AIR POLLUTION AND MIGRATION OF ETHNIC MINORITIES: EVIDENCE FROM CHINA

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Abstract. The urbanization process in China has been involved with the internal migration of ethnic minorities for a better habitant environment. The paper identifies the effect of air pollutant $PM_{2.5}$ (inhalable fine particles less than 2.5 μm diameter) on the migration of ethnic minorities by using individual censuses in China. We use IVprobit model to analyse whether $PM_{2.5}$ concentration affects the migration decision of ethnic minorities and the extent of this effect. Using average wind speed as instrumental variable to handle the endogeneity problem, we find that the environmental costs of industrialization drive ethnic minorities out of their birthplace and the minority autonomous regions. The estimation results are consistent for both the Han majority and the ethnic minorities in minority autonomous regions. The interaction effects indicate that an ethnic individual's migration decision responding to $PM_{2.5}$ pollution vary by household registration type, housing sources, income level, the number of children in the family. Ethnic minority groups are more concerned about the environmental quality of their residence places compared with the economic benefits and some preferential policies when considering out-migration. The conclusion of this paper also contributes to the integration and inclusiveness of East Asian economic regions.
Keywords: *$PM_{2.5}$, ethnic minority, migration, environment degradation, population mobility, minority autonomous regions*

JEL: J15, J61, Q53, I31, R23

Introduction

Research on environmental pollution and internal population migration has been widely discussed (Cao et al., 2015; Xu and Sylwester, 2016). Environmental quality is concluded to be an important contributing factor when explaining internal migration (Li et al., 2017). For example, air pollution has increased both immigration tendency (Lu et al., 2018) and actual migration behaviors (Chen et al., 2022). However, the impact of environmental pollution on internal migration has received limited attention in multi-ethnic countries from the perspective of ethnic minorities. Ethnic minority migration is one of the main drivers of local population change. The internal ethnic structure, religious structure, and culture/custom composition within a region can be changed by ethnic migration. Those factor changes may further present huge challenges to the local economic development and ecological environment. In a multi-ethnic country, government should be more careful and incorporate ethnic migration when making policies and providing services such as housing, health, and education (Darlington-

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Pollock et al., 2018). These characteristics highlight the importance and complexity of ethnic migration research.

China as a multi-ethnic country with 56 nationalities and 55 ethnic minorities, is taken as an example due to its environmental degradation and frequent movements of ethnic minority. According to the latest census, ethnic minorities have a total population of more than 120 million, counting for 9% of the total Chinese population at an increasing rate. With rapid development of economy, advancement of urbanization and national population policy adjustment, mobility and migration of ethnic minority groups have been increasingly active (Wang, 2018). *Table A1* describes the proportion of ethnic minorities across provinces in China (Except for Hong Kong special administrative region, Macau special administrative region, and Taiwan province of China, within the rest of 31 provincial administrative region the proportion of ethnic minorities in 17 regions reduced, while the proportion of ethnic minorities in 14 regions increased in the period of table reports). Five minority autonomous regions (MARs) that include Inner Mongolia Autonomous Region, Guangxi Zhuang Autonomous Region, Tibet Autonomous Region, Ningxia Hui Autonomous Region, and Xinjiang Uygur Autonomous Region in China where most ethnic minorities reside have been experiencing air pollution and health risks that are associated with rapid industrialization and energy consumption (Yang et al., 2017). Five MARs are important and of great development potentials for their abundant resource reservation (coal, oil, wind, etc.), geographic location, and ethnic culture diversity. And ethnic minorities also scattered in the rest of China. Moreover, some studies have found that air pollution may cause ethnic tension and unrest (Baranovitch, 2019), which poses a potential threat to national unity and social stability. The loss of population in MARs has a negative effect on the inheritance of ethnic culture (Liu et al., 2015). Thus, studying the effect of air pollution on this demographic group (ethnic minorities) warrants enough attention. This paper intends to investigate the role of air pollution played in the internal migration for ethnic minority groups in China.

In this paper, $PM_{2.5}$ (inhalable fine particles less than 2.5 μm diameter) is chosen as a measurement of air pollution since China has been the most $PM_{2.5}$ hit area in the world (Yale University, 2016). About 366,000 people in China died prematurely due to air pollution, particularly by $PM_{2.5}$ in 2013 (WHO, 2016; Xie et al., 2016). $PM_{2.5}$ is also one of the most common and standardized pollution measures in the world. Besides, it has become the fourth major risk factor threatening the premature death of Chinese people (Xie et al., 2016).

This paper will analyze the $PM_{2.5}$ air pollution effect on migration of ethnic minorities in China and mainly address three questions. Is the $PM_{2.5}$ air pollution a potential reason of ethnic minority's migration in China? Do migration decisions of $PM_{2.5}$ effect vary between ethnic groups differentiated by household type, income, and the amount of children / elderly in the household? How to balance some trade-off cost (such as potential health expenses due to $PM_{2.5}$ pollution and a series of benefits) of migration for ethnic groups? We use windspeed as instrumental variable for endogeneity problems between $PM_{2.5}$ and population migration. The 3rd and 11th Sustainable Development Goals (SDGs) have emphasized "good health and well-being" and "sustainable cities and communities". Motivated by these SDGs, the paper provides policymakers with empirical evidence on the relationship between environmental pollution and ethnic minorities' migration and presents policy recommendations on demographic dividend and cultural fusion for sustainable city construction in other multi-ethnic countries. Compared with previous studies, in terms of the problem of official statistical data unavailability, the contribution

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of this paper focuses on the effect of environmental aversion such as air pollution and preferential policies on the migration decision-making for ethnic minorities in China using more exact individual census data.

The rest of the paper is arranged as follows. The second section presents literature review and mechanism of $PM_{2.5}$ effect on ethnic minority's migration. The third section introduces the econometric model with variable definitions, data source and descriptive statistics. The fourth section shows the estimate specifications and robustness checks. The conclusion and relevant policy recommendations for ethnic population policy and environmental policy are given at the end.

Literature Review and Theoretical Framework

Relationship between environment and population migration has attracted attention from academia and the public. Environmental factors have "push" (O' Lear, 1997) and "pull" effects when they affect population migration (Warner et al., 2010; Lewin et al., 2012). Many studies have focused on the analysis of migration behavior caused by natural disasters and climate change (Thiede et al., 2016). Meanwhile, the number of empirical studies on the causal relationship between air pollution and population migration have increased (Li et al., 2017; Lu et al., 2018; Chen et al., 2022). Less literature has paid attention to the role of environmental factors (natural hazards) in the migration disaggregated by race (Fussell et al., 2010; Boustan et al., 2017; Gao and Wang, 2018). Gao and Wang (2018) concluded that natural environmental factors had an important effect on the distribution of minority nationalities. The migration behaviors affected by natural hazards are caused by racial heterogeneity of environmental damage exposure degree, such as White and Black (Fussell et al., 2010).

However, the potential relationship between environmental pollution and internal migration of ethnic minority is found to be relatively limited and mixed. On the one hand, previous studies showed that there were deep racial differences respond to air pollution (Cebula, 1975) and industrial pollution persisted (Crowder and Downey, 2010). It has been considered that the inequality of environmental pollution exposure among minority groups leads to the heterogeneity of migration behavior. On the other hand, Hunter et al. (2003) did not find different racially migration responses to environmentally harmful facilities. Besides, these studies mainly focus on developed countries such as the United States (Cebula, 1975; Crowder and Downey, 2010; Best et al., 2018).

