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Article

Population threshold for the evolution towards an advanced economy in Chinese cities

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Abstract: Although the problems created by exceeding Earth's carrying capacity are real, a too-small population also creates problems. The convergence of a nation's population into small areas (i.e., cities) via processes such as urbanization can accelerate the evolution of a more advanced economy by promoting new divisions of labor and the evolution of new industries. The degree to which population density contributes to this evolution remains unclear. To provide insights into whether an optimal "threshold" population exists, we quantified the relationships between population density and economic development using threshold regression model based on the panel data for 295 Chinese cities from 2007 to 2019. We found that when the population density of the whole city (urban and rural areas combined) exceeded 866 km^{-2}, the impact of industrial upgrading on the economy decreased; however, when the population density exceeded 15,131 km^{-2} in the urban part of the cities, the impact of industrial upgrading increased. Moreover, it appears that different regions in China may have different population density thresholds. Our results provide important insights into urban economic evolution, while also supporting the development of more effective population policies.

Keywords: population explosion; social evolution; carrying capacity; population threshold; population density

1. Introduction

Throughout human history, population increases have frequently exceeded Earth's carrying capacity (which increases as technology permits greater production of resources such as food per unit area), and in some cases, this has caused an ecological crisis (Cohen, 1995; Cassils, 2004; Chaudhary et al., 2018). To cope with the crisis, humans have evolved socially, such as changing from hunter–gatherer societies to more advanced agricultural and industrial societies (Funabashi, 2018; Shuai, 2018; Zheng et al., 2012). Other innovations include the progression from living in primitive sheltered areas such as caves to living in villages and eventually in large, densely populated cities (Wang and Chen, 2016). The pressure exerted by population growth and the concentration of populations in small areas have promoted the evolution of human society (Gerland et al., 2014; Lee, 2011). Fears over the consequences of this population growth have a long history, dating back to at least the 1790s, when Thomas Malthus described the crisis that would occur when population growth exceeded the ability of agriculture to feed the population (Malthus, 1798). However, because technological and economic innovations have thus far kept pace with population growth by increasing the Earth's carrying capacity, historians disagree over whether Malthusian theory is valid (Ashraf and Galor, 2011; Dong et al., 2016).

The phrase "population explosion" has been proposed to describe the rapid increase in human populations in recent centuries, and fear over the consequences has swept the globe, leading to changes in traditional family planning concepts and in some cases, changes in a country's population policy (Bongaarts, 1994; Stycos, 1964). For example, China's notorious one-child policy, implemented to prevent a Malthusian crisis, forced tens of millions of pregnant women to abort their pregnancy (Potts, 2006). This inhumane policy not only violated human rights, but also caused China to become the country with the world's fastest decline in its newborn population (Cai et al., 2018; Zhang, 2017). Although this policy has been discontinued, China's population growth is still slowing and will soon reverse, as many young and educated women are choosing to not have children. However, China is not alone in this trend; birth rates have decreased in many countries around the world, often to below replacement levels (Colleran and Snopkowski, 2018; Piotrowski and Tong, 2016). Researchers predict that the global population will stop growing by the end of the 21st century, and at that time, China's population will be less than 50% of the current population (Chappell, 2011; Gerland et al., 2014).

Population density is a major concern for researchers around the world (Fraumeni et al., 2019; Klasen and Nestmann, 2006; Wang and Chen, 2016). With improved agricultural production levels, the focus of concerns about too-large populations has shifted from the availability of sufficient food to the effects on industrial development and wealth enhancement from an economic perspective, to the effects of income growth and social security from a social perspective, and to the effects of environmental pollution and ecological carrying capacity from an ecological perspective (Cassils, 2004; Crist et al., 2017; Hui, 2006; Ni et al., 2023; Simon, 1980). On the other hand, a too-small population also has problems (Gerland et al., 2014; Liu and Zhu, 2023). There is the risk of a demographic crisis, with problems such as the inability of a much smaller population to support a large population of elderly citizens and uncertainty over whether a smaller population can sustain economic growth by sustaining consumption. In addition, with a too-small population, an equitable and efficient division of labor becomes more difficult to achieve, potentially hindering the development of innovations such as new industries and the resulting evolution towards a new and potentially more advanced economy (Berliant and Konishi, 2000). However, it is unclear how many people are required for optimal innovation and what the most desirable concentration of people may be.

