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Two decades of inter-city migration in China: The role of economic, natural and social amenities

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Abstract

China has experienced unprecedented largescale internal migration since the late 1970s. We analyse spatiotemporal changes in migration for 284 prefectural-level cities in China using the 2000, 2010 and 2020 censuses. These cities have over 90% of China's population. Attractiveness of cities varies with amenities, so we use econometric models to identify city-level and province-level economic characteristics and social and natural amenities that drive net migration. Inter-city migration in China is still growing rapidly, with striking regional disparities. China's three urban mega-regions (Beijing-Tianjin, Yangtze River Delta, Pearl River Delta) received most migrants over these two decades, with many coastal and tier-2 cities, especially inland provincial capital cities, emerging as new destinations since 2010. Conversely, inland lower-tier cities have experienced large population losses, especially in Northeast China recently. The importance of amenities in affecting migration patterns differs between all sample cities and 35 major cities, and changes over time. Employment opportunities, and higher wages and development levels still attract migrants, but migrants trade off levels versus growth (source areas are poorer but faster growing than destinations). Booming housing markets have not pushed migrants away. Both city and province fiscal pressures have negative impacts on the net migration rate, while province-level fiscal decentralization enhances attractiveness. Cities with better public transportation services and more pleasant climate are more attractive to migrants. These factors matter less for the major cities, apart from economic opportunities and transportation services. Air quality and province-level economic development significantly contribute to differences in net migration rates among the major cities. Findings from this study can help policymakers to formulate governance measures for sustainable city development during the largest rural-to-urban population flow in human history.

JEL Codes

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Keywords

inter-city migration
net migration rate
migration patterns
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I. Introduction

China relaxed the household registration system (hukou) and began to open up and reform the economy in 1978. This precipitated an unprecedented largescale internal migration, given the extant regional and rural-urban disparities (Cao et al., 2018; Mohabir et al., 2017; Sun and Fan, 2011). China’s decennial population censuses in 2000, 2010 and 2020 show that the migrant flow continues to grow. In particular, compared with the 1980s and 1990s, the size and rate of population flow to big cities in the eastern regions from small towns, small cities, medium-sized cities and even some big cities in the central and western regions, which is referred to here as inter-city migration, has increased. From 2000 to 2020, the stock of inter-city migrants increased from 144 million to 376 million (from 1-in-9 to more than 1-in-4 people in China).

These flows of population between cities reflect spatial differences in development of the urban economy, society and public services. The Yangtze River Delta (YRD), Pearl River Delta (PRD) and Beijing-Tianjin mega regions, that enjoy high levels of economic development, are the destinations for the largest migration flows (Li and Gibson, 2013; Liu and Xu, 2017). However, spatially unbalanced migration also hinders sustainable development and influences China's new urbanization strategy. With these massive flows into mega-regions, serious urban problems eventuated, like overcrowding, environmental pollution, contagious disease, and crime etc. (Lin et al., 2021; Liu et al., 2021; Yang, 2013). In addition, population loss in low-tier cities may stunt economic development and cause “hollowing village” issues (Luo et al., 2023; Mohabir et al., 2017). Large-scale population migration brings challenges to urban management. Thus, to address these issues, it calls for deep examination of the spatiotemporal patterns of China's inter-city migration and an analysis of the drivers of net migration, in order to support the rational and orderly distribution of population and the new urbanization strategy in China.

Migration is an important part of urbanization and economic development (De Haas, 2010; Shen, 2015; Sheng et a., 2022). Hence, there have been many theoretical and empirical studies on migration patterns and the driving factors in China and beyond. Early in the 1930s it was noted that differences in economic benefits, especially in wage levels, motivated migration (Hicks, 1932). Studies from the perspective of neoclassical economics mostly focused on the rational choice of individuals, using concepts of "rational person", "expected net income", "utility maximization" and "wage difference" (Sjaastad, 1962). These pointed out that population migration is a rational choice of individuals based on income maximization under the unbalanced distribution of capital, labor and living conditions among different regions. The dual sector model (Lewis, 1954) and the push-pull model (Everett and Lee, 1966) are typical representatives of this kind of research. In the population push-pull theory, differences in specific factors between regions are the root cause of population migration. Many empirical studies showed that places with a higher economic development level, more job opportunities, lower unemployment and higher wages, were significantly more attractive to migrants (Buch et al., 2014; Gao et al., 2023).

In addition to economic factors, social and natural amenity factors are considered by theories of migration (Graves, 1976; Ullman, 1954). Ravenstein was the first to mention unattractive climate in his migration research (Ravenstein, 1889). Likewise, Semple, Ullman and Graves revealed that milder climate and better living conditions led to inflow of migrants (Graves, 1976; Semple, 1911; Ullman, 1954). It is argued that non-tradable and place-specific natural amenities may compensate migrants for less ideal economic opportunities (Gottlieb, 1994; Knapp and Gravest, 1989). Given the intensification of climate change and environmental pollution issues, researchers increasingly focus on climatic and environmental attributes as examples of natural amenities — using factors such as temperature, rainfall, humidity, sunshine, and air quality (Liu and Shen, 2014a; Rappaport, 2009). In addition, from the perspective of Maslow's hierarchy of needs theory, when people's basic needs are satisfied, they will consider pursuing higher-level pursuits. Applying this theory to the study of population migration, it can be assumed that once the migrant population has a better economic welfare level, living conditions and public services may also become indicators (in addition to wages and employment opportunities) to be considered in their migration decisions (Wang, 2011). Numerous studies have revealed that the quality and the accessibility of social services, such as education, health care, transport and cultural and artistic services, are closely associated with migration (Lin et al., 2019; Rodríguez-Pose and Ketterer, 2012; Zheng, 2016). Regions with better social amenities and easier accessibility for migrants can save them material costs of transportation, and alleviate the psychological pressure caused by changes in the living environment. Overall, these studies suggest that different economic, social and natural amenities play a key role in migration.

China's internal migration has also attracted a lot of attention. Unlike other countries, China's population migration is closely related with the Hukou system. In 1955, China established an internal registration ("Hukou") system, aiming to control rural migration to urban areas. It entrenched agricultural vs. non-agricultural ("rural" vs. "urban") status, which is passed down through mothers and is very difficult to change (Wu and Treiman, 2004). This system limited migrants' access to local social welfare and services. Due to the Hukou system, population migration in China can be classified as permanent migration and temporary migration. The former refers to those migrants who get the Hukou in their migrant destinations, while the latter are known as non-hukou migrants or floating population, who have not changed their Hukou status to reflect their new location. As non-hukou migrants account for by far the largest proportion of migrants in China (Gao et al., 2023), most studies focus on non-hukou migration when they analyse the spatial distribution of migration, the role of migration laws and so on, by examining the large-scale migration trend across the country or between regions at provincial, prefectural city or county level (Cao et al., 2018; Liu et al., 2015; Wang et al., 2017). Numerous studies stress that differences in economic activity, in social and public services and in natural environments are important factors affecting population migration in China (Cao et al., 2018; Wu et al., 2019b; Yu et al., 2019). However, the existing literature has paid little attention to the relative importance of amenity factors across different levels of the sub-national administrative hierarchy. In addition, we know little about the changing spatial pattern of migration and changes in the drivers of migration for the period from 2000 to 2020 (and the two decadal sub-periods), and how these differ between all cities versus major cities.