Race and ethnicity are two concepts that are fundamentally different. Race is a group of people with common physical characteristics formed in the early stages of human development, generally divided by physical characteristics such as skin color, hair color, eye color, head shape, face shape, and other signs. Ethnicity, on the other hand, refers to a stable community of people formed historically with a common language, a common territory, a common economic life, and a common psychological quality expressed in a common culture. It is generally divided by social factors such as language, territory, economic life, and psychological quality. Hunter et al. (2003) was concerned with the racially differentiated effects of hazardous environmental wastes on the county-level migration pattern in developed countries. Therefore, this study begins to fill these gaps in literature by employing empirical evidence of environmental pollution effect on ethnic minority's migration using an example of China as largest developing country. Unlike Hunter et al. (2003), this paper focuses on air pollution rather than relatively fixed hazardous environmental wastes. It combines socio-economic characteristics to

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comprehensively measure migratory decision-makings based on economic opportunities such as income, as well as preferential policies (such as college entrance examination awarded marks). The study helps to understand the trade-offs ethnic minorities make affected by environmentally aversive goods and socio-geographical contexts. Besides, the paper contributes to understanding the determinants of ethnic population distribution patterns in developing countries.

Industrialization, urbanization, and economic development are often associated with all types of environmental costs including air pollution (Hunter et al., 2003). In general, industrial air pollution is accompanied by economic benefits of growth and high-paying industrial jobs (Hunter et al., 2003). However, ethnic minorities may face more trade-offs between air pollution and migration which leads to complex and difficult decision-makings in China. Ethnic minorities have great differences in national culture, religious beliefs, living habits, folk etiquette and dietary preferences compared with the Han nationality in China. Those ethnic characteristics are directly being influenced by the economic development and environments of residence areas.

Besides, there are some preferential policies for ethnic minorities related to their residence areas. For example, ethnic minorities living in ethnic populated areas can obtain higher extra scores in college entrance examinations (Gaokao) than those living in ethnic scattered areas. According to the projects and requirements for the admission of the general colleges and universities in Hebei Province in 2010, minority candidates from Hebei Autonomous County increased by 10 points, while scattered minority candidates only increased by 5 points. There is also lower admission passing score for college entrance examination candidates in some MARs (such as Xinjiang Uygur Autonomous Region) than other provinces. Even Han nationality candidates living in ethnic populated areas and ethnic candidates living in Han populated areas may be admitted preferentially under the same conditions in some provinces (such as Hunan, Chongqing) (See https://gaokao.chsi.com.cn/gkxx/ss/201604/20160413/1529345794.ht
ml). These benefits can be summarized as economic benefits accompanied by industrialization, ethnic characteristics, and some preferential policies for ethnic minorities. Therefore, whether to migrate or not, depends on the trade-off cost (such as potential health expenses due to $PM_{2.5}$ pollution) and a series of benefits mentioned above.

If clean air is a normal product, the net benefit of migration behavior is usually considered a "latent variable" when an individual is making the choice to migrate. When considering air pollution, the assumption is that people are aware of the local air quality and adverse consequences of continuing to live there in their migration decision-making (Smith et al., 2004). Hence, we use *M* to denote an individual's migration decision. An individual's migration behavior can then be observed when the latent variable (the benefit of migration behavior) is positive, that is, $M^{*}>0$.

$$M = \alpha x + \varepsilon \quad M = \begin{cases} 1, & if \quad M^{*} > 0 \\ 0, & otherwise \end{cases} \qquad \text{(Eq.1)}$$

Although the environmental quality factor is important in the migration decision (Warner et al., 2010), socio-economic conditions (e.g., employment opportunities and welfare levels, ethnic characteristics, ethnic preferential policies, etc.) of the original residence are also important and could hinder the labor force's out-migration (Enchautegui, 1997; Li et al., 2017). Although some pollution victims are fully aware of the health risks involved, those who rely on employment and compensation in polluting

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industries tend to despise or even ignore pollution and its health risks (Tilt, 2006). Notably, if individuals can adjust their behavior to reduce the potential health risks associated with $PM_{2.5}$ pollution or take actions to mitigate health risks (Qin and Zhu, 2017), such as buying anti-$PM_{2.5}$ facemasks (Zhang and Mu, 2018), air purifiers, and reducing outdoor time, they may not choose to migrate out.

An individual's adaptive behavior and defensive measures to minimize pollution damages are taken as their health investment. Next, the indirect utility function of individual *i* in a region *r* is denoted as V_{ir} and it is determined by the environmental quality (*E*), socioeconomic development level (*W*), and amount of health investment (*H*) and other individual and household characteristics (*R*).

$$V_{ir} = V_{ir}[E_r\ W_{ir}\ H_i\ R_i] \tag{Eq.2}$$

An individual who considers making a migration decision evaluates the indirect utility of the household registered in place *b*, the indirect utility of the current residence *l*, and migration cost *C*. Migrations occur when the indirect utilities of place *b* minus the indirect utilities of place *l* is greater than migration cost *C*. The index M^* represents the difference in utility between the two locations. This total utility difference (ΔV) is also a function of environmental quality factors, socioeconomic conditions, health investment, other individual and household characteristics and migration cost. When this utility difference is greater than 0, the occurrence of migration behavior is observed ($M_i=1$):

$$\begin{gathered} M_i^* = \Delta V = V_{il}(E_l\ W_{il}\ H_i\ R_i) - [V_{ib}(E_b\ W_{ib}\ H_i\ R_i) - C_i], \\ M_i = 1 \ \ if\ and\ only\ if\ M_i^* > 0 \\ M_i = 0 \ \ otherwise. \end{gathered} \tag{Eq.3}$$

The linearization equation of M^* is:

$$\begin{gathered} M_i^* = \delta_1 + \delta_2(E_l - E_b\ ) + \delta_3(W_{il} - W_{ib}\ ) + \delta_4(H_l - H_b\ ) \\ + \delta_5(R_l - R_b\ ) + \delta_6 C_i + \varepsilon_i \\ \begin{cases} M_i^* > 0 \Leftrightarrow \varepsilon_i > -II'R_i \\ M_i = 1 \Leftrightarrow \varepsilon_i > -II'R_i\ , \\ M_i = 0 \ \ otherwise \end{cases} \end{gathered} \tag{Eq.4}$$

and

$$\begin{gathered} II'R_i = \delta_1 + \delta_2(E_l - E_b\ ) + \delta_3(W_{il} - W_{ib}\ ) + \delta_4(H_l - H_b\ ) \\ + \delta_5(R_l - R_b\ ) + \delta_6 C_i \end{gathered} \tag{Eq.5}$$

The possibility of migration increases when an individual's benefits from the increase in environmental quality and socioeconomic conditions. The possibility of migration decreases when an individual's benefits from health investment decrease. When an individual experiences bad air quality, the migration decision is made when the benefit of the migration, after paying the migration cost *C*, is still greater than the utility difference between places *b* and *l*.

