes	yes	yes
Observations	326	326	326	326	277	210
Overall R^2	0.3848	0.3805	0.3860	0.3782	0.3862	0.3648

Notes: OS = overall satisfaction, HS = high satisfaction, OD = overall dissatisfaction, HD = high dissatisfaction. Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

RQ_2: *Does this relationship differ in case of capital cities, Eastern Europe cities and sea-side cities, compared to others?*

We found statistically significant differences in migration behavior caused by different types of cities. Estimations show that Eastern European cities on average attract more people compared to western cities, and that seaside cities attract less people in comparison with the rest of the sample. However, these differences are not connected to air pollution and thus can be contributed to other non-observed factors.

We also explored that the availability of job opportunities can pull new inhabitants to the city. The same result was found in case of the quality of public services, but this variable was statistically significant just in two models.

Based on the results presented above, we suggest some recommendations to economic policymakers. The concentration of the above-mentioned pollutants is linked to economic activity. They arise, among other things, in energy or transport (EEA, 2019a). Therefore, to combat traffic-related air pollution (and therefore the potential health impacts of pollution on city population), the cities management can develop transportation strategies that will reduce pollution. An example can be the support of ecological public transport. Another strategy to improve the air conditions in cities can be the planting greenery, which, among other things, helps capture pollutants and thus improves air quality (Isaifan and Baldauf, 2020).

There is large evidence that air pollution is a predictor of the migration of highly educated people (e.g. Levine et al., 2020; Lu et al., 2018; Wang and Wu, 2021). It can be assumed that the awareness of the danger of pollution and its impacts on human health plays a role (Lu et al., 2018) as well as greater migration possibilities due to the assumed higher incomes of more educated people, since higher accumulation of human capital is associated with higher incomes (Schultz, 1961). The results of this paper confirm that air pollution is negatively associated with migration, which is in line with the conclusions of the studies presented in the literature review.

As mentioned above, polluted areas may face a so-called “brain drain” (DeGolyer, 2008). Thus, the emigration of the educated workforce can have a negative effect on the economic development of the areas from which these workers with high human capital leave, since the accumulation of human capital is associated with economic growth (Barro, 2001). If this includes also younger people or people with small children (Balcar and Šulák, 2020), further negative consequences can be assumed in relation to the future development of the given area. A typical example of such areas can be transforming regions whose economy was based on heavy industry. Policymakers should support the transition from heavy industry to a high-value-added, innovation-based economy in such regions that will create jobs not only for workers with high human capital. As was presented in the results of this work, the availability of job opportunities can affect immigration, and the unavailability, on the contrary, the emigration. It can be assumed that the development of modern and innovative industries and the attenuation of polluting industries will help to improve the state of the environment and therefore to remove the migration incentive due to air pollution.

Several limitations can be identified within this research. This is mainly about the availability of data at the level of cities, where, based on the knowledge of the authors of this work, there is no database of objective characteristics of cities at least in the same form and depth as data available from the European Commission’s Eurobarometer survey on the subjective assessment of residents’ satisfaction with the areas of life in the given cities.

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7 ANNEX

Tab. 3: Multicollinearity test (VIF), dependent variable: the net migration per 1000 inhabitants in year t

	(1.1)	(1.2)	(1.3)	(1.4)	(1.5)	(1.6)	(1.7)	(1.8)	(1.9)
	Air quality (OS)	**Air quality (HS)**	**Air quality (OD)**	**Air quality (HD)**	**PM_{10}**	**$PM_{2.5}$**	**SO_2**	**NO_2**	**BaP**
Environmental variable	1.70	1.72	1.75	1.57	1.81	2.34	1.79	1.75	2.61
Public services	3.01	2.87	3.02	2.93	2.70	2.81	2.78	2.62	3.11
Labor market	1.76	1.84	1.76	1.73	1.75	1.83	1.78	1.88	1.87

Notes: OS = overall satisfaction; HS = high satisfaction; OD = overall dissatisfaction; HD = high dissatisfaction.