We hypothesized that there is an optimal population density that can promote an economic transition to a more advanced stage, and that this threshold density would vary depending on a city's historical and other characteristics. Here, we defined "advance" as progression along the spectrum from primarily resource-based sectors such as agriculture and forestry to industrialization relying on fossil fuels, and then to an economy dominated by tertiary industries, including the knowledge economy. To determine the population required to support the development of new industries and create a more advanced society, we collected the panel data for 295 Chinese cities from 2007 to 2019 and analyzed the relationships between population density and economic development using threshold regression model. Our results provide insights into the evolution towards a more advanced economy, and will support the development of more effective population policies and potentially promote a civilization's evolution toward a more advanced economy.

2. Materials and methods

2.1. Study areas

We selected 295 Chinese cities as our research subjects (**Figure 1**). The cities covered a range of levels and stages of economic and social development. To test for the possible existence of different population thresholds in different regions of China, we divided the 295 cities into three major geographic regions according to the definitions used by China's Ministry of Statistics, which were based on a combination of national policy objectives and the regional economic development level (**Figure 1**). Because of low populations and low funding for collecting urban statistics in western China, much less data is available for this region. Better data will be required in future research. The total sample size was 95,114, and 86 cities, respectively, in the eastern, central, and western regions.

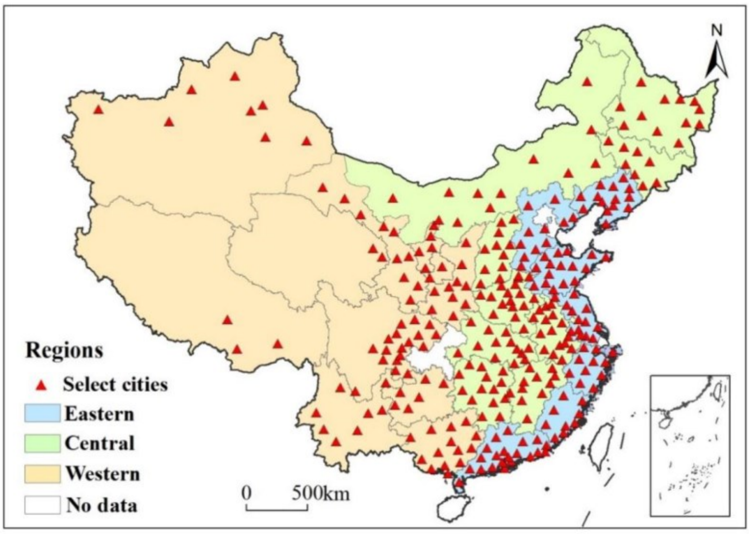

Figure 1. The distribution of the cities in the study sample and their relationships to the three regions.

2.2. Data sources

We obtained the data for each city from China's statistical yearbooks for each province and from the Statistical Communique on the National Economy and Social Development of China for each city (National Bureau of Statistics, 2008–2020). These data are collected using consistent guidelines to facilitate comparisons among provinces and cities. Thus, although the data undoubtedly contain some sources of bias, they are perhaps less biased than alternative sources that don't follow consistent data compilation guidelines. The map we used was based on the standard map produced by the Map Technology Review Center of the Ministry of Natural Resources.

2.3. Research methods

To explore the relationship between population density and economic development, we selected the comprehensive development level of the regional economy as the dependent variable (**Table 1**), which we calculated using the entropy method. The entropy method is a multi-attribute decision-making method proposed by

Hwang and Yoon in 1981, widely used in fields such as benefit evaluation and comprehensive evaluation (Hwang and Yoon, 1981). We used the entropy method to determine the weights of various indicators of regional economic level. The equations were:

$$Y_{ij} = \frac{Z_{ij}}{\sum_{i=1}^{m} Z_{ij}} \tag{1}$$

$$e_j = -\frac{1}{Lnm}\sum_{i=1}^{m} Y_{ij}\ln Y_{ij} \tag{2}$$

$$f_j = 1 - e_j \tag{3}$$

$$w_j = \frac{f_j}{\sum_{j=1}^{n} f_j} \tag{4}$$

$$U_s = \sum_{j=1}^{n} w_j Z_{ij} \tag{5}$$

Y_{ij} is the weight of the indicator j in the year i, m and n are the number of years and the number of indicators respectively. e_j, d_j, w_j and S_{ij} are information entropy, redundancy of information entropy, indicator weight and vulnerability index of single indicator, respectively. U_z is comprehensive index.

Table 1. Indicators for measuring the regional economic level.