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Methods and Materials

Econometric methodology

We use *IVprobit* model to analyze whether $PM_{2.5}$ concentration affects the migration decision of ethnic minorities and the extent of this effect. Gardner (1981) was the first to investigate the effects of macro factors on micro migration decisions and constructed the "micro–macro decision-making model."

There may be a reverse causality between population migration and environmental pollution (Chen et al., 2022). With fast economic development and urbanization process brought by industrialization, the large-scale population aggregation has led to increasing resource demand and environmental pollution (O'Lear, 1997; Cao et al., 2015; Fan et al., 2016). Increasing consumption of electricity and heating resources has deteriorated air quality. Ecological environment and urbanization process always come along hand in hand (Cao et al., 2015; Rafiq et al., 2017). Ma and Hofmann (2019) argued that both general population and immigrant population were related to air quality improvements rather than deterioration.

Tiwari (2017) used natural experiments to solve the endogeneity problem between economic development and migration. As concerned about reverse causality and omitted variable bias, the instrumental variable (IV) method is adopted to solve the endogeneity problem of $PM_{2.5}$ concentration and ethnic minority individuals' migration (*IVprobit* model). First step of the *IVprobit* model is as follows.

$$PM2.5_{i,j} = \alpha_1 + \beta_1 \boldsymbol{IV}_j + \beta_2 \boldsymbol{R}_i + \beta_3 \boldsymbol{W}_i + u_i + \varepsilon_{i2} \quad \text{(Eq.6)}$$

Dependent variable is the $PM_{2.5}$ concentration variation in county *j*. Vector ***IV*** refers to instrumental variables of $PM_{2.5}$. Considering availability of data, the average wind speed (*Windspeed*) at household registered place is used as the IV of the $PM_{2.5}$ concentration. The average wind speed is independent and exogenous to an individual's decision-making on migration. There is an expected negative correlation between $PM_{2.5}$ concentration and *Windspeed* (Westervelt et al., 2016; Fontes et al., 2017). Vector ***R*** and vector ***W*** contain the same control variables as in *Equation (7)*.

The second step of *IVprobit* model is set up in *Equation (7)*.

$$Migration_i = \alpha_1 + \beta_1 \boldsymbol{PM2.5}_j + \beta_2 \boldsymbol{R}_i + \beta_3 \boldsymbol{W}_i + u_i + \varepsilon_{i1} \quad \text{(Eq.7)}$$

Subscript *i* represents a minority individual; subscript *j* refers to household registration place where a minority individual *i* has moved out from; The dependent variable *Migration* is a binary variable refers to the migration decision of whether a minority individual migrates within the survey year. Minority residents who leave their household registration place in the data recorded year (when the census survey took place) are defined as migrants in that year. Minority residents who have never left their household registration place or left before the data recorded year are defined as non-migrants in that year. The identification variable is whether the household registration place is different from current residence when the census survey took place. Moving within a county is not considered as migration in this research and we also assume the $PM_{2.5}$ concentration within one county is not of big difference. The mean $PM_{2.5}$ concentration in the location of household registration is the key explanatory variable and denoted as $PM_{2.5mean}$. All standard errors are clustered at the individual level.

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Variable α_1 is a constant term; vector $\boldsymbol{PM_{2.5j}}$ is measured by the mean $PM_{2.5}$ concentration variation in county j; vector $\boldsymbol{R}$ contains individual characteristics and household characteristics; vector $\boldsymbol{W}$ contains regional socioeconomic conditions where an individual i resides; variable u_i is the controlled fixed effect of province and nationality, ε_{i1} is the random error term. Coefficient β_1 is the parameter of interest in the model. More descriptions of variables follow.

$$Migration = \begin{cases} 1, & when\ they\ leave\ birth\ place\ within\ the\ survey\ year \\ 0, & when\ they\ leave\ birth\ place\ before\ survey\ year\ or\ never\ leave \end{cases} \quad \text{(Eq.8)}$$

In addition to the key explanatory variable, we include control variables. Existing literature on ethnic migration has been focusing on social factors such as demographic characteristics and community networks (Liu et al., 2015; Darlington-Pollock et al., 2018; Joxhe, 2018). Vector $\boldsymbol{R}$ contains individual characteristics of ethnic migrants, including gender (*Gender*), age (*Age*), education status (six levels in total). An ethnic minority individual 's education level is categorized into six dummy variables according to the survey: elementary school (Pri-edu), junior high school (Jun-edu), high school (Sen-edu), university college (Col-edu), and undergraduate (Gra-edu) and graduate (Pos-edu). The base group comprises those who never attended school), marital status (Marr), work status (Work), and home-ownership status (House) of the migrating year in the census. Studies have shown that individual characteristics, such as gender, age, education level, marital status, and employment can affect migration behavior (Boustan et al., 2012; Thiede et al., 2016; Lu et al., 2018).

The dataset does not provide information regarding individual income, which is an important factor that affects the migration decision (Enchautegui, 1997; Rupasingha et al., 2014; Lu et al., 2018). Instead, we use a dummy variable of home ownership as a proxy to measure a minority individual's income level. Investing in real estate is popular in China and Chinese people tend to own their residence instead of renting one. Hence, income level can positively affect Chinese residents' home ownerships (Yao et al., 2014).

For household characteristics, vector $\boldsymbol{R}$ also includes the number of children under 16 years old (*Childnum*), the number of elderly people (women over 55 and over 60 years old) that denoted as *Oldnum*, and the agricultural versus non-agricultural household registration type (*Non-agricultural*). The minimize legal working age in China is 16 years old, so it is not considered a child whose age is above 16. The average retirement age according to the China Labor Law. Previous studies concluded that family structure was a determinant of migration intentions (Lu et al., 2018) and migration behaviors (Enchautegui, 1997). Li et al. (2017) also included the number of children (population dependency ratio) and household registration type (agricultural/non-agricultural) in the model to illustrate the impact of $PM_{2.5}$ on labor migration decisions.

Literature has shown that the size of urban population and economic development level are also related to migration decisions (Xu and Sylweste, 2016; Li et al., 2017). The migration willingness of individuals would decrease with the improvement of regional economic conditions (Tiwari, 2017). In this study, the regional characteristics (vector $\boldsymbol{W}$) contain GDP per capita (*Pergdp*) and population density (*Popden*) at county level at the end of survey year. Per capita GDP is calculated based on provincial consumer price index to eliminate the price factor. Population density variable is added following Rupasingha et al. (2014), as a typical factor in migration model. Disasters also affect domestic

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migration. County-level cumulative average drought (*Drought*) and flood frequency (*Flood*) are adopted as control variables in the county where an individual migrated from. In addition, a better medical condition can partly reduce an individual's adverse expectation of air pollution risks. Thus, we include the medical condition variable (*Medcare)*, which also represents the urban infrastructure level. Tiwari (2017) stated that good infrastructure construction and health services could reduce urban–rural migration.

