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Does air pollution influence internal migration? An empirical investigation on Italian provinces

Anna Rita Germani [a,*], Pasquale Scaramozzino [b], Angelo Castaldo [a], Giuseppina Talamo [c]

[a] Department of Juridical and Economic Studies, Institute of Economics and Finance, Sapienza University of Rome, Italy
[b] School of Finance and Management, SOAS University of London, U.K., and Department of Economics and Finance, University of Rome Tor Vergata, Italy
[c] Faculty of Economics and Law, Kore University of Enna, Italy

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ABSTRACT

This research analyzes the role that air pollution plays, controlling for other socio-economic factors, in the movement of the population among Italian provinces. In spite of the increased prominence of environmental degradation in the public policy debate, empirical evidence on the effects of air quality on the attraction or retention of people is still limited in Italy. This study aims at partly filling this gap. Specific attention is paid to the environmental risks presented in provinces contaminated by air pollution. We investigate whether population moves away from provinces with higher levels of air pollution emissions toward those characterized by lower levels, net of the other contextual factors associated with migration streams. While many factors can come into play on mobility decisions, it is suggested that the increased concerns with environmental risks may be influential in shaping internal migration choices. We discuss the implications of our findings for future policy options.

1. Introduction

Air pollution features amongst the main environmental problems in Italy, especially in those provinces which suffer from heavy levels of pollution caused by industrial activities. Increasing attention is being devoted to the effects of living in polluted areas and how air pollution may negatively impact on people's health and living standards (Lam et al., 2021; Hill et al., 2019; Knittel et al., 2016; Brook et al., 2010; Brunekreef and Holgate, 2002). Over the past decades, the environmental awareness and concern of the Italian people on the potential health risks associated with environmental degradation has greatly increased. The public's environmental concern has begun to take a new level of importance in Italy and the willingness of several grassroots organizations, activists, NGOs and local communities, to react against local environmental risk represents a significant shift in the public perception of the environment. To confirm this growing attention, several public and private initiatives at national, regional and municipal levels (e.g., plastic free cities, smoke free areas, ecological Sundays, traffic bans on the most polluting cars, etc.) have long been adopted in recognition of the fact that environmental factors can affect human health (Ministero dell'Ambiente, 2019).[1] The Land of Fires in the Campania region is a clear example of how, during the twenty years of environmental conflicts, the local inhabitants have reinforced their networks, denouncing not only the environmental burden of illegal trafficking of waste (with the resulting burying and burning of toxic waste) but also the tragic health consequences of such criminal activities (Germani et al., 2016). Another Italian example is the complex situation experienced by the population of Taranto (in the Puglia region), and in particular by the population of the Tamburi district. This neighbourhood is located near the ILVA plant, a steel plant that today is at the centre of a complex political and economic debate. The environmental pollution in Taranto remains at very high levels and has dramatic negative

* Corresponding author.
E-mail addresses: annarita.germani@uniroma1.it (A.R. Germani), ps6@soas.ac.uk (P. Scaramozzino), angelo.castaldo@uniroma1.it (A. Castaldo), giuseppina.talamo@unikore.it (G. Talamo).

[1] In relation to this, already in 2006, the Italian Ministry of Health funded a project called "SENTIERI" with the purpose of analysing the mortality of populations living in proximity to a number of industrial agglomerates which, by their nature, could potentially cause a high risk of hazardous health and/ or environmental contamination such as to be classified as SIN (Sites of National Interest for Remediation) - http://www.epiprev.it/sentieri/home.

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consequences on human health, the ecosystem, and economic activities, such as tourist flows.[2] This increasing awareness has aroused more attention to the effects of pollution and people have begun to realize that environmental risks can be found in their own backyard.

This research explores the possibility that concerns about environmental risk may be reflected in the choice of one's city of residence. More specifically, we consider the relationship between the presence of air pollution and population movements among provinces in the different regions within Italy. While many factors can come into play on mobility decisions, we test whether the increased concerns with environmental risk posed by air pollution may be influential in shaping the Italian's internal movements choices. We aim to investigate whether population flows move away from areas with higher levels of air pollution, towards those characterized by lower levels of air pollution, net of the other contextual factors associated with a population's movements.

Using a panel-level dataset at provincial level in Italy from 2011 to 2015, we empirically investigate the extent to which air pollution is a significant driver of migration by analyzing the relationship between migration flows and air pollution, while accounting for demographic and socio-economic heterogeneity. Our analysis fits into that stream of empirical works (Piras, 2017; Fratesi and Percoco, 2014; Lamonica and Zagaglia, 2013; Mocetti and Porello, 2012; Piras, 2012a, 2012b; Biagi et al., 2011; Etzo, 2011) which investigate the main determinants of internal migration within the country. However, while internal migration in Italy, in general, has been widely and very extensively studied (Piras, 2017), there is scant economic empirical evidence, to the best of our knowledge, on environmental factors as key determinants of migration. In trying to reduce such a gap, our main contribution is to extend the literature in this vein by understanding the relationship between air pollution and the inter-provincial migration of population while controlling for socio-economic, demographic, and unobserved heterogeneity. Living in polluted areas may negatively affect people's health and living standards; hence, in this work, we posit that environmental pollution can be an important push factor affecting the decision to migrate internally.

The remainder of the manuscript is organized as follows. In Section 2, we frame the contribution of our manuscript within the relevant literature. Sections 3 introduces the data and presents the econometric methodology. Estimation results are discussed in Section 4. Section 5 summarizes the findings and discusses some policy implications.