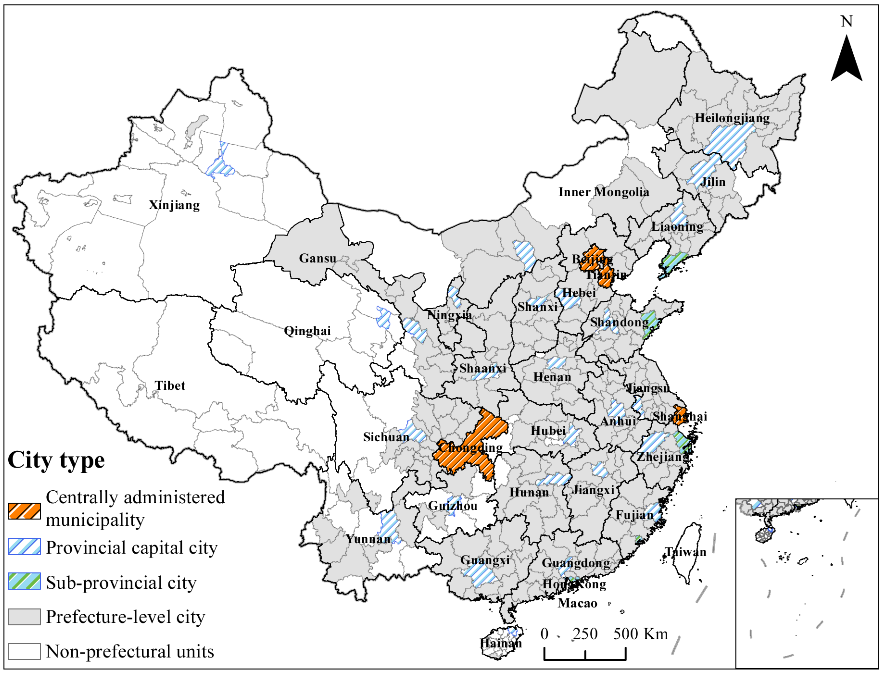
Prefecture-level cities (the second sub-national level) within provinces in China are often larger than some European countries, so studies at the prefectural city level instead of the more widely researched province level may shed more light on spatial disparities of migration patterns (Yu et al., 2019). Thus, this study focusses on the role of economic, social and natural amenities in population migration at the prefectural city level. However, our models also allow for effects of province-level factors. We expect to improve the understanding of spatiotemporal changes in migration patterns and to see what factors are associated with the redistribution of migrants at the prefectural city level in China over the full 2000 to 2020 period and for the two decadal sub-periods. We compare results for all cities and for a sub-sample of 35 major cities because the requirements for settling in the major cities are often more onerous. In the remaining sections, we outline our data and variables and estimation approach in section 2. We describe the changing spatial patterns of population migration and present the econometric analysis of the driving mechanisms that affect the changing migration patterns in section 3. Conclusions and policy implications are provided in section 4.

II. Materials and methods

Study Area

A total of 284 cities are selected in this sample considering data availability. The term "city" here refers to prefectural-level cities (and municipalities). China's sub-national administrative hierarchy has four levels: province (4 centrally administered municipalities, 23 provinces, 5 autonomous regions, and 2 special administrative regions); prefecture (293 prefectural-level cities, and 40 autonomous regions or leagues); county (2843 districts, county-level cities or counties); and town (38602 towns). There can be movement between these levels (e.g. Chongqing was upgraded to municipality status in 1997) so these details are current as of 2022 (Zhang et al., 2024). The selected cities in this study include 35 major cities, which comprises the four municipalities (Beijing, Shanghai, Tianjin and Chongqing), 26 provincial capital cities, and the five sub-provincial cities that are not capital cities (Dalian, Ningbo, Qingdao, Shenzhen and Xiamen). The remainder of the sample has 249 prefecture-level cities (Figure 1). The full sample and the 35 major cities are home to 93.2% and 26% of China's resident population respectively, according to the seventh population census in 2020.

Figure 1: Spatial autocorrelation in GDP and night-time lights data



Data Sources

Data used in this study include population data, various statistical data on social and economic amenity indicators at city and province level, and climatic and environmental data on natural amenity indicators (Table 1). Population variables are from China population census data in

2000, 2010 and 2020, which are used to calculate inter-city population migration. This refers to persons who have resided for more than six months in a city that is other than the city of their household registration (Gao et al., 2023; Yu et al., 2019). Thus, the number of net migrants in each city equals the city's total resident population (those residing in the city for more than six month) minus its household-registered population. The net migration rate of each city, which is the dependent variable in this study, equals the ratio of net migrants to the registered population in a city. The data on indicators of social and economic amenities are from the China City Statistical Yearbooks and China Statistical Yearbooks, for the year before each census. The nominal wage and income are deflated by the Consumer Price Index (CPI), investment in housing is deflated by the investment in fixed asset price index, and nominal GDP is deflated by the GDP deflator. As to data on natural amenity indicators, climatic data are from the China Meteorological Data Service Center (CMDC, http://data.cma.cn/en, accessed on 16 January 2024). The mean annual average value of each climatic indicator for the decade prior to the census year is used. The air quality indicator PM2.5 data for the year before each census are processed based on the PM2.5 dataset estimated by Socioeconomic Data and Applications Center (SEDAC, https://sedac.ciesin.columbia.edu/search/data?contains=PM2.5, accessed on 16 January 2024).

Table 1: Descriptions of dependent and independent variables for inter-city migration analysis at city level in China

Variable type	Name	Description	References
Dependent variable (2000, 2010, 2020)	Net migration rate (NMR)	Ratio of net migrants to registered population (%)	Yu et al., 2019
Economic amenities (1999, 2009, 2019)	Per capita GDP (GDP_p)	Per capita GDP by resident (10,000 yuan)	Yu et al., 2019; Gao et al., 2023
	Annual GDP growth rate (GDP_growth)	GDP growth rate (%)	Wu et al., 2019
	Industrial structure (Nag_ratio)	Proportion of non-agricultural industry in GDP (%) (the share of secondary and tertiary industry relative to the gross domestic product)	Yu et al., 2019; Gao et al., 2023
	Wage levels (Wage)	Average wage of employed staff and workers (10,000 yuan) (deflated value)	Yu et al., 2019; Wu et al., 2019; Gao et al., 2023
	Employment opportunities (Unemp_rate)	Unemployment rate (%) (Registered Unemployed Persons in Urban Areas) / (Registered Unemployed Persons in Urban Areas+ Persons Employed in Urban Units at Year-end)	
	Housing market development (House_inv)	Investment in real estate development per unit area (10,000 yuan per km^2)	Wu et al., 2019; Su et al., 2019
Social amenities (1999, 2009, 2019)	Governmental financial pressure (Fdr)	Fiscal deficit ratio ((public budget expenditure-public budget revenue)/public budget revenue)	Wu et al., 2019
	Educational services (Edu_p)	Number of teachers in middle and primary schools per 1,000 students (person)	Yu et al., 2019; Wu et al., 2019; Gao et al., 2023
	Health care services (Doc_p)	Number of doctors (certificated and assistant doctors at hospitals) per 1,000 residents (person)	Yu et al., 2019; Wu et al., 2019
	Health care services (Bed_p)	Number of hospital beds per 1,000 residents (bed)	Qiang and Hu, 2022
	Public transportation service (Bus_p)	Number of public transportation vehicles (buses) per 10,000 residents	Wu et al., 2019
	Public transportation infrastructure (Road_p)	Per capita paved road area (m^2)	Yu et al., 2019

	Artistic and cultural service (Book_p)	Per capita books in public library by resident (10,000 copies per capita)	Gao et al., 2023
Natural amenities (1999, 2009, 2019)	Green space (Green_rate)	Greenery coverage rate of urban area (%) ("shixiaqu")	Yu et al., 2019; Wu et al., 2019
	Air quality index (PM2.5)	Annual mean PM2.5 (ug/m^3)	Guo et al., 2022; Zhao et al., 2021
	Annual sunshine hours (Sunhour)	Annual sunshine hours (past 10-year average) (hours)	Grimes et al., 2016; Yu et al., 2019
	Average annual rainfall (Rainfall)	Average annual rainfall (past 10-year average) (mm)	
	Temperature severity (Temsev)	Difference of average temperature between January and July (past 10-year average) (°C)	Liu and Shen 2014; Yu et al., 2019
	July humidity (Rhjuly)	July humidity (past 10-year average) (%)	
Province-level socioeconomic amenities	Per capita GDP at province level (PGDP_p)	Province-level economic development: per capita GDP of a province (10,000 yuan/person)	Jiang et al., 2012; Tan et al., 2019
	Industrial structure at province level (PNag_ratio)	Non-agricultural GDP as percentage of total GDP within a province (%)	Zhang et al., 2014
	Governmental financial pressure at province level (PFdr)	Fiscal deficit ratio ((public budget expenditure-public budget revenue)/public budget revenue)	Huang et al., 2015; Chen, 2016
	Fiscal decentralization at province level (PFdec)	Ratio of fiscal expenditure per capita at provincial level to that at national level	
	Degree of openness at province level (PFdi)	Foreign direct investment per capita (1 $ per capita)	Jiang et al., 2012

Note: The "references" column includes examples of studies that have used the particular dependent and independent variables in empirical migration models.

Methods

Exploratory spatial data analysis

The exploratory spatial data analysis (ESDA) is applied in this study to reveal the spatial agglomeration and differentiation characteristics of inter-city migration in China during 2000-2020. The global Moran's I is used to measure spatial autocorrelation of inter-city migration across China, calculated as follows (Zhao et al., 2022):

$$Moran's\ I = \frac{n \cdot \sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j}(NMR_i - \overline{NMR})(NMR_j - \overline{NMR})}{\sum_{i=1}^{n}(NMR_i - \overline{NMR})^2 \cdot \sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j}} \quad (1)$$

where, NMR_i and NMR_j are the net migration rate in city i and j, n is the number of cities ($n = 284$), $\overline{NMR}$ is the average value of the NMR amongst all of the cities, and $w_{i,j}$ is the spatial weight matrix (based on queen contiguity). The Moran's I ranges from −1 to +1. Significant positive values indicate clustering of like-with-like (i.e. spatial agglomeration), while negative values indicate spatial differences.