According to population division of China's ethnic autonomous regions and their major ethnic minorities, this paper considers the regressions of five MARs. There are some interaction terms we focus particularly on in the study. The literature has indicated that perception of environmental quality on migration may vary by income level (Enchautegui, 1997; Franzen and Meyer, 2010). In addition, the willingness of migration caused by $PM_{2.5}$ pollution may vary by household registration type, that is, non-agricultural or agricultural. Those groups with non-agricultural household registration type may be more sensitive to $PM_{2.5}$ pollution due to higher average education and income level. Overall, this study considers $PM_{2.5}$ pollution to estimate the interaction effect with household registration type (*Non-agri*), house source (*Housesource*), income level (*Income*), number of children (*Childnum*) and elder people (*Eldernum*) in the family, respectively.

As we have mentioned before, ethnic minorities usually make choices between economic benefits (accompanied by industrialization, ethnic characteristics, some preferential policies) and $PM_{2.5}$ air pollution. We wonder how $PM_{2.5}$ pollution affects the migration of ethnic minorities when these factors (economic benefits accompanied by industrialization, ethnic characteristics, some preferential policies) are controlled. Average salary level (*Wage*) in household registration province is employed to represent economic benefits accompanied by industrialization. Ethnic characteristics are controlled by dummy variables of ethnic category.

Considering data availability, the policies of awarded marks in College Entrance Examination for ethnic minorities are used as an example of preferential policies. The reason for picking this policy to control is that its data is easy to quantify, and it is a very special treatment for ethnic minorities. There are three types of awarded marks policy in College Entrance Examination for ethnic minorities. The first one is unconditional awarded marks. 8 provinces of Beijing, Tianjin, Anhui, Shanghai, Jiangsu, Zhejiang, Henan, and Hubei are implementing it. Ethnic minorities can get awarded marks no matter whether they live in ethnic minority communities or not. The second type does not give awarded marks but preferential admission to ethnic minority candidates when they have the same entrance scores as non-ethnic groups. Only Shanxi province is implementing this policy type. The other 22 provinces (Hebei, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Fujian, Jiangxi, Shandong, Hunan, Guangdong, Guangxi, Hainan, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang) in China are applicable to the third type that vary according to their household registration provinces (except Hong Kong, Macau, and Taiwan). Since the second category cannot obtain awarded marks and there is only one out of 31 provinces implementing it, we will not include Shanxi province in these preferential policies analysis. In our sample, there are only 73 samples of minority families in Shanxi Province with children under 18 years old. We consider the first and third types, which are denoted as a dummy of whether an individual's household registration province has policy of awarded marks in College Entrance Examination relevant to registration place (*Gaokao_res*) in China. The sample in this part focuses on all ethnic minority groups (excluding Bai) with children under 18 years old in the family since the policy related to

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College Entrance Examination is considered. Bai candidates do not receive awarded marks in College Entrance Examination since their overall well-being are leveled up with Han majority. These variables' definitions are summarized in *Table 1*.

Table 1. *Variables detailed definitions*

Variable	Definition
Dependent variable	
Migration	1=migrant; 0=non-migrant
Pollution	
$PM_{2.5mean}$	$PM_{2.5}$ mean value of the household registered place in the migration year ($\mu g/m^3$)
Individual characteristics	
Gender	Dummy: 0=female; 1=male
Age	Age in the migration year (years old)
Pri-edu	Dummy: 0=others; 1=primary school
Jun-edu	Dummy: 0=others; 1=junior school
Sen-edu	Dummy: 0=others; 1=senior school
Col-edu	Dummy: 0=others; 1=junior college
Gra-edu	Dummy: 0=others; 1=graduate
Pos-edu	Dummy: 0=others; 1=postgraduate and higher
Marr	Dummy: 0=single (including divorced or spouse loss); 1=married
Work	Dummy: 0=not work; 1=work (including temporary vacation or study)
House	Dummy: 0= no house; 1=have a house
Household characteristics	
Childnum	Number of children under 18 years old of the household in the migration year
Eldernum	Number of elder women over the 55 years old and elder men over 60 years old of the household in the migration year
Non-agri	Dummy: 0=agricultural household registration type; 1=non-agricultural household registration type
Macroeconomic characteristics	
Pergdp	GDP per capita in the location of household registration during the migration year (10000 CNY)
Popden	Population density in the location of household registration during the migration year ($10^3/km^2$)
Medcare	Number of sanitary institutions in the location of household registration during the migration year (10^2 unit)
Drought	The drought occurrences in the location of household registration during the migration year
Flood	The flood occurrences in the location of household registration during the migration year
Interacted variables	
Housesource	0=no house; 1=housing is rented; 2=housing is purchased
Income	0=no house; 1=monthly rental cost less than 100 CNY; 2=monthly rental cost between 100 and 200 CNY; 3=monthly rental cost between 200 and 500 CNY; 4=monthly rental cost between 500 and 1000 CNY; 5=monthly rental cost between 1000 and 1500 CNY; 6=monthly rental cost between 1500 and 2000 CNY; 7=monthly rental cost between 2000 and 3000 CNY; 8=monthly rental cost above 3000 CNY; 9=purchased a house
Instrumental variables	
Windspeed	The mean average wind speed in the location of household registration (m/s)
Other variables	
Wage	Average salary level in the province of household registration (1,000 CNY)
Gaokao_res	1= province of household registration is in Hebei, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Fujian, Jiangxi, Shandong, Hunan, Guangdong, Guangxi, Hainan, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia or Xinjiang; 0= province of household registration is in Beijing, Tianjin, Anhui, Shanghai, Jiangsu, Zhejiang, Henan and Hubei

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Materials and data

Micro migration data of ethnic minorities is obtained from a large micro sample of sixth national census (2010 wave) in China which has a 0.1% sampling ratio. The sixth national census is conducted by the National Bureau of Statistics in China at the end of 2010. The data provides detailed information on each ethnic individual, such as gender, age, education status, marital status, location of household registration, current residence, time of migrate out from household registration location, and some social-economic characteristics from the survey year.

The $PM_{2.5}$ concentration data is obtained from Raster data of National Aeronautics and Space Administration Socioeconomic Data and Applications Center. Observations range from 70^{th} parallel north to 60th parallel south with 0.5-degree by 0.5-degree accuracy. Annual $PM_{2.5}$ concentration ($\mu g/m^3$) is predicted using annual average Aerosol Optical Depth data observed by the medium-resolution imaging spectrometer and a multi-angle imager. Medical institution and average salary level data come from "China Statistical Yearbook". Data on drought, flood, and wind speed are obtained from "China Meteorological Data Sharing Service System" provided by China Meteorological Administration.

The paper matches the big sample of individual census with $PM_{2.5}$ concentration and macro level county data (controlled variables and IV variables) in the micro–macro regressions. For a small number of administrative divisions with missing PM2.5 data, we determine the nearest county-level division in the PM2.5 database and replace those missing PM2.5 values for them. Due to the changes in county-level divisions, the macro-data of a few county-level divisions are missing, such as GDP. The sample covers 31 province-level regions (including MARs and municipalities directly under the central government) and 2,856 county-level divisions in China. This sample covers all the non-collective-registered ethnic individuals aged 16 years and older who are eligible to make a migration decision independently. The minimum legal working age in China is 16 years old. There are 6,166 ethnic migrants and 109,155 Han migrants in the sample.