2. Environmental degradation and human migration

The determinants of migration flows in the existing literature are commonly explored at either macro or micro level, often within the gravity spatial equilibrium framework, and are grounded on the premise that different locations have different characteristics that act as push or pull factors in encouraging or deterring people from moving (Cadwallader, 1989). Push factors are identified with negative characteristics operating in the province of origin, whereas pull factors identify the positive characteristics in the province of destination. Neo-classical macro-economists identify the major factors behind migration as wage differentials, variations in employment conditions between locations, and migration costs (Todaro, 1969; Harris and Todaro, 1970). Neo-classical micro-economists focus on the rational decision by individuals to maximize their income or their expected positive net return from movement (Sjaastad, 1962; Todaro, 1969; Stark et al., 1991; Stark and Bloom, 1985). Wolpert (1966); Speare (1974); Greenwood (1985, 1997) and Knapp and Graves (1989) were among the first to suggest taking into consideration other environmental variables, as either stressors or locational characteristics, that can influence the migration choice. The migration literature is devoting increasing attention to climatic, environmental factors and quality of life issues and there is, nowadays, an extensive empirical literature on both positive and negative amenities as important factors for understanding why people prefer some cities over others. Banzhaf and Walsh (2008) starting from Tiebout's suggestion, and using a general equilibrium model of location choice, show that when the environmental quality of a community improves, people would be expected to move closer to environmental amenities, if they care about such values. Moreover, when environmental amenities improve locally, it is mostly wealthier people that move since they tend to attach a very high value to environmental goods. Tiebout (1956) argues that, under specific circumstances, one may detect a population's preferences for the provision of public goods by allowing people to "vote with their feet". Based on the assumptions that individuals i) are fully mobile and ii) have perfect information, they may choose the community in which to live that best satisfies their preferences. While environmental pollution may represent negative locational characteristics, positive environmental attributes increase destination attractiveness (Hunter et al., 2003). In our paper, it is argued that individuals who migrate among Italian provinces may choose to do so based on environmental air quality, and thus reveal a preference for environmental aspects, in addition to income and other socio-economic characteristics.

Several empirical investigations on the drivers of migration in the United States found that natural amenities play a key role in determining the geographical appeal of places (Partridge and Rickman, 2003, 2006; Partridge, 2010; Scott, 2010; Glaeser and Gottlieb, 2009; Hunter, 1998; Hsieh and Liu, 1983; Mueser and Graves, 1995). The quality of public goods could be a motivating force for migration, and this can be seen as a particular example of the Tiebout (1956) model, whereby cities in competitive equilibrium offer amenities that will attract individuals, who otherwise will migrate elsewhere.[3] In Europe, with regard to the attractiveness of local amenities, some scholars (Garretsen and Marlet, 2017; Arntz, 2010; Faggian and McCann, 2009; Niedomysl and Hansen, 2010) have found that amenities do not affect or play a marginal role in migration and urban growth, highlighting the predominance of economic factors. However, others have found mixed results (Cheshire and Magrini, 2006),[4] and some (Faggian and Royuela, 2010) have even found that regional amenities play a relevant role to migrate across the EU's regions. Xu and Sylwester (2016) found that air pollution is positively associated with emigration (to OECD countries) rates but mostly for higher educated migrants, although the estimated magnitudes suggest that pollution is not a dominant factor as to why people emigrate. In recent years, environmental factors have increasingly featured migration analysis in China. Li et al. (2017) found that amenities or environmental degradation exert a substantial a effect on the geographical appeal of regions. Cui et al. (2019) show that air pollution does affect the population outflows from cities, thus confirming that air quality management is a critical factor for urban tourism and environmental competitiveness. Li et al. (2020) found that in cities with more air pollution, migrants have a lower willingness to settle down, preferring to buy houses in other cities even if this means earning lower incomes.

With regard to Italy, there are a wide number of studies that focus on internal migration flows which have been taking place especially from the Southern to the Central-Northern provinces or regions. A detailed analysis of the empirical works on internal migration across Italian regions goes beyond the scope of the present study: for an extensive review

[2] There is still an open debate at the political level, and this confirms how complex is the coexistence between the factory and the Ionian capital, at the peak of a story that began 60 years ago http://www.arpa.puglia.it/web/guest/rete_aria_ILVA

[3] This approach has been used to analyze the environment as an amenity and to explain internal migration on the basis of either weather characteristics in certain locations or local waste problems.

[4] They found that amenities (i.e., weather) mattered, but only on a national scale and were insignificant at a European level.

of these empirical studies, we refer to Piras (2017) and Basile et al. (2018).

Building on the insights by Bonasia and Napolitano (2012) and by Biagi et al. (2011), we aim to further advance the investigation into the role of environmental factors, specifically air pollution, mainly ignored by traditional empirical research, and focus on the role of environmental pollution in driving inter-provincial migration. Bonasia and Napolitano (2012) investigated the economic (i.e., income, employment differentials, house prices) and non-economic (i.e., carbon dioxide emissions and juvenile crime) determinants of inter-regional migration for unskilled and skilled migrants. With regard to CO_2 emissions, they find a positive impact on migration rate: despite the fact that air pollution should be seen as a cost for health and a disincentive to migrate, their results show that it is an attraction factor, highly correlated with urban agglomeration which creates spillovers in generating economic growth. Biagi et al. (2011) found that economic factors are the main drivers for migration in Italy: amenities or quality of life-related characteristics play a role only in short-distance movements, within the same region and not at the country level as a whole.

Based on the review of this literature, it is clear that most migration research in Italy has examined inter-regional or inter-provincial flows focusing on the economic determinants (income, unemployment, wage differentials) as the key variables that influence the decision to emigrate or not. Italy is one of the less investigated countries with regard to the assessment of whether air pollution can contribute to migration by pushing people out of the most affected areas. In what follows, we aim to bridge the gap between classical theories on migration, which tend to ignore the environment as a driver of migration, and theories on environmental governance, which tend to ignore migration flows. The results can be relevant because they offer the first empirical validation of the association between air pollution and population migration in Italy.

3. Data description and empirical strategy

3.1. Data and variables description

We implement a simple model of environmental migration which posits a relationship between migration flows in each province in the years 2011–2015, and air pollution emissions at provincial level, plus some socio-economic and demographic control variables in order to explore the main research question, namely, to what extent does pollution lead to migration to other provinces within the country. Our dependent variable measures the transfers of residence by province of origin and place of destination in the years 2011–2015. The Tagliacarne Institute and the Union of Italian Chambers of Commerce provided the relative data. For our main independent variable, we use the information on air pollution provided by the Italian Institute for Environmental Protection and Research (ISPRA, 2015),[5] which is responsible for the National Emission Inventory. Data concerning the resident population and the changes of residence are extracted from ISTAT demographic data.[6] Table 1 presents a description of the variables that we use in our estimations.