While the global Moran's I shows spatial autocorrelation, it cannot reveal the grouping of spatial patterns. Thus, the hot-spot analysis based on Getis-Ord Gi* statistic (Gi*) is also applied, in order to analyze the clustering patterns (hot spots and cold spots) of the net migration rate. Specifically, the standardized Gi* statistic with a Z-score is calculated as follows (Wang et al., 2020):

$$(G_i^*) = \frac{\sum_{j=1}^{n} w_{i,j} NMR_j - \overline{NMR} \sum_{j=1}^{n} w_{i,j}}{S\sqrt{\frac{n\sum_{j=1}^{n} w_{i,j}^2 - (\sum_{j=1}^{n} w_{i,j})^2}{n-1}}} \quad (2)$$

$$S = \sqrt{\frac{\sum_{j=1}^{n} NMR_j^2}{n}} - \overline{NMR}^2 \quad (3)$$

where the $Z(G_i^*)$ is the standardized Gi* for city i at a distance standardized as a z-score. NMR_j is the NMR value of neighbor city j; S is the standard deviation. A significant positive $Z(G_i^*)$ score indicates a hot spot cluster of high net migration rate cities. Conversely, a significant negative $Z(G_i^*)$ score indicates a cold spot cluster of low values. The cities located in hot/cold spots are identified with their p-value < 0.05.

Econometric model specification

A balanced panel data of 284 cities, observed three times from China's population censuses in 2000, 2010 and 2020 is used to clarify the role of urban amenities (social, economic and natural) in inter-city migration in China. The model is as follows:

$$NMR_{it} = \beta_0 + \beta_1 Eco_{it} + \beta_2 Soc_{it} + \beta_3 Nat_{it} + \beta_4 Year_t + \varepsilon_{it} \quad (4)$$

where $NMR_{it_{it}}$ is the net migration rate of city i at year t (2000, 2010, 2020), calculated as the ratio of the net migrant stock to the registered population; Eco_{it}, Soc_{it}, and Nat_{it} represent independent variables related to economic, social, and natural amenities; $Year_t$ is a time trend; ε_{it} is the error term of city i at year t. The details of the selected independent variables are shown in Table 1, along with references to previous studies that have used each type of variable. Generally, inter-city migration is determined by the attractiveness of cities, which depends on a bundle of economic, natural, and social amenities (Buch et al., 2014; Gao et al., 2023; Grimes et al., 2016; Qiang and Hu, 2022; Wu et al., 2019b; Yu et al., 2019; Zhang et al., 2014).

For economic amenities, researchers often use wages, unemployment rates and job opportunities as proxies for economic opportunities. In this study we use average wage (Wage), the unemployment rate (Unemp_rate), and per capita gross domestic product (GDP_p) as indicators of economic opportunities at the city level. We also use the share of non-agricultural industries in GDP (Nag_ratio) and annual GDP growth rates (GDP_growth) to represent each city's stage in the economic development process (Gao et al., 2023; Wu et al., 2019b; Yu et al., 2019). In addition, as housing prices have a complex relationship with the quality of life and matter a lot in migration decisions (Peng and Tsai, 2019; Su et al., 2019), investment in real estate development per unit area (House_inv) is included as an economic amenity to represent the city's housing market development level.

Our literature review showed regional differences in social welfare and public services, such as educational, health care, public transportation, artistic and cultural services, can be important factors in migration decisions. In addition, cities with high governmental financial pressure will be less attractive to migrants (Wu et al., 2019b). Therefore, we use the number of teachers in middle and primary schools per 1,000 students to represent educational services (Edu_p), number of doctors (Doc_p) and hospital beds (Bed_p) per 1,000 residents to represent health care services, number of public transportation vehicles per 10,000 residents (Bus_p) and per capita paved road area (Road_p) to indicate public transportation services, per capita books in public libraries to indicate artistic and cultural services (Book_p), and the fiscal deficit ratio (Fdr) as a proxy for financial pressure on sub-national governments.

Recently, people in China are more concerned about the natural and environmental conditions in their living areas. The government also applied greater efforts to improve air quality and the living environment. Therefore, referring to previous research and considering data availability (Liu and Shen, 2014b; Wu et al., 2019b; Yu et al., 2019), we use the greenery coverage rate of urban areas (Green_rate) and the PM2.5 concentrations (PM2.5) to represent environmental conditions, while annual sunshine hours (Sunhour), average annual rainfall (Rainfall), temperature severity (Temsev) and July humidity (Rhjuly) are used as the climate amenities. The temperature severity index is the differences in the average temperature between January and July, and July humidity is average relative humidity in July (Liu and Shen, 2014).

Apart from economic, social and natural amenities of each city, we assume that socioeconomic and institutional factors across different administrative levels will affect inter-city migration (Jiang et al., 2012; Pérez Campuzano and Santos Cerquera, 2008). Thus, we include provincial-level factors that drive the inter-city migration. Specifically, we select per capita GDP (PGDP_p) and share of non-agricultural industries in the GDP (PNag_ratio) at province level to indicate provinces' economic development level, fiscal deficit ratio at province level (PFdr) to indicate provincial governmental financial pressure, ratio of fiscal expenditure per capita at provincial level to that at national level to indicate fiscal decentralization at province level (PFdec), and foreign direct investment per capita to represent the degree of openness at province level (PFdi). Many scholars have emphasized the role of fiscal decentralization and foreign direct investment in promoting China's economic development and regional income (Song, 2013; Wei, 2002).

Here, panel regression models are conducted to explore how various urban amenities affect inter-city migration during 2000-2020 and how effects differ by city type (all sample cities vs. major cities) and over time (2000-2010 vs. 2010-2020). Specifically, we estimate regressions for all sample cities and then for the 35 major cities, separately for time periods: 2000-2020, 2000-2010 and 2010-2020. We also report models with, and without, province-level variables. To avoid possible multicollinearity and endogeneity, except for the climatic condition variables, we use the one-year lagged value of the independent variables. Table 2 presents the descriptive statistics of the variables used in this study. From initial estimations, we used a robust Hausman test that indicated the superiority of the random effects specification (p=0.21, cannot reject the null hypothesis that "independent variables are not related to random effects”). Based on this regression strategy, our study should be useful in reflecting the broad patterns of the inter-city migration process and the correlates with some of the underlying mechanisms driving this process in China.

Table 2: Descriptive statistics for dependent and independent variables in panel regression models for inter-city migration analysis at city level in China

Type	Variable	Mean	Std. dev.	Min	Max
Dependent variable	Net migration rate (%)	1.68	33.61	-35.98	473.29
Economic amenities	GDP_p (10,000 yuan/person)	0.76	0.47	0.14	4.42
	GDP_growth (%)	8.91	5.26	-25.42	26.00
	Nag_ratio (%)	84.00	10.50	46.90	100.00
	Wage (10,000 yuan)	2.63	1.83	0.43	11.29
	Unemp_rate (%)	5.35	3.07	0.06	25.68
	House_inv (10,000 yuan per km^2)	166.88	518.25	0.02	9696.67
Social amenities	Fdr (ratio)	1.52	2.06	-0.40	22.14
	EDU_p (person per 1,000 students)	61.75	14.61	30.52	144.10
	Doc_p (person per 1,000 residents)	20.10	8.31	3.73	64.15
	Bed_p (beds per 1,000 residents)	35.88	15.33	0.14	107.69
	Book_p (10,000 copies per capita)	0.48	0.57	0.02	7.00
	Bus_p (vehicles per 10,000 residents)	7.25	6.93	0.27	103.00
	Road_p (m^2 per capita)	9.98	8.25	0.31	95.00
Natural amenities	Green_rate (%)	35.34	9.92	0.18	70.00
	PM2.5 (ug/m^3)	37.94	13.67	13.24	88.18
	Rainfall (mm)	1040.06	523.55	63.94	2642.69
	Rh_july (%)	76.01	7.29	39.71	87.11
	Temsev (℃)	25.27	7.38	7.32	44.83
	Sunhour (hours)	2012.91	491.47	963.35	3265.15
Province-level economic status	PGDP_p (10,000 yuan/person)	0.73	0.28	0.23	2.42
	PNag_ratio (%)	86.57	6.63	62.50	99.70
	PFdr (ratio)	1.19	0.78	0.14	5.60
	PFdec (ratio)	483.84	2051.59	0.00	29346.77
	PFdi (1 $ per capita)	26.38	31.26	0.48	239.90

Note: There are 852 observations, based on 3 time periods and 284 cities.