Summary statistics

Table 2 shows the descriptive statistic of the cross-sectional sample for those ethnic groups who migrated in 2010 and the non-migrant ethnic groups. Compared with the non-migrant sample, mean $PM_{2.5}$ value for migrant sample are 1.23 $\mu g/m^3$ higher. The WHO recommends that the average annual concentration of PM2.5 should not exceed 10 μg/m3 (WHO, 2006). There are 53.2% male and 57.8% married migrants. Those migrants have average age of approximately 30 years old, higher education levels and less children and elderly people in the family. The economic development degree, population density and the level of health services (*Medcare*) of household registration location are lower for migrant sample. The mean value T-test between the migrants and non-migrants and significance levels are listed in the last column of *Table 2*. Most of the variables rejected the H_0 hypothesis of T test that there are significantly different characteristics between the two groups.

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Table 2. *Descriptive statistics of key variables*

Variable	Migrant		Non-migrant		T test
	Mean	S.D.	Mean	S.D.	
Pollution					
$PM_{2.5mean}$	23.149	8.558	21.919	10.211	-9.186***
Individual characteristics					
Gender	0.532	0.500	0.492	0.500	-5.965***
Age	30.586	11.018	40.433	16.032	47.280***
Pri-edu	0.202	0.402	0.269	0.443	13.984***
Jun-edu	0.509	0.500	0.401	0.490	11.392***
Sen-edu	0.135	0.342	0.142	0.349	-16.584***
Col-edu	0.074	0.261	0.066	0.248	1.386
Gra-edu	0.050	0.219	0.045	0.208	-2.468**
Pos-edu	0.003	0.055	0.004	0.064	-1.777*
Marr	0.578	0.494	0.715	0.451	22.664***
Work	0.817	0.387	0.722	0.448	-16.127***
House	0.998	0.036	0.998	0.038	-0.265
Household characteristics					
Childnum	0.652	0.933	0.791	1.002	10.507***
Eldernum	0.432	0.739	0.637	0.859	18.145***
Non-agri	0.146	0.353	0.290	0.454	24.334***
Macroeconomic characteristics					
Pergdp	1.448	1.518	2.595	2.955	29.946***
Popden	0.022	0.056	0.056	0.280	9.594***
Medcare	5.952	2.408	6.293	2.901	8.956***
Drought	0.132	0.731	0.087	0.521	-6.290***
Flood	0.017	0.225	0.022	0.301	1.359
Instrumental variables					
Windspeed	44.405	11.769	48.205	12.483	22.891***
Other variables					
Wage	31.420	3.036	32.986	6.040	32.367***
Gaokao_res	0.937	0.243	0.929	0.257	-2.418**

Note: * Significant at 10% level; ** significant at 5% level; *** significant at 1% level

Results and Discussion

Basic results

Based on $PM_{2.5}$ mean value, columns (1)-(4) of *Table 3* report the two-stage regression results of the *IVprobit* model for Han and ethnic minority using average wind speed as IV. For ethinc minority sample, columns (5)-(6) of *Table 3* report the results of the *IVprobit* model for $PM_{2.5}$ mean value only using average wind speed as IV. Using *IVprobit* model, the Wald tests of exogeneity show that there are endogeneity problems between $PM_{2.5}$ and migration of ethnic minorities. The paper also conducts weak instrumental variable tests. Both the AR and CLR coefficients show that IV is closely related to the endogenous variable, which enhances the effectiveness of IVs.

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Table 3. *Results of $PM_{2.5}$ effects on ethnic minority migration*

IV	(1) $PM_{2.5mean}$	(2) Han Migration	(3) $PM_{2.5mean}$	(4) Minority Migration	(5) $PM_{2.5median}$	(6) Minority Migration
$PM_{2.5mean}$	-	0.073***	-	0.091***	-	
	-	(0.003)	-	(0.018)	-	
$PM_{2.5median}$	-	-	-	-	-	0.074***
	-	-	-	-	-	(0.015)
Windspeed	-0.044***	-	-0.044***	-	-0.055***	-
	(0.001)	-	(0.002)	-	(0.002)	-
Gender	-0.089***	0.083***	-0.078**	0.052***	-0.074**	0.052***
	(0.011)	(0.003)	(0.035)	(0.014)	(0.037)	(0.014)
Age	0.002***	-0.017***	-0.000	-0.021***	-0.001	-0.021***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.002)	(0.001)
Pri-edu	0.014	0.073***	0.557***	-0.022	0.547***	-0.011
	(0.030)	(0.012)	(0.079)	(0.042)	(0.083)	(0.043)
Jun-edu	0.180***	0.156***	0.713***	0.040	0.733***	0.054
	(0.031)	(0.012)	(0.085)	(0.045)	(0.089)	(0.046)
Sen-edu	0.265***	0.087***	0.590***	-0.003	0.567***	0.010
	(0.033)	(0.013)	(0.098)	(0.048)	(0.102)	(0.048)
Col-edu	0.296***	0.304***	0.572***	0.215***	0.532***	0.236***
	(0.037)	(0.014)	(0.116)	(0.056)	(0.121)	(0.055)
Gra-edu	0.411***	0.367***	0.723***	0.297***	0.657***	0.325***
	(0.039)	(0.015)	(0.127)	(0.063)	(0.133)	(0.061)
Pos-edu	0.617***	0.405***	1.208***	0.343***	1.276***	0.371***
	(0.066)	(0.027)	(0.275)	(0.133)	(0.298)	(0.134)
Marr	0.032**	-0.025***	0.057	-0.041**	0.081*	-0.042**
	(0.014)	(0.004)	(0.043)	(0.018)	(0.045)	(0.019)
Work	0.147***	0.110***	-0.016	0.071***	-0.022	0.073***
	(0.013)	(0.004)	(0.044)	(0.019)	(0.046)	(0.019)
House	0.084	-0.327***	0.545	-0.246	0.854*	-0.266
	(0.199)	(0.041)	(0.539)	(0.218)	(0.484)	(0.221)
Childnum	-0.025***	-0.048***	0.017	-0.074***	0.056***	-0.079***
	(0.007)	(0.002)	(0.020)	(0.009)	(0.021)	(0.009)
Eldernum	0.099***	-0.018***	-0.077***	-0.009	-0.081***	-0.011
	(0.007)	(0.002)	(0.022)	(0.009)	(0.023)	(0.010)
Non-agr	0.491***	-0.322***	0.943***	-0.287***	1.025***	-0.284***
	(0.014)	(0.005)	(0.054)	(0.025)	(0.057)	(0.026)
Pergdp	0.348***	-0.100***	0.267***	-0.133***	0.245***	-0.131***
	(0.002)	(0.001)	(0.015)	(0.013)	(0.015)	(0.013)
Popden	0.327***	-0.220***	1.790***	-0.759***	1.832***	-0.749***
	(0.019)	(0.023)	(0.215)	(0.142)	(0.218)	(0.145)
Drought	-0.164***	0.021***	-0.408***	0.092***	-0.427***	0.089***
	(0.005)	(0.001)	(0.044)	(0.013)	(0.045)	(0.013)
Flood	-0.836***	0.052***	0.348***	0.085***	0.137***	0.065**
	(0.020)	(0.008)	(0.029)	(0.027)	(0.029)	(0.027)
Medcare	0.014***	-0.001***	0.011***	-0.002***	0.011***	-0.002***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
Province fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Nationality fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Constant	13.183***	-1.087***	13.21***	-0.369	-0.369	0.007
	(0.950)	(0.062)	(0.701)	(0.362)	(0.362)	(0.339)
Wald test	-	455.09***	-	22.91***	-	22.45***
Marginal effect	-	0.012	-	0.014	-	0.011

Note: * Significant at 10% level; ** significant at 5% level; *** significant at 1% level. Standard errors are in parentheses

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In the first stage regression, it shows that the average wind speed is estimated to be negative, which means that the $PM_{2.5}$ pollution can be negatively affected by average wind speed. In the second stage, estimated coefficients of $PM_{2.5}$ mean value are positive both for the Han and ethnic sample at 1% significant level. It indicates that ethnic people are more likely to make migration decisions when $PM_{2.5}$ air pollution changes greatly. The conclusion is also hold for the $PM_{2.5}$ median value in columns (5)-(6) of *Table 3*.