By merging the above described environmental, demographic and economic data, we produced a database that, as we believe, can contribute to the extremely exiguous literature on the relation between

Table 1
Variable Description and Data Sources.

Variable	Description	Source
Dependent variable		
Net Migration rate	Net migration standardized over the province's population	Tagliacarne Institute + authors' own elaboration (2011–2015)
Environmental explanatory variable		
Local air pollution index	NOx + VOC + CO + PM_{10} air pollution emissions in all the Italian provinces	ISPRA – Air Emissions Provincial Inventory – year 2010
Economic explanatory variables		
GDP per-capita	Taxable income measured in euro (€)	Tagliacarne Institute
Real Estate	Average property values by province	Osservatorio del Mercato Immobiliare
Education	Average years of study of the population aged at least 25 years	ISTAT
Unemployment rate	Rate of unemployment	ISTAT
Entrepreneurship	Number of registered firms at provincial level (every 100 inhabitants)	Tagliacarne Institute
Infrastructures	General economic infrastructure index (Italy = 100)	Tagliacarne Institute
Demographic and geographic explanatory variables		
Ratio age 0–14	No. of residents aged between 0 and 14 years over the total population	ISTAT data Census
Ratio age 15–19	No. of residents aged between 15 and 19 years over the total population	ISTAT data Census
Ratio age 20–39	No. of residents aged between 20 and 39 years over the total population	ISTAT data Census
Ratio age 40–59	No. of residents aged between 40 and 59 years over the total population	ISTAT data Census
Ratio age 60–64	No. of residents aged between 60 and 64 years over the total population	ISTAT data Census
Ratio age 65 and over	No. of residents aged 65 and more over the total population	ISTAT data Census
Territorial dummies: northern provinces, central provinces[a]	- North regions: Liguria, Lombardia, Piemonte, Valle d'Aosta, Friuli-Venezia Giulia, Emilia Romagna, Trentino-Alto Adige, Veneto - Central regions: Toscana, Marche, Umbria, Lazio - Southern regions: Abruzzo, Basilicata, Calabria, Campania, Molise, Puglia, Sardegna, Sicilia	ISTAT
Instrument(s)		
Judicial inefficiency	criminal trials' length (expressed in number of days) divided by the population	Italian Ministry of Justice
Environmental crimes	number of environmental crimes in the Italian provinces divided by the population	Legambiente

[a] The geographical distinction in the three macro-areas has been built following the ISTAT classification (2013) - https://www.istat.it/it/files/2013/03/Noi-Italia-2013.pdf.

[5] ISPRA is the Institute for Environmental Protection and Research established by Italian Law 133/2008.

[6] The data used for the calculation of the net migration rate have one potential limitation in that they refer to those people who are registered as "resident" in a given territory which may not correspond exactly to the population that actually live there. This study uses the total migration inflows (within Italian provinces and from abroad) and the internal migration outflows only (within Italian provinces). The migration outflows directed abroad were excluded from the calculation of the net migration rate.

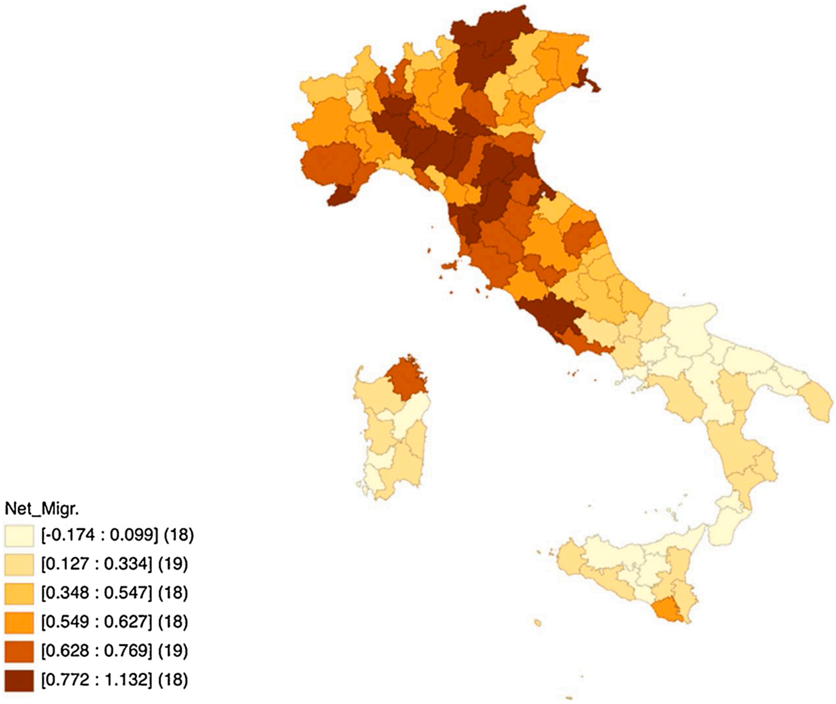

Fig. 1. Net Migration rate (average values, 2011-15).
Source: author's elaboration on Tagliacarne Institute data.

migration and air pollution in Italy.

3.1.1. Dependent variable

Our dependent variable (y) is the net migration rate of Italian citizens calculated at a provincial level (NUTS 3), in the timeframe 2011–2015. For each of the 110 Italian provinces,[7] the net migration rate is calculated as in-migration (people coming into a province) minus out-migration (people leaving a province) of province *i,* with respect to the total population of the same province. When the net migration rate is positive, a province has a net in-migration flow; if it is negative, a province has a net out-migration flow. Fig. 1 graphically illustrates the dynamic of net migration rate by province in the selected timespan. The provinces with a darker colour exhibit higher average numbers of net in-migration flows: in the Northern regions of Lombardia and Emilia Romagna, the provinces of Milan and Bologna show the highest degree of attractiveness, with a net migration rate value of 1.12 and 1.09, respectively followed by the province of Parma with a value of 1.02. In the Central regions, the provinces of Firenze and Prato show the highest values of net migration rates, with a value of 1.13 and 0.91, respectively, followed by Rome with a net migration rate equal to 1.02. A peculiar feature, typically related to the well-known Italian dualism, lies in the evidence that the Southern provinces are less attractive than the rest of the country and show the highest average values of net-outmigration flows, with the interesting exceptions of the provinces of Ragusa with a value of 0.54, in Sicily, which show amongst the highest level of in-migration flows. Ragusa is among the most urbanized Sicilian provinces and is characterized by an economic-entrepreneurial model that is on average more efficient than that shown in the other Sicilian provinces and in most of the southern ones; in terms of economic structure, Ragusa shows the highest entrepreneurial density, i.e., 11 local units per 100 inhabitants, a value that places the province in 49th position in the national ranking (ISTAT, 2015). In the South, the lowest values of the average net migration rate are those of Nuoro (-0.17), in Sardinia, and Vibo Valentia (-0.13) and Taranto (-0.12), in the Calabria region, which show the weakest attractive capacities. This is likely to be due to factors that might heavily influence the choice to emigrate, that is scarcity of job opportunities, lack of adequate access routes and infrastructures, low income, economic depression.