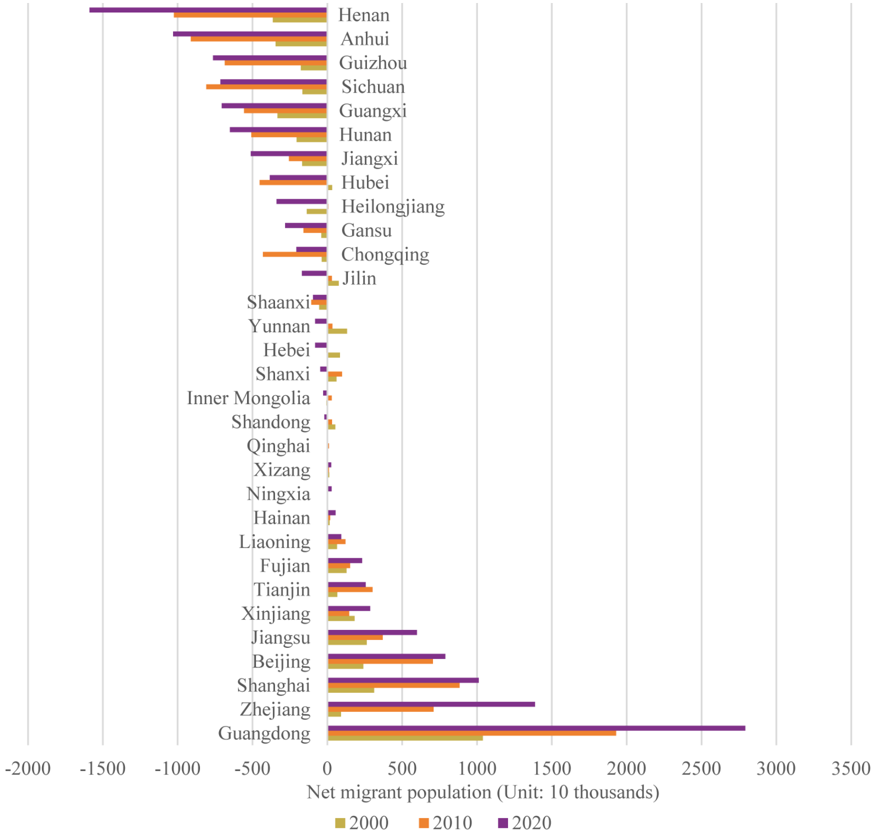
III. Results

Overview of China's migration patterns

The last three censuses show China's "floating population" of internal migrants is still growing rapidly, albeit with considerable regional variation. For example, the 2020 census shows that the phenomenon of inconsistency between the place of residence and the place of household registration is now very common; 493 million people live outside of the townships or streets where they are officially registered. This floating population accounts for about 35% of China's total population. Amongst these 493 million, the inter-city migrant population is 376 million (in other words, 117 million are living somewhere other than their place of registration but still reside within the same prefecture). The size of this inter-city floating population group has increased by nearly 70% in 10 years. While China's overall annual average population growth rate was just 0.51% from 2010 to 2020, the annual growth rate of the floating inter-city migrant population was 6.97% and so the growth of cities is predominantly due to migration.

A province-level overview is provided in Figure 2. Each bar shows the net number of migrants (based on a criteria of residing in a different prefectural level city than the city of registration) at the time of each of the last three censuses. This figure shows that the migrant population continues to cluster in riverine and coastal areas, such as Beijing-Tianjin; Yangtze River Delta (YRD) (Shanghai, Zhejiang, and Jiangsu); and the Pearl River Delta (PRD) (Guangdong). However, there was much slower growth between 2010 and 2020 for Beijing and Shanghai, and a shrinkage in the number of migrants for Tianjin. In the same period, almost eight million more non-hukou migrants came into Guangdong (taking the total almost to 30 million) and about the same number entered Zhejiang (taking the total to 14 million). Conversely, Henan had over five million people emigrate between 2010 and 2020, taking its out-migration total to over 16 million. There are numerous challenges created by these large population movements, including reform of the welfare system for the floating population, the equalization of basic public services for the floating population and the social integration of the floating population. Overall, there is an urgent need for a new top-level design and institutional arrangement for the policy on the floating population.

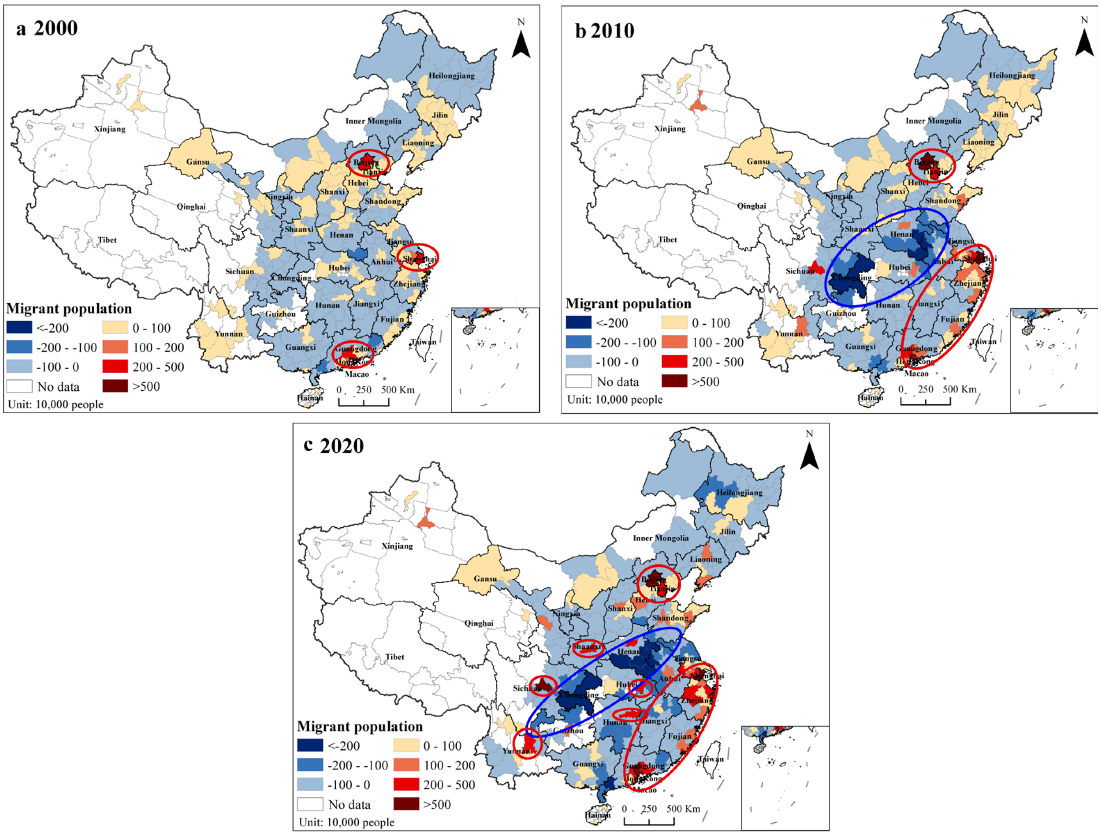
Figure 2: Net inter-city migrant population by province in China in 2000, 2010 and 2020



Spatiotemporal patterns of net migration at the city level

China's migration pattern can be described as a funnelling from many source cities to a small number of destinations, and this pattern strengthens over time. For example, 165 of the 284 prefectural-level cities in the 2000 census had a net outflow of population (fewer residents than registered population) and the number of cities that had suffered net losses of population increased to 184 in 2010 and 201 in 2020 (see Figures 3a, 3b, and 3c for the locations of these cities). Thus, the problem for prefectural level cities of losing people (and the economic activity they generate) is becoming more widespread in China. On the other hand, the earlier top five destinations of Beijing, Shanghai, Guangzhou, Shenzhen and Dongguan, (each with large net inflows exceeding seven million net migrants as of 2020) have recently been joined by several tier-2 cities such as Chengdu, Zhengzhou, Hangzhou, Wuhan, and Kunming as popular destinations (Figure 3c). In terms of locations, except for provincial capital cities, most cities with net outflows were distributed widely throughout central and northeast China, especially in Chongqing and especially for cities in Henan, Anhui and Guizhou provinces (see the blue ovals in Figures 3b and 3c).