Based on the IV method, our paper uses a large sample of ethnic minorities to prove that an environmental aversion product (e.g., a $PM_{2.5}$ pollutant) shows a "pushing" effect on the migration of ethnic minorities. Baranovitch (2019) found that environmental degradation (air pollution or water pollution) contributed to the ethnic tension in Xinjiang, China. These ethnic tensions may further lead to the out-migration of those ethnic minority groups.

Regarding other control variables, the coefficient of age (*Age*) is negative at a 1% significant level and suggests that the probability of individual migration decreases with increasing age (Enchautegui, 1997). Studies have indicated that young and middle-aged groups are more likely to migrate (Boustan et al., 2012; Thiede et al., 2016). The coefficient of Gender is estimated to be positive significantly, suggesting that men are more likely to migrate than women. The finding is also supported by Li et al. (2017). Gender can affect migration possibility and is also related to the accessibility to economic opportunities (Lewin et al., 2012). Ethnic minorities' migration probability also increases with education years. Education level, as a factor of human capital, can also increase the possibility of migration significantly (Enchautegui, 1997; Lewin et al., 2012; Gustafsson and Yang, 2015). Unemployed people cannot afford the migration cost (Tiwari, 2017); thus, the estimated coefficient of *Work* is positive. The coefficients of Married status (*Marr*) and asset-owning status (*House*) are estimated to be negative, and these results imply a significant hindrance to migration.

The estimation results also confirm that ethnic minority groups with less children (*Childnum*) are more likely to migrate. Enchautegui (1997) also documented that the complexity of family structure inversely affects migration, and families with more members are less likely to migrate. The linear estimate of Li et al. (2017) has indicated that population dependency ratios could hinder individuals' migration. The coefficients of population density (*Popden*) are estimated to be negative. It is consistent with the view that population density is a standard pull factor as migration determinants (Rupasingha et al., 2014). The higher the level of economic development (*Pergdp*) of registered residence, the fewer people want to move out. The estimated coefficients of *Drought* and *Flood* are significantly positive, indicating that natural disasters increase the possibility of migration. The coefficient of variable *Medcare* that measures medical conditions and health services is found to be significantly positive. The estimated results are basically similar and robust when the variable that measures medical conditions and health services is replaced by the number of medical institutions and number of beds in medical institutions.

Minority autonomous region regressions

Does residence location in MARs matter when making migration decision? i.e., will the Han majority living in the same autonomous make the same migration decision as those minorities living in the same region? To disentangle this effect of "MAR" from ethnic characteristic when making migration decisions, the estimated results of ethnic minorities, all residents (including both the Han and ethnic minorities) and Han residents living in the same MARs are compared in *Table 4* after control variables are retained.

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$PM_{2.5}$ concentration is found to be positive for both "all residents", "ethnic minorities" and "Han residents" in MARs at 1% significant level. It is worth noting that, in terms of the marginal effect coefficient, the effect of $PM_{2.5}$ air pollution on the migration of Han residents is higher than that of ethnic minority residents, which also implies that ethnic minority residents may need to make more trade-offs in the face of environmental pollution and other factors.

Table 4. *MAR specification regression results*

	All residents in Ethnic Autonomous Region		**Ethnic Minority in Ethnic Autonomous Region**		**Han in Ethnic Autonomous Region**	
IV	**$PM_{2.5mean}$**	**Migration**	**$PM_{2.5mean}$**	**Migration**	**$PM_{2.5mean}$**	**Migration**
Windspeed	-0.016***	-	-0.033***	-	-0.045***	-
	(0.001)	-	(0.003)	-	(0.001)	-
$PM_{2.5mean}$	-	0.213***	-	0.090***	-	0.072***
	-	(0.009)	-	(0.032)	-	(0.003)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Province fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Nationality fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Constant	8.919***	-1.098***	6.014***	0.514	10.978***	-1.054***
	(0.388)	(0.184)	(0.679)	(0.419)	(0.223)	(0.062)
Wald Test	-	117.46***	-	8.81***	-	471.59***
Marginal effect	-	0.050***	-	0.014**	-	0.011***

Note: * Significant at 10% level; ** significant at 5% level; *** significant at 1% level. Standard errors are in parentheses

However, after using instrumental variable method to solve the endogeneity problems, the regression coefficients of the *probit* model are all positive at 1% significance level. It indicates that both "all residents" and "minorities" living in MARs tend to make migration decisions when facing $PM_{2.5}$ pollution. This result implies that in the process of western development strategy (covering all five MARs), the migrating out situation does not only happen to ethnic minorities but also to all the residents there despite of ethnic minority groups. The general migration trend in MARs is really an environmental pollution issue rather than a social or political issue. Policy makers could have clearer target when making national and regional population policies for sustainable development. For example, the government can publicize the advantages of ecological environment or environment regulation effects to attract demographic dividend of ethnic minorities.

Social-economic factor interaction results

The regression results of the interaction between $PM_{2.5}$ concentration and a series of social economic variables using *IVprobit* methods are shown in *Table 5*. The interaction term of household type shows that non-agricultural ethnic minorities are less likely to migrate. The ethnic minorities who own houses tend to make migration decisions respond to $PM_{2.5}$ pollution compared with those who rent or have no house. People with higher income level are more likely to bear the migration cost. The ethnic minority households with more children tend to migrate in response to $PM_{2.5}$ pollution in column (3) of *Table 5*. However, the number of elderly people in the household cannot promote the migration

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of ethnic minorities affected by $PM_{2.5}$ pollution. Li et al. (2017) found that family dependence and family size have positive and negative effects on labor force outflow, respectively. The medical burden of the elderly is heavier and requires individual care. Due to the imperfect medical insurance system, it is difficult to reimburse medical treatment in different places. The elderly may not be able to migrate out with those ethnic minorities while there is $PM_{2.5}$ air pollution. The more elderly people a family needs to care for, the less likely for the family to migrate out while there is $PM_{2.5}$ pollution. The interacted coefficient between income level and $PM_{2.5}$ is also positive, which suggests that ethnic minorities are more likely to migrate due to $PM_{2.5}$ pollution as their incomes increase. According to Qin and Zhu (2017), residents with higher income can afford to move to resist potential air pollution.