3.1.2. Independent variables

The ISPRA (2015) dataset includes data on air emissions in all the Italian provinces (110 provinces distributed over 20 regions). This is a comprehensive database that collects all emission estimates of the major pollutants including greenhouse gases, ozone precursors, benzene, particulate matters, heavy metal and polycyclic aromatic hydrocarbon.[8] To build our strategic independent variable used in the regression model, we defined two province-level indexes of air pollution: i) one obtained by the aggregation of four main local pollutants (i.e., nitrogen monoxide, carbon monoxide, volatile organic compounds, particulate matter$_{10}$), and ii) the other one relative to the main global pollutant, i.e. CO_2. Our focal indicator of local air pollution index refers to the aggregation of the total emissions of nitrogen monoxide (NO_x), carbon monoxide (CO), volatile organic compounds (VOC) and particulate matter's (PM_{10}), which are considered to be amongst the main anthropogenic emissions responsible for the quality of the air and the most

[7] In Italy, a province is an administrative sub-division of a region, which is an administrative sub-division of the State. Italy, in the timeframe considered, was divided into 110 provinces. Provinces are equally distributed on the territory between northwest, northeast, center and south, even though the level of urbanization is higher in the northern part of the country.

[8] The ISPRA data at provincial level are disaggregated by the type activity according to the SNAP (Selected Nomenclature for Air Pollution) classification which consists of 11 macro-sectors. We used data relative to all the 11 macro-sectors: 1) combustion - energy and processing industry; 2) combustion – non industrial; 3) combustion – Industry; 4) production processes; 5) extraction, distribution of fossil, geothermal fuels; 6) use of solvents; 7) road transport; 8) other mobile sources; 9) waste treatment and disposal; 10) agriculture; 11) other sources of emission and absorption. Disaggregazione dell'Inventario Nazionale, data available at http://www.sinanet.isprambiente.it/it/sia-ispra/inventaria/disaggregazione-dellinventario-nazionale-2015/view

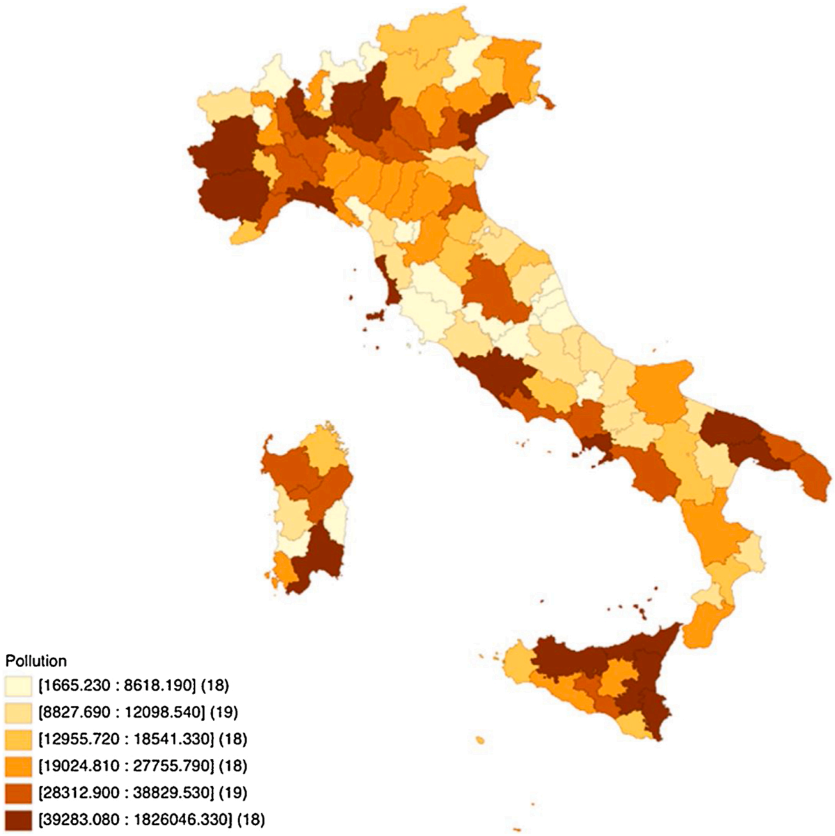

Fig. 2. Air Pollution index (NOx + VOC + CO + PM_{10}).
Source: author's elaboration on ISPRA data (Air Emissions Provincial Inventory) – year 2010.

important pollutants in terms of potential risk for human health (Iodice and Senatore, 2015; Ferrante et al., 2015; European Environment Agency – EEA, 2018). Based on the 2010 air pollution emissions data, provided by the Italian Institute for Environmental Protection and Research (ISPRA, 2015) which is also responsible for the National Emission Inventory, Fig. 2 illustrates air emission levels for the 110 Italian provinces. Note that our *"pollution"* variable, in the model, is specified as per capita emissions to provide a better measure of emissions intensity.