Figure 3: Spatial patterns of net migration at the city level across China in (a) 2000, (b) 2010, and (c) 2020

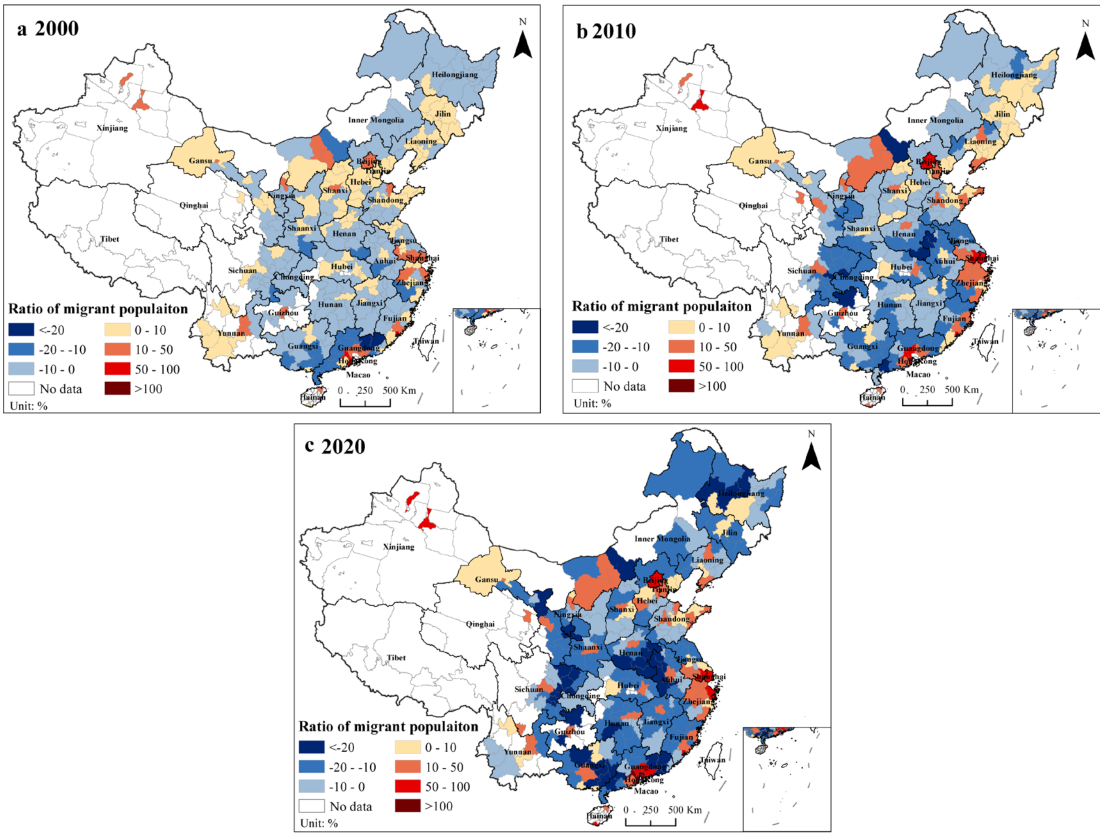


The three panels in Figure 3 showed patterns in terms of the numbers of net migrants. Given the rapid growth in migration there is naturally a more dramatic picture of population movement in panel c (for 2020) than in a (for 2000). For example, the average city with net losses of population had 0.22 million net out-migrants as of the 2000 census, with this average rising to 0.46 million at the 2010 census and 0.64 million at the 2020 census. Conversely, the cities with net gains of population also have higher numbers of inward migrants over time.

Therefore, an alternative way to portray spatiotemporal changes is to examine rates, using the ratio of net migrants to the registered population of each city (Figure 4). At the time of China's fifth census in 2000, there were not yet proportionally large outflows from most cities; for example, for a threshold ratio of net migrants to registered population more negative than -10%, few cities in the 2000 census were in this group (Figure 4a). Yet by 2010, 43% of cities had a net migration ratio of -10% or larger (more negative) and by 2020 two-thirds of cities were in this position. In Figure 4c most of central and northeastern China is covered by the dark blue shades indicating a net outmigrant ratio greater than 10%. Yet at the same time, there was an increase in the number of Tier-1 and coastal cities that had a net migration gain; spreading the popular destinations beyond the Beijing-Tianjin, Yangtze River Delta and Pearl

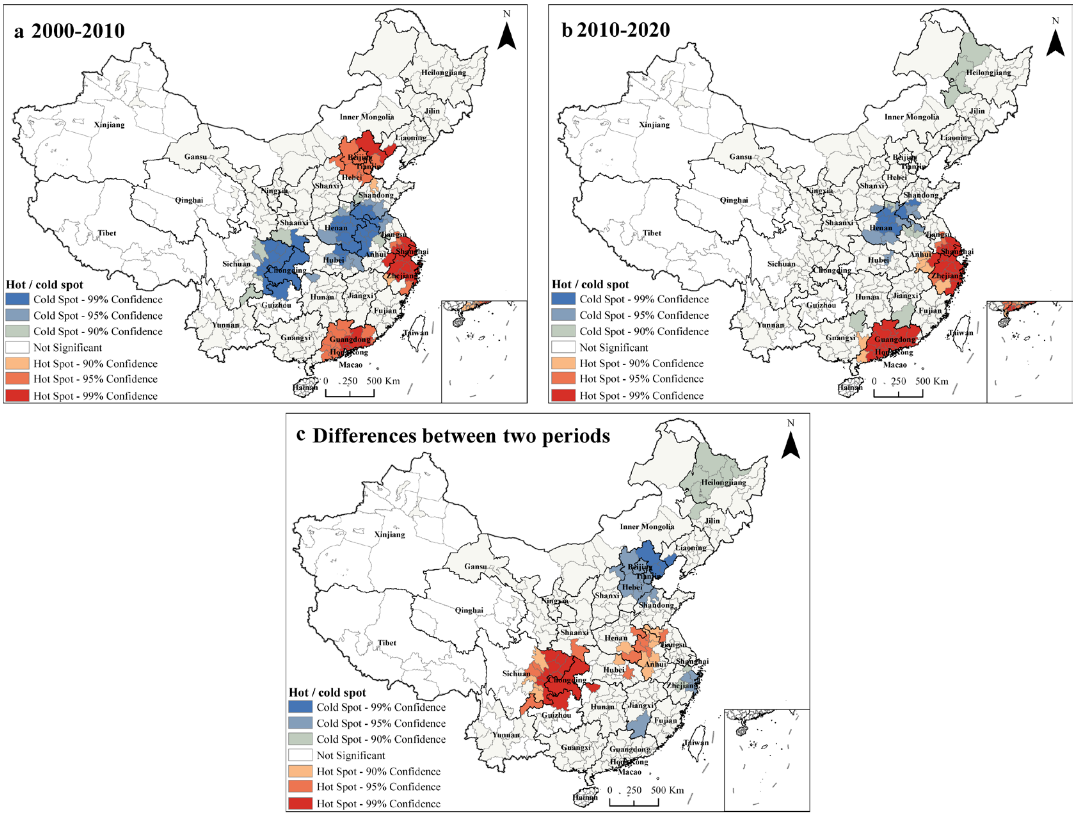
River Delta destinations. In other words, there is some spatial dispersion in the cities that are attracting migrants. This phenomenon can also be seen in trends in the global Moran's I and in the hot/cold spot analysis results shown in Figure 5.

Figure 4: Spatial patterns in the net migration ratio at city level across China in (a) 2000, (b) 2010, and (c) 2020



In line with the spreading of migrant destinations the global Moran's I declined from 0.417 in 2000 to 0.392 in 2010 and 0.385 in 2020 (all changes are statistically significant), indicating a dispersion of the migrant destinations in China. Further, based on the $Z(G_i^*)$ score, hot/cold spots analysis of the average annual growth of the net migrant population for 2000-2010 and 2010-2020, and differences in the growth between these two time periods are shown in Figure 5. During 2000-2010, three regions were hot spots of migration growth: Beijing-Tianjin, the YRD, and the PRD regions. The cold spots in this period were mainly in central China, such as Chongqing city, and cities in Henan, Anhui and Sichuan provinces. However, during 2010-2020, the spatial pattern of migration distribution changed, with only the PRD and YRD regions still as hot spots (while Beijing-Tianjin was not). Also, the cold spots shifted somewhat from central China to Northeast China. Figure 5c compares the average annual growth rates across the two time periods, and it is apparent that there has been some spatial restructuring of the migration destinations, perhaps due to efforts to limit the population growth in cities such as Beijing. Meanwhile, cities in central China, such as Chongqing city, slowed down the pace of population outflow while the rate of population loss was accelerating in Northeast China.