Table 5. *Social-economic factor and $PM_{2.5}$ interaction results*

IV	(1) Migration	(2) Migration	(3) Migration	(4) Migration	(5) Migration
$PM_{2.5mean}$	0.090***	0.066**	0.085***	0.087***	0.051**
	(0.021)	(0.026)	(0.021)	(0.021)	(0.020)
Interaction	-0.016***	0.012*	0.004***	-0.002	0.001***
	(0.003)	(0.007)	(0.001)	(0.001)	(0.000)
Urban	0.061	-	-	-	-
	(0.069)	-	-	-	-
Housesource	-	-0.752***	-	-	-
	-	(0.179)	-	-	-
Childsum	-	-	-0.184***	-	-
	-	-	(0.028)	-	-
Eldersum	-	-	-	0.031	-
	-	-	-	(0.034)	-
Income	-	-	-	-	-0.135***
	-	-	-	-	(0.009)
Control variables	Yes	Yes	Yes	Yes	Yes
Province fixed effect	Yes	Yes	Yes	Yes	Yes
Nationality fixed effect	Yes	Yes	Yes	Yes	Yes
Constant	-0.339	1.278**	-0.138	-0.205	0.045
	(0.383)	(0.532)	(0.384)	(0.384)	(0.387)
Pseudo R^2	0.137	0.138	0.136	0.136	0.168

Note: * Significant at 10% level; ** significant at 5% level; *** significant at 1% level. Standard errors are in parentheses

Regional salary factor and the policy-controlled regressions

Table 6 presents $PM_{2.5}$ effect on the migration of ethnic minority groups using IVprobit model when regional average salary level and policy of awarded marks in College Entrance Examination relevant to household registration place are controlled. We employ a dummy of whether an individual's household registration province has policy of awarded marks in College Entrance Examination relevant to registration place (*Gaokao_res*) and average salary level (*Wage*) in household registration province. Columns (1)-(4) of *Table 6* focus on all ethnic minority groups (excluding Bai) with children under 18 years old in the family since the policy that related to College Entrance

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Examination is considered. Bai candidates do not obtain awarded marks in College Entrance Examination. The Bai people are too similar to the Han people and the productivity level is not weaker than the Han people, so no special treatment is needed.

Table 6. *Regressions with regional salary factor and policy of awarded marks in College Entrance Examination*

	(1) **Wage** **Migration**	**(2)** **Policy Dummy** **Migration**	**(3)** **Wage+Policy Dummy** **Migration**
$PM_{2.5mean}$	0.098***	0.099***	0.098***
	(0.024)	(0.024)	(0.024)
Wage	-0.114***	-	-0.114***
	(0.017)	-	(0.016)
Gaokao_res	-	2.388***	2.297***
	-	(0.583)	(0.588)
Control variables	Yes	Yes	Yes
Province fixed effect	Yes	Yes	Yes
Nationality fixed effect	Yes	Yes	Yes
Constant	3.082***	-2.599***	0.785
	(0.814)	(0.869)	(1.023)
Wald Test	13.13***	13.80***	13.13***
Marginal effect	0.015**	0.015**	0.015***
N	34416	34416	34416
	(4)	(5)	(6)
	Subsample when Policy==1	Children=0	Children+Elderman>0
	Migration	Migration	Migration
$PM_{2.5mean}$	0.086***	0.063**	0.177***
	(0.025)	(0.027)	(0.027)
Wage	-0.097***	-0.104***	-0.152***
	(0.018)	(0.014)	(0.028)
Gaokao_res	-	-	2.806***
	-	-	(0.553)
Control variables	Yes	Yes	Yes
Province fixed effect	Yes	Yes	Yes
Nationality fixed effect	Yes	Yes	Yes
Constant	2.484**	6.603***	0.924
	(0.965)	(0.928)	(1356)
Wald Test	11.50***	5.57**	10.92***
Marginal effect	0.013***	0.010***	0.040***
N	33091	36817	15040

Note: * Significant at 10% level; ** significant at 5% level; *** significant at 1% level. Standard errors are in parentheses

Column (1) of *Table 6* compares the trade-off of $PM_{2.5}$ pollution and average salary level in household registration province. The regression results show that after removing the impact of average salary level, $PM_{2.5}$ pollution has a push effect on the migration of ethnic minority groups. Average salary level in household registration province is estimated to be negative significantly, suggesting a key factor to inhibit migration of ethnic minorities.

Column (2) of *Table 6* includes $PM_{2.5}$ pollution and policy of awarded marks in College Entrance Examination relevant to household registration place. It demonstrates

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that the estimated coefficient of $PM_{2.5}$ is positive at 1% significance level after the policy is controlled. The policy (*Gaokao_res*) is estimated to be positive significantly which attracts ethnic minorities to migrate. Both considering average salary level and the policy, column (3) of *Table 6* reports migration regression results of $PM_{2.5}$ effect. After controlling average salary level and the policy, $PM_{2.5}$ is estimated to be 0.098 at the 1% significance level. These coefficients prove that despite there are policies of awarded marks in College Entrance Examination and the high or low level of regional average salary, $PM_{2.5}$ air pollution can promote those ethnic minority groups to migrate.

Column (4) of *Table 6* concentrates on the sub-sample that household registration provinces of ethnic minority groups have implemented the policy of awarded marks in College Entrance Examination relevant to household registration place. It indicates that $PM_{2.5}$ can significantly drive ethnic minorities to make migration decisions after the average salary level being controlled. Column (5) of *Table 6* reports the estimated coefficient of $PM_{2.5}$ effect on migration decision of ethnic minorities with no children in the household. Column (6) of *Table 6* shows the effect of $PM_{2.5}$ on the migration decisions of ethnic minorities with both children and the elderly in the household (three generations). These coefficients further illustrate that the migration effect of $PM_{2.5}$ pollution is robust regardless of family structure for ethnic minorities. As many ethnic minorities are fully conscious of the severe pollution in their home region and perceive it as a serious threat to their health, livelihood, and cultural survival (Baranovitch, 2019), they are more inclined to make migration decisions respond to $PM_{2.5}$ air pollution. Our finding further suggests that environmental quality plays a key role in the migration of ethnic minority groups compared with economic benefits and some preferential policies.