While air pollution in the Northern provinces is generally higher due to the high level of industrialization and urbanization, in the Southern provinces, the illegal disposal of hazardous industrial waste, together with the presence of high environmental impact industrial plants, play a very relevant role. Air pollution emissions are expressed in megagrams: the average level of air releases is 48719.38 megagrams with a minimum value of 1665.23 megagrams (Ogliastra) and a maximum value of 1,826,046 megagrams (Catania). The average per-capita air emission level is 0.125 megagrams with a minimum value of 0.052 (Barletta-Andria-Trani) and a maximum value of 0.466 megagrams (Taranto). We are aware of the fact that the use of a too broad scale or unit of analysis has been discouraged (Banzhaf et al., 2019; Anderton et al., 1994) due the potential risk of running into ecological fallacy, but the most disaggregated available Italian data on air pollution are only at provincial level.

The other independent variables were chosen according to the most commonly used in studies on migration (Piras, 2017; Etzo, 2011) and are motivated by the main types of factors underlying the Mueser and Graves (1995) specifications: i) unemployment and other economic factors; ii) demographic factors; and iii) other provincial factors. Additional variables, such as the entrepreneurial spirit and the infrastructural endowment constitute an improvement upon previous studies. We control for *per capita GDP* and for property values (*real estate*); relatively low/high per capita GDP level and property values in the province can be considered as a push/pull factor. The Tagliacarne Institute/Union of Italian Chambers of Commerce provided the data related to GDP, which is defined as taxable income per declarant (household income) and is measured in euros (€). The Italian Observatory on Real Estate provided

Table 2
Descriptive Statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
Net migration rate	110	0.478	0.31	−.174	1.132
Air Pollution (per capita)	110	0.125	0.074	0.052	0.466
GDP (per capita)	110	21782.46	2063.98	17936.9	29788.82
Real Estate	103	1013.5	503.96	31.99	3751.79
Education	110	9.56	0.53	8.31	11.2
Unemployment rate	110	8.66	3.99	2.69	19.42
Entrepreneurial density	110	10.39	1.40	7.24	14.87
Infrastructures	110	100.19	81.57	25.5	708.8
Center	110	0.2	0.402	0	1
North	110	0.41	0.49	0	1
South	110	0.373	0.486	0	1
Ratio age 0−14	110	0.135	0.014	0.107	0.173
Ratio age 15−19	110	0.048	0.007	0.035	0.065
Ratio age 20−39	110	0.248	0.017	0.205	0.283
Ratio age 40−59	110	0.291	0.009	0.269	0.312
Ratio age 60−64	110	0.065	0.004	0.054	0.075
Ratio age 65 and over	110	0.213	0.027	0.149	0.276
Judicial inefficiency	110	0.001	0.001	0	0.007
Environmental crimes	110	0.074	0.062	0.005	0.345

the data on the value of real estate properties.[9] Other socio-economic factors, such as *education* and *unemployment rate* are also considered relevant variables that can affect migration (Xu and Sylwester, 2016). Demographic variables are examined as well (Chaix et al., 2006; Greenberg, 1993).

We introduce two geographical dummy variables (*Northern Italy* and *Central Italy)* to reflect the well-known territorial Italian divide in terms of economic growth, productivity, labour market trends, crime rates and investments (SVIMEZ, various years; Giannola, 2015; Bagnasco, 1977); the dummy *Southern Italy* is left out as the benchmark. Table 2 provides the descriptive statistics for all variables included in our analysis. Although some variables are converted into logarithmic form for the regression analysis, we report descriptive statistics for each variable in their original metrics.

A cursory look illustrates significant heterogeneity in our variables. The mean for local air pollution index is 0.125 megagrams; standard deviation values show that local air pollution levels vary widely across provinces, with some cities having fairly low levels of pollution and other cities having very high pollution levels. Our income data indicate an average income of € 21782.46.

3.2. Econometric methodology

We implement a simple model of migration which posits a relationship between 2010 provincial-level environmental quality variables and 2011–2015 migration flows in each province, plus some 2010 socio-economic-demographic control variables. The main research question we are seeking to address is whether, and to what extent, pollution does lead to internal migration within Italian provinces. The estimated model takes the following form:

$$netmigration_{it} = \beta_0 + \beta_1 pollution_{it} + \beta_2 X_{it} + \varepsilon_{it} \quad (1)$$

where the subscripts i and t represent province and time period, respectively. The dependent variable measures the net migration rate of the population. Those individuals who reported a change of residential location across provinces are considered migrants. The vector X includes a set of socio-economic and demographic variables (i.e., income, unemployment, level of education, age, etc.). It is expected that provinces with relatively high air pollution, low income, high unemployment rate will have a negative net migration rate, whereas less air pollution and economically prosperous provinces with favourable labour market conditions will attract resident inflows (Piras, 2017; Xu and Sylwester, 2016; Rodriguez-Pose and Ketterer, 2012).

A possible issue that could arise when estimating an empirical migration equation is that some of the explanatory variables may potentially be endogenous. In particular, environmental pollution may itself be affected by population density and therefore also by migration flows (Xu and Sylwester, 2016). We, therefore, face a bi-directional causality, where both (a) the amount of pollution might affect migration due to the fact that people can decide to live in less polluted areas or may be attracted to locate in more polluted/low-income areas (Hamilton, 1993, 1995) for economic reasons (*e.g.*, cheaper rents), and (b) migration may affect pollution levels (Price and Feldmeyer, 2012) by increasing local population, which places more pressure on community infrastructure and on the environment. In order to reduce the risk of this endogeneity bias, we regress net migration flows over the period 2011−15 on environmental and socio-economic variables dated 2010. The orthogonality assumption that is required for the validity of the estimates is that shocks to migration flows over 2011−15 are uncorrelated with shocks to environmental and socio-economic variables in

[9] Housing market values in Italy are released by OMI (Osservatorio del Mercato Immobiliare, https://www.agenziaentrate.gov.it/portale/web/guest/schede/fabbricatiterreni/omi/banche-dati) which is part of the Italian Revenue Agency (Agenzia delle Entrate). OMI provides semiannual estimates of the maximum and the minimum values of many types of buildings based on the actual trades that take place in the real estate market within a given time period. OMI reports 19 different building categories: in this study, we focus only on residential buildings and an average value is calculated for each province.

Table 3
OLS Empirical Results – net migration rate (2011-2015).