Tab. 4: Results of principal-component factors method

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor 1	4.11209	3.19448	0.5874	0.5874
Factor 2	0.91761	0.36585	0.1311	0.7185
Factor 3	0.55176	0.00439	0.0788	0.7974
Factor 4	0.54737	0.12792	0.0782	0.8755
Factor 5	0.41945	0.14956	0.0599	0.9355
Factor 6	0.26989	0.08805	0.0386	0.9740
Factor 7	0.18183	.	0.0260	1.0000

Tab. 5: Results of factor analysis – rotated factor loadings (pattern matrix) and unique variances

Variable (OS)	Factor 1 (PS)	Uniqueness
Public transport	0.8136	0.3380
Health care services	0.6815	0.5355
Sport facilities	0.7868	0.3810
Cultural facilities	0.7813	0.3895
Green spaces	0.8772	0.2306
Cleanliness	0.7643	0.4158
Personal feeling of safety	0.6344	0.5975

Notes: OS = overall satisfaction, PS = public services.

Tab. 6: Estimations of basic models with interactions

	(1.1)	(1.2)	(1.3)	(1.4)	(1.5)	(1.6)
	Air quality (OS)	**Air quality (HS)**	**Air quality (OD)**	**Air quality (HD)**	$\mathbf{PM_{10}}$	$\mathbf{PM_{2.5}}$
Environmental variables	0.036*	0.075*	−0.039*	−0.033	−0.081**	−0.157**
	(0.020)	(0.042)	(0.020)	(0.021)	(0.037)	(0.078)
			Models with interactions			
	(1.1.2)	(1.2.2)	(1.3.2)	(1.4.2)	(1.5.2)	(1.6.2)
Environmental variables	0.042	0.090	−0.046*	−0.061**	−0.073	−0.122
	(0.027)	(0.061)	(0.026)	(0.030)	(0.057)	(0.138)
Dummy "East"	7.801**	7.473**	4.766	5.450**	5.612*	6.905
	(3.741)	(3.385)	(3.118)	(2.772)	(3.403)	(4.717)
Interactions "East" with envir. var.	−0.030	−0.085	0.034	0.073*	−0.002	−0.025
	(0.041)	(0.085)	(0.040)	(0.043)	(0.081)	(0.172)
Country	yes	yes	yes	yes	yes	yes
Observations	326	326	326	326	277	210
Overall R^2	0.3926	0.3902	0.3940	0.3932	0.3874	0.3697
	(1.1.4)	(1.2.4)	(1.3.4)	(1.4.4)	(1.5.4)	(1.6.4)
Environmental variables	0.024	0.062*	−0.028	−0.031	−0.063	−0.186**
	(0.024)	(0.037)	(0.023)	(0.029)	(0.042)	(0.087)
Dummy "Capital City"	−0.027	0.661	3.320	1.694	2.603	−0.082
	(1.746)	(1.299)	(2.731)	(1.631)	(2.541)	(3.287)
Interactions "Capital City" with envir. var.	0.036	0.084	−0.032	−0.009	−0.035	0.160
	(0.041)	(0.119)	(0.040)	(0.043)	(0.081)	(0.146)
Country	yes	yes	yes	yes	yes	yes
Observations	326	326	326	326	277	210
Overall R^2	0.3829	0.3791	0.3843	0.3761	0.3809	0.3676
	(1.1.6)	(1.2.6)	(1.3.6)	(1.4.6)	(1.5.6)	(1.6.6)
Environmental variables	0.040	0.104**	−0.041*	−0.031	−0.079**	−0.147*
	(0.024)	(0.052)	(0.024)	(0.025)	(0.039)	(0.087)
Dummy "Seaside City"	−2.261	−1.540	−2.151	−1.611	0.217	−0.628
	(2.044)	(1.373)	(2.031)	(1.314)	(3.201)	(3.077)
Interactions "Seaside City" with envir. var.	−0.001	−0.052	−0.004	−0.030	−0.120	−0.137
	(0.039)	(0.074)	(0.038)	(0.043)	(0.123)	(0.201)
Country	yes	yes	yes	yes	yes	yes
Observations	326	326	326	326	277	210
Overall R^2	0.3848	0.3806	0.3861	0.3795	0.3863	0.3655

Notes: OS = overall satisfaction, HS = high satisfaction, OD = overall dissatisfaction, HD = high dissatisfaction. Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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