In addition to the main results shown in previous sections, we have run regressions with five most populated ethnic minority groups (Mongolian, Zhuang, Tibetan, Hui, and Uygur) in MARs. In accordance with the Chinese guideline value (35 $\mu g/m^3$) and sample mean value (20 $\mu g/m^3$) for annual $PM_{2.5}$ concentrations, 3 groups are divided for sub-sample regressions. It can be concluded that the migration probability of ethnic minority groups increases significantly as $PM_{2.5}$ air pollution exceeds the threshold guidelines. Following the push and pull theory, the negative effects of air pollution create a "push" force for residents to move out. On the one hand, $PM_{2.5}$ pollution can cause respiratory diseases, cardiovascular diseases, depression and other health problems, endangering people's lives (He et al., 2016; Zhang et al., 2017). $PM_{2.5}$ pollution also has a negative impact on the macroeconomic development of cities. The deterioration of air quality will reduce the overall competitiveness of the city, which is not conducive to attracting investments and upgrading the industrial structure. It in turn may have a negative impact on local employment. Besides, the deterioration of air quality may also prompt local government to implement more stringent environmental regulatory policies. Local enterprises will avoid additional costs of controlling pollution by improving green production technology or relocating their original factories to regions with relatively loosen environmental regulation. This may also have an adverse impact on local employment. Employment in the secondary industry (*employment*) in the location of household registration at city level is used as dependent variable, as $PM_{2.5}$ is generally strongly associated with the secondary industry. It shows that $PM_{2.5}$ pollution exerts a negative effect on local employment. The results of interaction term between $PM_{2.5}$ and *employment* are estimated to be significantly positive, indicating that higher $PM_{2.5}$ pollution and fewer secondary employment increase the migration probability of ethnic minority groups. These results illustrate that $PM_{2.5}$ can contribute to the migration of

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ethnic minority groups by negative health effects and employment reduction effects. Robustness checks are also carried out using ethnic minority population proportion at county-level census as the migration dependent variable and the results are consistent throughout (Due to limited paper length, these results mentioned are available upon request for reference).

Conclusions

The paper empirically identifies the effect of $PM_{2.5}$ concentration on ethnic minorities' migration in China using a large census sample. High speed economic development has brought regional prosperity as well as air pollution which threats public health. Using average wind speed as instrumental variable to handle the endogeneity problem, we have found that the environmental costs from industrialization indeed has pushed ethnic minorities out from their birthplace and the MARs. Ethnic minority groups are more concerned about the environmental quality of their places of residence compared with the economic benefits and some preferential policies when considering out-migration. How to adjust the current industrial development strategy and ethnic minority policy for sustainable development, more conclusions with policy implications are listed as follows.

First, mean $PM_{2.5}$ value in the migration year has significant positive effect on out-migration of ethnic minorities after the endogeneity problem been solved. Facing by an environmental aversion product ($PM_{2.5}$ pollution), similar to Han, ethnic minorities are more likely to make migration decisions. Our findings also support those previous conclusions about factors such as wind speed that can significantly affect $PM_{2.5}$ concentrations (Westervelt et al., 2016; Fontes et al., 2017). Ethnic minority groups are more likely to migrate if they are male, younger, educated beyond college level, unmarried, employed, urban registration and have no or less children in the household. The effect of environmental quality degradation (e.g., $PM_{2.5}$ pollution) can lead to migration behaviors for ethnic and Han residents both live in MARs.

Second, the interaction effect regressions conclude that a minority individual's migration decision affected by $PM_{2.5}$ pollution vary by household registration type, house source, income, the number of children in the family. For those who are rural, own houses, have more children and higher income levels, $PM_{2.5}$ pollution promotes the migration of ethnic minorities more significantly than counterparts. Ethnic minorities are having similar responses to $PM_{2.5}$ pollution as the majority Han group.

Third, controlling regional average salary level, the policy of awarded marks in College Entrance Examination relevant to household registration place and ethnic characteristics, $PM_{2.5}$ air pollution can promote ethnic minorities to make migration decisions. Our finding further suggests that environmental quality plays a key role in the migration of ethnic minority groups compared with economic benefits and some preferential policies. Besides, the migration probability of ethnic minority groups increases more as $PM_{2.5}$ air pollution exceeds the threshold guidelines. Mechanism analyzes suggest that $PM_{2.5}$ can contribute to the migration of ethnic minority groups by negative health effects and employment reduction effects.

The urbanization process in China has been involved with the internal migration of ethnic minorities for a better living environment. The multi-nationalization of cities is the inevitable result of urbanization, and environmental pollution ($PM_{2.5}$) essentially accelerates this process. The migration of ethnic minorities has also exerted some pressure on the environment and society which may lead to urban congestion and social security.

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With the increased ageing and a sharp decrease in birth rate, the competition for migration as labor inputs among cities will become increasingly severe. Therefore, based on this paper's findings, some important policy considerations are drawn for the government and policymakers.

First, our findings have confirmed and re-emphasized the necessity of control $PM_{2.5}$ pollution sources especially in MARs. $PM_{2.5}$ is mainly from fossil energy combustion, vehicle emissions and industrial production. Regarding coal combustion and industrial production, local governments should continue the coal-to-gas project, adopt the "blacklist" system of air pollution control, and encourage reporting illegal pollution sources through the internet and social media. For motor vehicle pollution, local governments should encourage residents for green travel behaviors such as riding bicycles, taking public transportation, and carpooling.

The private sector is also a key player in environmental protection. Thus, governments should initiate private-public partnerships to actively promote air pollution control projects with all types of social capital. To stabilize ethnic minority community, policy makers should protect environment while promote economic growth, especially in MARs.

Second, central and local government should take important characteristics (household registration type, house source, income level, the number of children in the family) of ethnic minorities into consideration when making western development strategy related policies for socially sustainable. These characteristics significantly affect migration decision according to our findings. For example, policy makers can further develop various measures to improve the regional wage level and provide more job opportunities while keep the favorable policies for ethnic minorities or five MARs.

Third, government should provide more protection of basic rights for ethnic minority migrant groups and guide them to integrate into new living environment for a more stable and integrated society. The coordination mechanisms between ethnic minorities should be strengthened. According to the characteristics of ethnic minorities, adaption suggestions and services can be provided for the migrating ethnic minorities. More attention needs to be given to the migration of ethnic minority groups to achieve the SDGs in the future. Besides, the quarterly migration behaviors are difficult to be observed affected by air pollution or Gaokao policy due to data limited which can be further studied. The findings can be further extended in the future if 2020 census at individual level becomes available.

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APPENDIX

Table A1. *The proportion of ethnic minorities across provinces in China*

Province	Minority%		Change	Province	Minority%		Change
	2000	2010			2000	2010	
Beijing	4.31	4.09	-0.22	Tianjin	2.71	2.56	-0.15
Hebei	4.35	4.17	-0.18	Shanxi	0.32	0.26	-0.06
Inner Mongolia	20.83	20.46	-0.37	Liaoning	16.06	15.19	-0.87
Jilin	9.15	7.96	-1.19	Heilongjiang	4.89	3.59	-1.3
Shanghai	0.63	1.2	0.57	Jiangsu	0.36	0.49	0.13
Zhejiang	0.86	2.23	1.37	Anhui	0.67	0.66	-0.01
Fujian	1.71	2.16	0.45	Jiangxi	0.31	0.34	0.03
Shandong	0.7	0.76	0.06	Henan	1.25	1.19	-0.06
Hubei	4.36	4.31	-0.05	Hunan	10.13	9.97	-0.16
Guangdong	1.49	1.98	0.49	Guangxi	38.38	37.17	-1.21
Hainan	17.38	16.44	-0.94	Chongqing	6.47	6.72	0.25
Sichuan	5	6.1	1.1	Guizhou	37.84	35.7	-2.14
Yunnan	33.42	33.39	-0.03	Tibet	93.94	91.83	-2.11
Shaanxi	0.5	0.51	0.01	Gansu	8.75	9.42	0.67
Qinghai	45.97	46.98	1.01	Ningxia	34.56	35.15	0.59
Xinjiang	59.43	59.52	0.09	-	-	-	-

Note: Data from the 2000 and 2010 Census in China.

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