Dependent Variable	Net Migration *(a)*	Net Migration *(b)*	Net Migration *(c)*	Net Migration *(d)*
Air pollution	−0.948**	−0.591**	−0.530**	−0.606**
	(0.424)	(0.285)	(0.2631)	(0.249)
log_Income		1.363***	1.016***	
		(0.279)	(0.303)	
log_Real Estate		0.016	0.024	0.066**
		(0.024)	(0.026)	(0.028)
log_Education		0.236	0.439	1.231***
		(0.400)	(0.389)	(0.382)
Unemployment		−0.034***	−0.021***	−0.021***
		(0.005)	(0.007)	(0.007)
Entrepreneurial Density		0.064***	0.059***	0.050***
		(0.012)	(0.012)	(0.012)
Infrastructures		0.001***	0.001***	0.001***
		(0.000)	(0.000)	(0.000)
Centre			0.171***	0.221***
			(0.054)	(0.054)
North			0.162**	0.242***
			(0.063)	(0.059)
constant	0.597***	−14.127***	−11.339***	−3.202***
	(0.061)	(2.389)	(2.631)	(0.916)
F-Stat	5.01**	49.87***	47.98***	44.76***
R^2	0.052	0.78	0.80	0.78
Observations	110	103	103	103

Table 4
OLS estimations with Net Migration Rate as dependent variable (with demographic controls).

Dependent Variable	Net Migration *(a)*	Net Migration *(b)*
Air pollution	−0.510**	−0.481**
	(0.222)	(0.230)
log_Real Estate	0.058*	0.054*
	(0.033)	(0.030)
log_Education	1.145***	1.038***
	(0.382)	(0.385)
Unemployment	−0.010*	−0.008
	(0.006)	(0.006)
Entrepreneurial Density	0.028**	0.034**
	(0.013)	(0.014)
Ratio age 0−14	8.715***	4.870
	(-3.019)	(-4.402)
Ratio age 15−19	−37.109***	−34.128***
	(-5.657)	(-5.805)
Ratio age 40−59	−5.185	−6.762*
	(-3.181)	(-3.766)
Ratio age 60−64	−5.070	−8.922
	(-7.840)	(-7.477)
Age 65 and over	0.669	−0.765
	(-1.904)	(-2.194)
Centre		0.101*
		(0.059)
North		0.114
		(0.078)
Infrastructures		0.001*
		(0.000)
constant	−0.363	1.119
	(-2.195)	(-2.563)
F-Statistic	58.70***	49.51***
R^2	0.83	0.84
Observations	103	103

Robust Standard errors in parentheses. Statistical significance is indicated as follows * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

2010. We believe that this is a plausible assumption, given that the explanatory variables are pre-determined and are unlikely to have been affected by future migration flows.

Therefore, to address the concern of reverse causality between migration flows (emigration and immigration) and income level, we take the assumption that migration flows and income level are pre-determined as argued by Mayda (2010). Moreover, using province-level data makes the issue of locating on the basis of cheaper rent less of a problem. In fact, previous empirical evidence (Faini et al., 1997) supports the idea that, in Italy, internal migration is generally low when compared with other countries, such as the USA. Bonasia and Napolitano (2012) found that wage differential, for the period 1995–2006, was an important determinant of internal migration in Italy; on the other hand, housing price differentials seemed to have little or no power to explain migration from one region to another. Furthermore, migration is a forward-looking decision which is usually carefully planned, and which is made on the basis of a full consideration of the benefits and cost of moving (Carrington et al., 1996). It is, thus, plausible to assume that air pollution and the other economic and socio-demographic conditions (pre-determined environmental, economic, social and demographic provincial characteristics) take some time before they exhibit their effects on migration flows.

4. Estimation results

Tables 3 and 4 display the OLS estimates on the relationship between measures of net migration, pollution, and economic and demographic conditions, which provides the results of our exploration of the correlation between migration flows and air pollution in Italy.[10]

In model *(a)* of Table 3, results for the baseline specification are presented. The findings suggest a negative and statistically significant relationship between *local air pollution* and the net migration rate, implying that air pollution is perceived to be considered an inducer of emigration that produces displacement effects on residential decisions acting as a push factor to move from provinces with higher levels of air pollution toward those characterized by lower levels of air pollution.[11]

In model *(b)* we add socio-economic variables to the set of regressors. The result for air pollution is in line with the baseline estimation. *Income* is statistically significant, and it performs as an attraction/pull factor (characteristics of the destination province), suggesting that people tend to move towards wealthier provinces. *Unemployment* is statistically significant and is negatively related to the dependent variable: it thus has a negative effect on net inflows and can be regarded as a push factor, leading people to move from provinces with higher levels of unemployment toward those characterized by greater opportunities of employment in the job market. *Entrepreneurial density* and *infrastructure* exert a positive effect on the dependent variable revealing that residents can be attracted to move towards provinces characterized by greater opportunities related to the business/corporate sector and by better infrastructure. These factors can thus be seen as acting as pull factors.

In models *(c)* and *(d),* macro-territorial dummies *Centre* and *North* are added to the regressors set. As we can see, geography also matters: *Central* and *Northern* regions appear to attract more than the Southern regions, other factors being equal, confirming the general well-known Italian dualism for which the South is a more disadvantaged area, in both economic performance and level of development, compared with the rest of the country. This gap, therefore, plays a role in the choice to migrate amongst Italian provinces. Note that in model *(d)*, once *Income* is excluded from the specification, *Real Estate* and *Education* become significant: this is due to the structural interplay between *Income* and its determinants. As a matter of fact, *education* illustrates a positive and statistically significant effect on the outcome variable confirming that residents are attracted to move towards provinces which are characterized by higher levels of education. This finding is consistent with the mechanisms of positive externalities associated, above all, with human capital in the new growth theories (Lucas, 1988) for which investments in human capital increase the productivity of labour that has a positive contribution on the output growth. Moreover, *real estate* appears to play a role on the attractiveness of the provinces: the average property values, that represent a proxy of the wealth of the province itself, is positively correlated with the dependent variable.