Figure 5: Hot/cold spots of the average annual growth of the net migrant population by city for (a) 2000–2010, (b) 2010–2020, and (c) annual growth differentials between the two periods



Econometric models of net migration at the city level in China

Results for all sample cities

Table 3 presents the estimation results of the panel regression models of net migration for all sampled cities in 2000, 2010 and 2020. Models 1, 3, and 5, include only city-level urban amenities for 2000-2020, 2000-2010, and 2010-2020 respectively. Results with additional, province-level factors are in Models 2, 4, and 6. Regarding the impacts of city-level economic amenities, the results show that coefficients for Log(GDP_p), Log(Wage) and Unemp_rate are statistically significant with expected signs in Model 1, indicating that differences in economic development, especially job opportunities, and wages remain key driving forces for China's inter-city migration. Places with higher levels of economic activity, higher wages and lower unemployment rates are more attractive destinations for migrants. However, the coefficient for GDP_growth is significantly negative, indicating that the destination cities do not have higher rates of economic growth. Many of the lower-tier cities experienced high GDP growth rates during 2000-2020, yet they still had net outflows of population to cities with higher income levels but lower growth rates.

Cities with higher net migration rates have more (lagged) housing investment, shown by significant, positive, coefficients on Log(House_inv). Cities with high housing investment are mainly located in developed areas. These findings are consistent with previous research results that cities in more developed areas, with more job opportunities and higher wages are attractive to migrants (Grimes et al., 2016; Liu and Xu, 2017; Su et al., 2019). Furthermore, comparing the results of Model 1 to Model 3 and 5, shows changes in the significance of some variables across periods. For example, the coefficients of Log(GDP_p) do not pass the significance test for the period 2000-2010 in Model 3, but pass for 2010-2020 in Model 5. It may indicate that the relationship between local economic development and migration strengthens in 2010-2020 compared to in 2000-2010. Conversely, the Unemp_rate coefficient becomes insignificant in Model 5, implying that the importance of (lack of) job opportunities may have declined over the 2010-2020 period. In contrast, coefficients for Log(Wage), Log(House_inv) are always significant, indicating their important role in affecting migration.

In terms of social amenities, the results in Model 1 shows four social amenity variables, Fdr, Edu_p, Bed_p and Bus_p, pass the significance test. Fdr is significantly and negatively associated with migration (except for 2010-2020), suggesting that cities facing large fiscal pressure are less attractive to migrants. Unexpectedly, Log(Edu_p) and the two health-related variables, Log(Doc_p) and Log(Bed_p), are negatively related to migration. In other words, a high teacher-student ratio and more doctors and hospital beds per capita in cities do not signify attractiveness to migrants. As shown in Figure S1 and S2, cities with a high number of teachers per 1,000 students and hospital beds per 1,000 residents are mostly those with negative net migration rates. However, high quality education and health care facilities are still concentrated in large cities, which are attractive to the migrant population even when facing educational and medical excess demand given the proportionally lower number of teachers and doctors (Cao et al., 2023). It is also apparent, when comparing Model 3 and 5, that corelations between health and education services and net migration are more pronounced in 2010-2020. Likewise, the Log(Book_p) variable is only statistically significant in Model 5 (for 2010-2020), indicating that better cultural services may attract more migration in recent years. In other words, people may be paying more attention to the cultural atmosphere of cities where they choose to live.

The two transportation variables, Log(Bus_p) and Log(Road_p) are positively related to net migration. Log(Bus_p) passes the statistical test in Model 1, 3, and 5, while Log(Road_p) is only statistically significant in Model 5 for the second decade. Overall, this suggests that cities with more transportation services, which is important to people's ability to earn a living, can attract more migrants and these attributes appear to be becoming more important. Overall, the estimated results of social amenity variables suggest that places with abundant social welfare and public services are more attractive to migrants.

Regarding natural amenities, sunnier cities have higher net migration rates. In contrast, high humidity cities have lower net migration rates, across all specifications and time periods. Only in the last decade does air quality (PM2.5) appear to be related to migration patterns, with lower net migration the worse the air quality. The insignificance of air quality (and green space) in the earlier period may indicate that at that (earlier) stage of development the air pollution issue was a common challenge for most cities in China (Yu et al., 2019; Zang et al., 2015) and so migrants may not have had much choice on this attribute. Overall, the results indicate that migrants prefer less humid summers, warm winters and regions with more rainfall and sunshine. As the economy develops and people's income grows, more and more people begin to pay attention to the quality of life, in which the comfortable natural environment becomes an important decision-making factor for people to choose their migration destination.

The results in Models 2, 4, and 6 show whether province-level factors matter, holding constant the city-level variables. The economic factors, Log(PGDP_p) and the PNag_ratio, have no significant relationship with the net migration rates for cities within the province. Thus, whether the province in which a city is located is economically developed does not influence migration decisions, and people are more focused on the level of economic development of the city itself. Therefore, prior studies that have used province-level data may not be able to tell the full story. In a result that is similar to the city-level effect, PFdr mostly has significantly negative coefficients (except for 2010-2020), so if the province to which the city belongs has a large public debt, the city seems less attractive to migrants. However, high province-level fiscal decentralization is attractive to migrants. Fiscal decentralization is considered beneficial to public goods provision and economic growth given that local governments may have better information on people's needs and preferences, so decentralized fiscal power can promote a good match between the needs of local constituents and the government's supply (Wu et al., 2019a), and thus promote local economic development to make cities more attractive to migrants. The provincial FDI level does not show a relationship with net migration.

Table 3: Relationships between urban amenities and net migration: 284 cities in China in 2000, 2010 and 2020

Independent variables		Dependent variable: Net migration rate (NMR)					
		2000-2020		2000-2010		2010-2020	
City level		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Economic amenities	Log(GDP_p)	**4.176***	**3.929**	**3.25**	**3.877**	**6.580***	**3.852**
		(1.74)	(1.50)	(1.23)	(1.37)	(1.86)	(0.97)
	GDP_growth	**-0.264****	**-0.173**	**-0.223***	**-0.163**	**-0.199**	**-0.094**
		(2.32)	(1.50)	(1.89)	(1.37)	(1.02)	(0.48)
	Nag_ratio	**-0.179**	**-0.117**	**-0.117**	**-0.087**	**0.122**	**0.329**
		(1.57)	(0.94)	(0.93)	(0.65)	(0.64)	(1.54)
	Log(Wage)	**13.884*****	**12.610*****	**13.012*****	**10.916*****	**10.662****	**8.609***
		(3.67)	(3.32)	(3.15)	(2.66)	(2.08)	(1.66)
	Unemp_rate	**-0.349***	**-0.331***	**-0.377***	**-0.394***	**-0.156**	**-0.26**
		(1.73)	(1.66)	(1.69)	(1.80)	(0.64)	(1.06)
	Log(House_inv)	**2.844*****	**3.091*****	**2.355*****	**2.597*****	**3.508*****	**3.522*****
		(3.84)	(4.11)	(2.84)	(3.15)	(3.75)	(3.67)
Social amenities	Fdr	**-0.756****	**-0.281**	**-1.181*****	**-0.447**	**0.477**	**0.421**
		(2.06)	(0.70)	(2.89)	(0.91)	(1.18)	(1.04)
	Log(Edu_p)	**-14.903*****	**-15.517*****	**-4.347**	**-4.462**	**-11.767****	**-12.531*****
		(3.58)	(3.75)	(0.92)	(0.94)	(2.43)	(2.61)
	Log(Doc_p)	**-2.901**	**-2.096**	**-2.134**	**-0.977**	**0.72**	**1.339**
		(1.24)	(0.89)	(0.85)	(0.39)	(0.25)	(0.48)
	Log(Bed_p)	**-9.452*****	**-8.203*****	**-3.212**	**-2.25**	**-16.665*****	**-16.767*****
		(4.43)	(3.85)	(1.37)	(0.98)	(4.82)	(4.83)
	Log(Book_p)	**1.114**	**0.435**	**-0.916**	**-1.758**	**3.073*****	**2.474****
		(0.94)	(0.36)	(0.56)	(1.08)	(2.60)	(2.08)
	Log(Bus_p)	**3.161*****	**3.107*****	**3.762*****	**4.067*****	**2.950****	**2.637****
		(2.77)	(2.73)	(2.90)	(3.15)	(2.21)	(1.98)
	Log(Road_p)	**1.741**	**2.293***	**-0.038**	**-0.171**	**4.232*****	**4.226*****
		(1.43)	(1.88)	(0.03)	(0.12)	(3.20)	(3.21)
Natural amenities	Green_rate	**-0.105**	**-0.099**	**-0.046**	**-0.062**	**-0.178**	**-0.187***
		(1.35)	(1.29)	(0.56)	(0.76)	(1.64)	(1.74)
	PM2.5	**-4.55**	**-4.883**	**-1.257**	**-3.216**	**-6.014**	**-7.377***
		(1.42)	(1.53)	(0.26)	(0.66)	(1.41)	(1.68)