In models *(a)* and *(b)* of Table 4, even when we finally add demographic characteristics of the population, as a robustness check, our strategic determinant remains consistently highly significant and with the same sign. With respect to the young adult *class age 20−39*, which is the age group most prone to migration in response to employment opportunities and more easily able to take into account the gains from migration associated with human capital (Biagi et al., 2011), the results for age categories show that, in the full specification model *(column b)*, provinces with higher shares of people in the *age range 15−19* and *40−59* are statistically significant and negative and, thus, less attractive.

All our previous estimates remain substantially unchanged. Air pollution, education, unemployment, infrastructures, entrepreneurial density and geographic characteristics are confirmed as important factors in explaining the population's movements across Italian provinces.[12] Overall, we have very good fit with an R^2 of 0.84 and an F-statistic of 49.51 with 12 degrees of freedom. Hence, so far, our results provide support for the contention that air pollution plays a role when it is associated with migration.

4.1. Robustness checks

We are aware that assessing the extent to which air pollution might affect internal migration is a complicated task. Indeed, we can't exclude that the levels of air pollution could be correlated with unmeasured or unobservable characteristics of the provinces (for instance, the ability of the public enforcement authority to detect the pollution sources), which, in turn, may affect the relative attractiveness of a province. In order to minimize possible bias due to this endogeneity problem, we also estimate Eq. (1) using a two-stage least square (2SLS) model to further examine the robustness of the OLS estimates. We overcome this challenge and reach identification by exploiting two exogenous variables that might influence air pollution but do not exert a direct impact on internal migration rate: *judicial inefficiency* expressed in terms of trials' length (measured in number of days) of all criminal trial proceedings (in the year 2010) at provincial level, and e*nvironmental crimes* measured as the number of environmental crimes over the total population of the province.[13] Arguably, pollution will be lower in provinces with efficient courts (able to handle a high number of proceedings) and efficient enforcement (Germani et al., 2020), since long trials are likely to postpone the timing of punishment (Becker, 1968) and this could be an important factor inducing firms or individuals to undertake illegal environmental activities. As it is well known, law and economics scholars (Cohen, 2000; Polinsky and Shavell, 2000) show that increasing enforcement efforts and more efficient judicial courts lead to increased

[10] We conducted preliminary tests to ensure that the model and variables did not present multi-collinearity problems or violate other Gauss Markov assumptions, such as skewness and homoskedasticity.

[11] In models (b), (c) and (d) we have 103 observations due to missing data for 7 provinces, in the year 2010. For completeness, we have to say that in 2010, the number of provinces was increased from 103 to 110 (Barletta-Andria-Trani, Carbonia Iglesias, Fermo, Monza Brianza, Ogliastra, Olbia Tempio, Medio Campidano).

[12] We have also run the model using both in- and out migration separately on the set of independent variables but the estimates obtained using net migration rate provide the best fit to the data.

[13] Note that trial and appeal delays are one of the major problems associated with the inefficiency of justice in Italy.

Table 5
2SLS estimation results.

Dependent Variable	Net migration IV- 2 instruments *Justice Ineff. & EnvCrime*	Net migration IV- 1 instrument *EnvCrime*
Air pollution	−1.264**	−1.477**
	(0.655)	(0.669)
log_Real Estate	0.038	0.038
	(0.032)	(0.032)
log_Education	0.023	0.041
	(0.129)	(0.135)
Infrastructures	0.001***	0.001***
	(0.000)	(0.000)
Unemployment	−0.033***	−0.034***
	(0.007)	(0.007)
Entrepreneurial Density	0.039***	0.038***
	(0.013)	(0.013)
Centre	0.222***	0.216***
	(0.054)	(0.054)
North	0.213***	0.204***
	(0.065)	(0.065)
F-stat. (8, *95*)	167.63***	166.80***
Cragg-Donald Wald F	11.455*	17.794*
Hansen *J*-Test	0.533	0.562
Kleibergen-Paap rk LM (under. Id.)	17.145***	11.131***
R^2	0.74	0.74
Observations	103	103

Robust Standard errors in parentheses. Statistical significance is indicated as follows: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

deterrence. Similarly, our main idea behind the use of environmental crimes, as an instrumental variable, is that environmental violations (i.e., illicit disposal of waste, illegal constructions, forest fires, etc.) may contribute to activities that could be destructive for the environment, feeding environmental degradation through an increase of local air pollution.

Formally, in the first stage, *air pollution* is regressed on the two discussed instruments (i.e., *judicial inefficiency* and *environmental crimes*) along with a set of socio-economic and geographic controls (X) as discussed above:

$$pollution_{it} = \beta_0 + \alpha_1 Judicial\_inefficiency_{it} + \alpha_2 EnvCrime_{it} + \beta_X X_{it} + \varepsilon_{it} \quad (2)$$

where the subscript i denotes the province and ε is a randomly distributed error term. In stage 2, we estimate a model of the following form:

$$netmigration_{it} = \alpha_0 + \alpha_1 \widehat{pollution}_{it} + \beta_X X_{it} + \nu_{it} \quad (3)$$

where $\widehat{pollution}$ is the predicted value of *pollution* given the instrumental variable from the first stage, α_1 provides an estimate of the effect of *pollution* on the net migration rate, and ν is a randomly distributed error term. As proposed in Cragg and Donald (1993) and Stock and Yogo (2005), for the validity of the instrumental variable approach, we implement the minimum eigenvalue statistic test that confirms that our instruments are relevant (within the 10 % of relative bias). Furthermore, to test the validity of the set of instruments, we check for over- and under- identification by using a Hansen *J* statistic and Kleibergen-Paap rk LM statistic; both the statistical tests provide robustness on the validity of the restrictions made.

To assess the validity of the estimation results shown in Section 4, we conduct further robustness checks focusing on the estimates of column *(d)* in Table 3, which is our preferred specification for its simplicity, parsimoniousness as well as its goodness-of-fit ($R^2 = 0.78$): our results are largely confirmed in terms of statistical significance and coefficient signs. Specifically, in the 2SLS estimates (Table 5), statistical significance and sign of *air pollution* are confirmed, validating the existence of a negative correlation with net migration rate. Thus, in accordance with the push-pull framework, which explains the driving forces underlying migration flows, air pollution represents a push factor implying that residents tend to migrate out in the case of high levels of air pollution in the province of origin. Equally, people decide to migrate in towards provinces where employment opportunities are more favourable. *Entrepreneurial density* and *infrastructures* exert, again, a positive effect on the dependent variable acting as pull factors. These findings confirm that the *northern* and *central* regions are more attractive than the southern ones, other factors being equal.