	Log(Rainfall)	**13.310***** (2.74)	**12.742**** (2.57)	**8.436** (1.57)	**6.561** (1.16)	**13.535***** (2.80)	**15.034***** (2.98)
	Log(Rh_july)	**-0.915***** (3.68)	**-0.949***** (3.78)	**-0.864***** (2.94)	**-0.834***** (2.84)	**-0.610**** (2.51)	**-0.699***** (2.83)
	Log(Tmesev)	**-4.799** (0.68)	**-4.601** (0.65)	**-16.631**** (2.05)	**-17.209**** (2.09)	**-3.969** (0.56)	**-1.865** (0.26)
	Log(Sunhour)	**26.962***** (3.32)	**26.460***** (3.19)	**23.630**** (2.57)	**22.988**** (2.40)	**30.334***** (3.58)	**30.795***** (3.50)
Province-level							
	Log(PGDP_p)		**0.476** (0.09)		**-2.019** (0.32)		**4.565** (0.75)
	PNag_ratio		**-0.348** (1.44)		**-0.208** (0.71)		**-0.518** (1.41)
Economic status	PFdr		**-3.873**** (2.50)		**-4.424**** (2.36)		**-1.685** (0.61)
	PFdec		**0.001***** (3.80)		**0.001***** (3.67)		**0.001**** (2.03)
	Log(PFdi)		**-0.821** (0.99)		**0.693** (0.63)		**-1.658** (1.54)
Time variable	Year	**-1.407***** (3.88)	**-1.184***** (3.22)	**-1.620***** (3.11)	**-1.230**** (2.32)	**-1.379***** (3.01)	**-1.132**** (2.40)
Constant	Intercept	-74.359 (0.86)	-42.437 (0.46)	-64.192 (4.68)	-33.903 (1.24)	-149.156 (1.55)	-123.008 (1.11)

Note: There are 852 observations, based on 3 time periods and 284 cities. Absolute value of z-statistics in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Results for 35 major cities

Table 4 shows the regression results just for the sample of 35 major cities. Recall that these are the four municipalities, 26 provincial capitals and the five other sub-provincial cities. Many of the factors that were related to net migration for the all-cities sample do not show up as statistically significant factors for these major cities. In other words, there may be different driving forces for migration to major cities than for other cities. For example, the coefficients of Log(GDP_p) and Log(House_inv) are not significantly positive during the whole time period, and the coefficient of Log(Wage) is insignificant during 2010-2020. As the levels of economic development and housing market development among these major cities tend to be more similar, migrants may perhaps not choose one major city over another based on their level of economic and housing market development (Wu et al., 2019b). GDP growth of these cities was not a driving force for attracting more migrants over these two decades, and there is also a negative relationship with the province-level per capita GDP level. These anomalous results may be because of efforts to limit migrant inflows for some of the province-level municipalities with the highest levels of per capita GDP, such as Beijing and Shanghai.

Neither city-level nor province-level Fdr have significant effects on the net migration rate. Likewise, coefficients on education services (Log(Edu_p)) and cultural services (Log(Book_p)) are no longer significant. This may be because the differences in these services are not significant among major cities. Third, the coefficient of PM2.5 is significantly negative for the full period; air pollution in major cities is relatively more serious and people are more sensitive to the health impacts of pollution, so air pollution in major cities may matter more to migrants than for other cities. In addition, most climatic amenities have no significant influence on the net migration rate for major cities. It may be that better living infrastructure conditions (e.g. more widespread air conditioning) in large cities are sufficient to minimize the effects of climatic conditions. Finally, while PFdec was significantly positive for all sample cities it is not for major cities; while province-level decentralization may promote net migrant population increase for most less-developed cities it does not necessarily do the same for the major cities that are already more economically developed.

Table 4: Relationships between urban amenities and net migration for 35 major cities in China in 2000, 2010, and 2020

Independent variables		Dependent variable: Net migration rate (NMR) for 35 major cities					
		2000-2020		**2000-2010**		**2010-2020**	
City level		Model7	Model8	Model9	Model10	Model11	Model12
Economic amenities	Log(GDP_p)	**8.514**	**27.86**	**25.51**	**40.841**	**11.096**	**19.993**
		(0.42)	(1.31)	(0.87)	(1.42)	(0.51)	(0.75)
	GDP_growth	**-2.555***	**-3.183****	**-1.887**	**-2.907**	**-1.789**	**-2.488***
		(1.88)	(2.22)	(0.95)	(1.39)	(1.52)	(1.78)
	Nag_ratio	**1.894**	**1.666**	**1.229**	**0.334**	**3.965***	**4.027**
		(1.03)	(0.86)	(0.54)	(0.14)	(1.77)	(1.63)
	Log(Wage)	**57.711***	**83.071****	**33.626**	**102.622***	**52.451**	**47.017**
		(1.69)	(2.18)	(0.68)	(1.76)	(1.58)	(1.23)
	Unemp_rate	**-3.996*****	**-4.229*****	**-4.504****	**-4.353****	**-2.475**	**-2.459**
		(2.73)	(2.76)	(2.43)	(2.31)	(1.58)	(1.37)
	Log(House_inv)	**4.849**	**8.999**	**10.075**	**14.054**	**-5.089**	**-2.507**
		(0.63)	(1.12)	(0.94)	(1.24)	(0.70)	(0.32)
Social amenities	Fdr	**1.905**	**2.777**	**-0.957**	**-8.129**	**8.894**	**11.715**
		(0.20)	(0.24)	(0.07)	(0.42)	(0.97)	(1.07)
	Log(Edu_p)	**-37.827**	**-14.493**	**0.369**	**48.328**	**-16.295**	**-12.759**
		(1.03)	(0.37)	(0.01)	(0.94)	(0.41)	(0.28)
	Log(Doc_p)	**-34.730***	**-31.786**	**-50.874***	**-34.55**	**-21.631**	**-28.382**
		(1.66)	(1.42)	(1.65)	(1.02)	(1.07)	(1.23)
	Log(Bed_p)	**-32.35**	**-53.838****	**-35.34**	**-72.259****	**-26.295**	**-32.518**
		(1.54)	(2.13)	(1.25)	(2.30)	(1.35)	(1.27)
	Log(Book_p)	**-1.873**	**0.404**	**-3.592**	**-4.206**	**0.345**	**1.262**
		(0.28)	(0.05)	(0.32)	(0.39)	(0.07)	(0.20)
	Log(Bus_p)	**33.410*****	**34.267*****	**36.495*****	**31.166****	**33.861*****	**37.933*****
		(3.23)	(3.21)	(2.78)	(2.35)	(3.28)	(3.28)
	Log(Road_p)	**3.901**	**3.88**	**-13.423**	**-1.333**	**20.433***	**18.981**
		(0.32)	(0.29)	(0.77)	(0.07)	(1.87)	(1.46)

	Green_rate	**0.327**	**0.456**	**0.312**	**1.042**	**-0.494**	**-0.392**
		(0.44)	(0.59)	(0.35)	(1.07)	(0.51)	(0.38)
	PM2.5	**-35.323****	**-42.053****	**-23.785**	**-28.75**	**-10.963**	**-14.53**
		(2.08)	(2.43)	(0.76)	(0.96)	(0.59)	(0.74)
	Log(Rainfall)	**-6.838**	**-3.645**	**-11.257**	**8.644**	**-1.504**	**-9.501**
Natural amenities		(0.34)	(0.19)	(0.42)	(0.32)	(0.09)	(0.56)
	Log(Rh_july)	**-1.066**	**-1.156**	**-1.99**	**-2.062**	**-0.292**	**-0.327**
		(0.99)	(1.14)	(1.22)	(1.35)	(0.32)	(0.35)
	Log(Tmesev)	**-7.257**	**7.562**	**-38.322**	**-11.993**	**-31.588**	**-28.404**
		(0.27)	(0.29)	(0.93)	(0.27)	(1.27)	(1.10)
	Log(Sunhour)	**1.949**	**17.314**	**6.655**	**43.025**	**4.581**	**-1.519**
		(0.06)	(0.60)	(0.15)	(1.01)	(0.18)	(0.06)
Province-level							
	Log(PGDP_p)		**-54.783****		**-96.564****		**-7.569**
			(2.25)		(2.56)		(0.28)
	PNag_ratio		**0.583**		**2.910***		**-1.348**
			(0.53)		(1.83)		(1.10)
Economic status	PFdr		**0.592**		**9.232**		**-3.305**
			(0.07)		(0.66)		(0.42)
	PFdec		**0.000**		**0.000**		**0.000**
			(0.25)		(0.26)		(0.45)
	Log(PFdi)		**-0.416**		**-3.699**		**0.365**
			(0.08)		(0.45)		(0.07)
Time variable	Year	**-5.560***	**-8.115****	**-4.363**	**-13.336****	**-3.98**	**-3.384**
		(1.74)	(2.35)	(0.86)	(2.33)	(1.45)	(1.09)
Constant	Intercept	422.625	179.224	511.14	-294.001	-43.791	185.019
		(1.03)	(0.44)	(0.91)	(0.50)	(0.11)	(0.42)

Note: There are 105 observations, based on 3 time periods and 35 major cities. Absolute value of z-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

IV. Conclusions and policy implications

Since the relaxation of the household registration system and the economic reform in the late 1970s, China has experienced unprecedented largescale internal migration. Location choices of incoming and outgoing migrants are critical to the sustainable development of cities. While there are extant studies of China's migration, few focus on both city-level and province-level driving forces, nor consider attractiveness due to economic, natural, and social amenities. Also, the changes in spatial patterns of migration revealed by China's 2020 census are just beginning to be studied. Hence, our study of net migration changes for 284 prefectural-level cities, observed in China's 2000, 2010 and 2020 censuses, helps to fill these gaps in the literature.

Our study shows that China's migrant population is still growing rapidly but with some regional change. For example, the former trend for migrants to especially move to three urban mega-regions, of the Yangtze River Delta, the Pearl River Delta, and the Beijing-Tianjin area has changed since 2010. Several tier-2 cities such as Chengdu, Zhengzhou, Hangzhou, Wuhan, and Kunming emerged as migration destinations, with the Beijing-Tianjin region no longer a hot spot of migration growth during 2010-2020 (while the PRD and YRD were still hot spots). On the other hand, even with an increased number of cities that have lost at least ten percent of their registered population to out-migration, some lower-tier cities in central and western China reversed their trend of population decline but population loss accelerated in Northeast China.

Our regression models show which economic, social and natural amenities are related to the city-level net migration rate in China during 2000-2020. Overall, when we study all cities, migrants appear to be primarily concerned with job opportunities and wages, and uneven economic development still strongly affects the pattern of migration, with people trading off levels versus growth. A booming housing market, characterized by increasing housing investment, has not deterred migrants. When we focus just on major cities, which may be harder for migrants to settle in than some of the smaller cities, we find that variations in economic development and job opportunities are not significant correlates of migration. This suggests that migration to these cities is influenced by other, possibly non-economic, factors.

In terms of other amenities, cities (or the province it is in) with large debt obligations are less attractive to migrants (this effect does not apply for major cities). Province level fiscal decentralization is associated with migration in-flows to cities in the province, possibly because decentralization helps mobilize local resources for development of better amenities to attract migrants, especially in less-developed regions that are not major cities. Cities with better public transportation services are more attractive to migrants, which is more salient in less-developed regions. While more accessible education and health care services were not related to the net-migration patterns, it may be that the quality of those services matters and this is an aspect that could be investigated by future research. In terms of natural amenities, cities with less-humid summers, warm winters, more rainfall and sunshine attract more migrants. However, for the major cities these climate factors matter less (perhaps because the built environment in such cities is more developed with wider use of air conditioning) but outdoor air quality seems to matter more in major cities. Overall, in the last two decades, while regional disparities in economic opportunities still affect inter-city migration pattern, social and natural amenities are also becoming important drivers of migration in China.

Findings from this study may help to improve our understanding of China's internal migration and the relationships that various types of amenities have with differing (migration-driven) growth paths of cities. Nevertheless, there are some issues that can be further examined in the future. For example, the relationships between urban amenities and migration choice might be further analysed by combining the individual characteristics of different groups of migrants, such as migrants with different ages, educational backgrounds, skill levels etc. In addition, the choice to settle in different cities may also be affected by the local policy regimes of the potential destination cities, in terms of barriers they may put in place to deter settlement. It would be interesting to investigate the impacts of individual-level and city-level factors on the spatial disparity of people's migration choices amongst cities using a multilevel model.

Policy Implications

Our research results may also provide policy implications for sustainable city development governance measures. Firstly, the spatial imbalance of migration reflects uneven regional development (Yang et al., 2017), which will hinder China's development. More tier-2 cities, most of which are provincial capital cities, in inland China have emerged as new migration destinations. Considering their leading role in regional development, government might further support an enhancing of their economic development and attractiveness, thus to help improve net inflows of migration in the medium and small cities surrounding those tier-2 cities. In addition, cities in Northeast China have become new cold spot of population loss, and so the revitalization of Northeast China is important for promoting the balanced regional development.

Secondly, policies and regulations for migration control should be tailored with consideration of local characteristics. For example, for cities in less developed regions, local governments need to further improve their financial system to reduce local debts, and the central government should give local governments more fiscal power. Fiscal decentralization plays an important role in local government's pursuit of fiscal revenue and mutual competition (Wei et al., 2017), which significantly affect the migration-driven growth of cities, except for the major cities. China has a complex system of inter-governmental fiscal system, which is characterized by very high expenditure decentralization and high intraregional inequality among provinces (Tan and Tan, 2024). Thus, the central government may need to do more to ease intraregional inequality and to enhance fiscal decentralization of the provinces that need to attract migrations. In addition, it is important to improve the quality, not just the quantity, of education and health care services, especially for less developed regions. For major cities, there should be more focus on urban environment (such as air quality) improvement, given that these attributes appear to become more important to migrant's settlement decisions over time. In addition to enhancing economic growth and providing more job opportunities, more strategies should be focused on social and natural amenities.

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Figure S1: Spatial pattern of teacher-student ratio of cities across China in 1999, 2009 and 2019

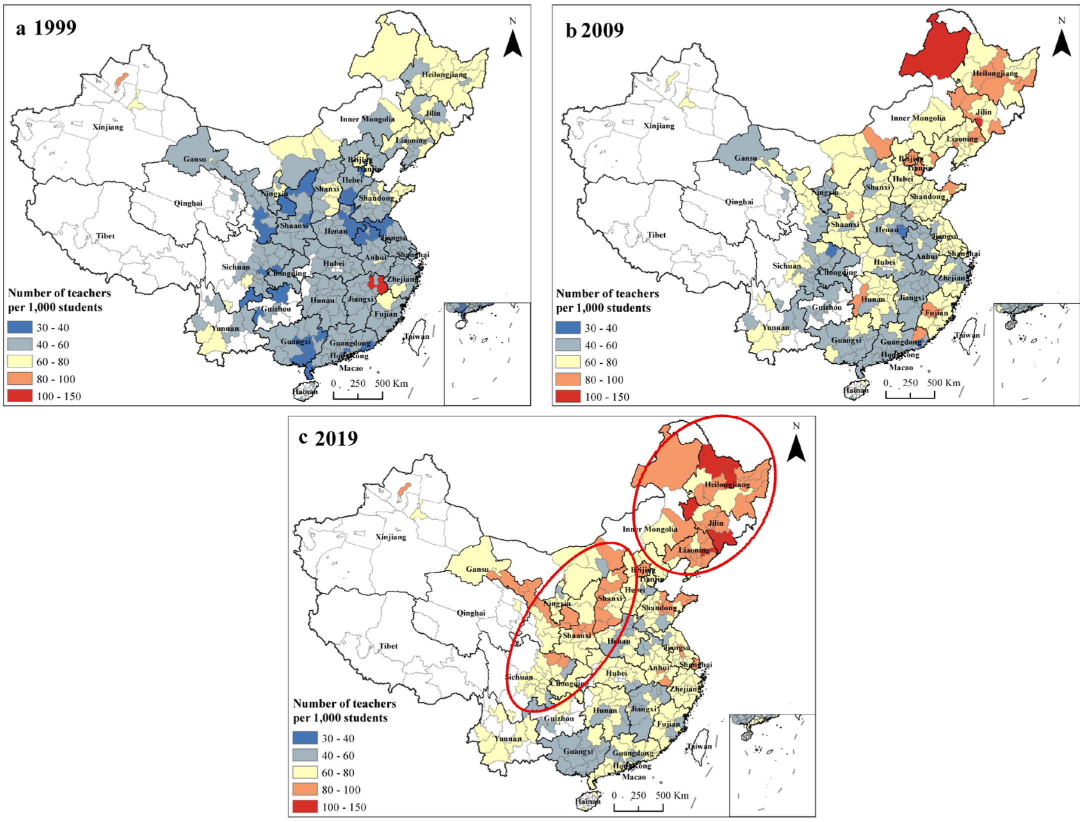

Figure S2: Spatial pattern of per capita hospital beds of cities across China in 1999, 2009 and 2019