One possible difficulty when using more than one instrumental variable is that conventional asymptotic approximations may weaken the sampling distributions of the resulting estimators. We therefore also include the 2SLS estimation with environmental crime as the only instrument, because this can be considered a strong predictor of environmental degradation (i.e., air pollution). The magnitude, sign and statistical significance of the coefficients remain overall very consistent with the previous findings, confirming that the negative relationship between net migration rate and air pollution still holds.

To tackle possible transboundary pollution effects, we have also included in our estimation carbon dioxide (CO_2) emissions[14] and its aggregated emissions (which are the most likely to generate geographical spillover effects) produced in the neighbouring provinces (Maddison, 2006). Following Costantini et al. (2013), we assume that emissions of nearby provinces (defined as direct neighbours sharing a common border) might affect the level of pollution of a province. We consider the first-order contiguity with direct neighbors, giving weight $wrs = 1$ to each *s-th* province neighbouring province r and $wrs = 0$ to all other provinces. Consequently, the spatial regressor is defined as the average of CO_2 emissions available in directly neighbouring provinces expressed as $D = \sum_{s=1,\, s\neq r}^{N} (E_s w_{rs})$, where Es is the emission level per unit area of the *s-th* province, N is the total number of provinces and $wrs = 1$ if s is neighbouring r. However, both the *global air pollution* (CO_2) and its spatial variable (i.e., release of neighbouring provinces) are not statistically significant, suggesting that the above-mentioned clustering effect is not occurring (see Table A2).

5. Conclusions

The key novelty of our study lies in the analysis of the role played by air pollution on net migration rate in the Italian provincial context. Based on air pollution data at provincial level, this study uses the aggregation of NOx, VOC, CO and PM_{10} emissions, to investigate its effects on internal migration. The estimates obtained indicate that net migration is positively associated with income, level of education, entrepreneurial density, level of infrastructure, and is negatively associated with local air pollution and unemployment. Results are obtained after controlling for various socio-economic and demographic characteristics; we are aware that our estimates are based on cross-sectional data and that reasons for migration cannot be sufficiently explained by the push-pull factors as it involves complex individual decision-making processes, so caution must be taken in generalizing the outcomes reported here. Nonetheless, our findings appear to concur with those in other studies that postulate environmental pollution as a contributing factor for emigration, allowing us to say that, in Italy, a clean environment might influence the decision to move; people can be induced to counterweight economic activity that raises income in favour of increased environmental quality. This could, eventually, induce bigger proportions of population to move toward places with a better environmental quality.

The peculiarity of the Italian context in terms of dualism across more developed northern/central and less developed southern regions is also confirmed with the evidence that the northern and the central regions attract more people than all the other geographical areas. These results

[14] CO_2 emissions takes particular relevance not only because this pollutant is the main gas responsible for global warming among the entire greenhouse gases (UNEP - United Nations Environment Programme, 1999), but also because it is one of the key indicators (if not the key indicator) adopted by Eurostat to monitor the European climate change (Roca et al., 2001).

Table A1
Correlation Matrix.

	Net Migration	Air pollution	ln_Income	ln_Real Estate	ln_education	Unemployment	Entrepr.	Infrastructures
Net Migration	1							
Air pollution	−0.244	1						
ln_Income	0.726	−0.202	1					
ln_Real Estate	0.429	−0.0702	0.461	1				
ln_Education	0.611	−0.180	0.716	0.231	1			
Unemployment	−0.760	0.0418	−0.607	−0.326	−0.531	1		
Entrepreneurship	0.295	−0.124	−0.0870	0.108	−0.00449	−0.168	1	
Infrastructures	0.263	0.0961	0.333	0.318	0.350	−0.178	−0.280	1

Table A2
OLS estimations with CO_2 emissions (a) and with the aggregation of CO_2 emissions in all neighbouring provinces (b.).

Dependent Variable	Net migration *(a)*	Net migration *(b)*
Air pollution (local)	−0.658*** (0.249)	−0.548** (0.254)
CO_2 emissions (global)	4.86e-09 (3.28e-09)	
CO_2 emissions_neighbouring provinces		6.12e-06 (4.01e-06)
log_Real Estate	0.060** (0.028)	0.065** (0.028)
log_Education	1.152*** (0.373)	1.257*** (0.391)
Infrastructures	0.001** (0.000)	0.001*** (0.000)
Unemployment	−0.022*** (0.008)	−0.021*** (0.007)
Entrepreneurial Density	0.051*** (0.012)	0.055*** (0.013)
Centre	0.220*** (0.054)	0.215*** (0.056)
North	0.235*** (0.060)	0.218*** (0.064)
constant	−2.984*** (0.891)	−3.346*** (0.949)
F-stat. (9, 93)	39.50***	40.13***
R^2	0.78	0.74
Observations	103	103

call for an enhancement of the link between environmental and migration policies. If population movement depends in part on environmental quality, an obvious suggestion is that migration policies and environmental policies are interlinked and cannot be optimally designed without taking into account their complementarity. This confirms that non-economic factors, alongside traditional economic factors, are relevant determinants of migration that could reshape the societal understanding of population distribution across the territory. Despite continuous improvements in recent decades, air pollution is still the single largest environmental risk in Italy generating considerable economic impacts and affecting the general health of the population (Ministero dell'Ambiente, 2019). Policymakers may find these insights useful for the creation of social and environmental policies designed to improve society's need to cope with environmental degradation, in combination with the development or implementation of a wide range of strategies able to ensure better, and more uniform, environmental and quality of life standards across all Italian provinces.

CRediT authorship contribution statement

Anna Rita Germani: Conceptualization, Methodology, Data curation, Writing - original draft, Writing - review & editing. **Pasquale Scaramozzino:** Formal analysis, Methodology, Software, Writing - review & editing, Supervision. **Angelo Castaldo:** Formal analysis, Methodology, Software, Writing - review & editing. **Giuseppina Talamo:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

Table A1

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