System	Target layer	Indicator layer	Calculation method	Attribute	Weight
Regional economic level	Economic aggregates	GDP per capita	GDP/total population at the end of the year	+	0.37
	Income of residents	Disposable income per capita	Total disposable income of all residents/total population at the end of the year	+	0.27
	Social consumption	Total retail sales of consumer goods per capita	Total retail sales of consumer goods/total population at the end of the year	+	0.36

The population density and urban population density were selected as the threshold variables (Fraumeni et al., 2019). Because Chinese cities, unlike most Western cities, often include extensive rural and agricultural areas, we separated the data for the urban and rural areas to allow separate analysis of data from the whole city and data from only the urban areas. What's more, we choose industrialization (Liu and Zhu, 2023; Prego, 2021) and industrial upgrading (Ni et al., 2023) as core independent variables, and marketization, technological progress, agricultural resources, medical level, infrastructure and environmental pollution as control variables (Bekele et al., 2024; Carillo, 2024; Cui and Diwu, 2024; Li et al., 2021; Zhen et al., 2024). **Table 2** defines the specific variables we used. To eliminate variables with excessive autocorrelation (multicollinearity), we calculated the variance inflation factor (VIF). The results (VIF < 5) showed no multicollinearity, which indicates that all variables could be included in the analysis and that the model can fully reflect the threshold effect of population density on economic development.

To test for a significant relationship between the population density and economic development, we used version 17.0 of the Stata software (https://www.stata.com/) to perform baseline regression to verify the robustness of the sample data.

Table 2. The indicators selected for use in the regression analysis and results of the multicollinearity test based on the variance inflation factor (VIF).

Variable type	Variables	Calculation method	Units of measurement	*N*	Mean value	*SD*	Minimum value	Maximum value	*VIF*
Dependent variable	Regional economic level	Calculated by using the entropy method	-	3835	0.19	0.13	0.01	0.84	-
Core independent variables	Industrialization	Secondary industry added value / permanent population at the end of the year	10^3 RMB/person	3835	0.22	0.18	0.08	1.61	2.44
	Industrial upgrading	Added value of tertiary industry / permanent population at the end of the year	10^3 RMB/person	3835	0.18	0.16	0.01	1.31	4.90
Threshold variable	Population density	Total population at the end of the year / region area	No. persons/km^2	3835	420.36	494	0.58	6626.27	2.03
Control variables	Marketization	Urban private and individual employment/ total population at the end of the year	-	3835	0.12	0.09	+0.00	0.92	1.93
	Technological progress	Number of patents granted / permanent population at the end of the year	No. per 10^3 persons	3835	0.08	0.18	0.00	2.98	2.36
	Agricultural resources	Grain growing area / permanent population at the end of the year	m^2/person	3835	0.16	0.65	0.00	10.31	1.07
	Medical level	Number of beds in medical institutions / Total population at the end of the year	No. per 10^3 persons	3835	0.41	0.14	0.05	1.44	1.49
	Infrastructure	Highway mileage/total area of the region	km/km^2	3835	0.99	0.53	0.02	4.52	1.79
	Environmental pollution	Air $PM_{2.5}$ density × per capita volume of inhaled air	100 mg	3835	0.44	0.15	0.03	1.08	1.62

The Equation we used was:

$$Y = \alpha + \beta_0 X_{it} + \sum_{j=1}^{n} \beta_j X'_{itj} + \mu_i + \varepsilon_{it}, \qquad \text{where } \varepsilon_{it} \sim N(\mu = 0, \sigma^2 = \mathrm{I}) \quad (6)$$

where *i* represents the city, *t* represents the year, *Y* is the dependent variable (the regional economic level), *X* is the core independent variable (population density), *X'* is a control variable, *β* is the regression coefficient, *μ* represents the cross-sectional individual effect of city that does not change over time, and *ε* is the random error term.

Models 1 to 6 in **Table 3** present regression analyses of the effects of industrialization, industrial upgrading, and control variables on regional economic level, respectively. The regression results showed that industrialization, industrial upgrading, and control variable coefficients are significant at the 5% level, indicating that the model are robust. Meanwhile, the test results showed that the model passed the Hausman test (**Table 3**).

We then constructed a threshold regression model based on Equation (1) to quantify the relationship between population density and the economic and social indicators and calculated the corresponding thresholds of population density by using the Stata software (Hansen, 2019). The number of thresholds is determined by the significance of threshold effect estimation results. We repeated the simulation of likelihood ratio 300 times using Bootstrap method to test the existence and rationality of the threshold effect.

The formula is:

$$\begin{aligned} Y = \alpha + \theta_1 X_{it} \cdot I(q_{it} \le \gamma_1) + \theta_2 X_{it} \cdot I(q_{it} > \gamma_2) + \cdots + \theta_{2n-1} X_{it} \cdot I(q_{it} \le \gamma_{2n-1}) + \theta_{2n} X_{it} \cdot I(q_{it} > \gamma_{2n}) \\ + \sum_{j=1}^{n} \beta_j X'_{itj} + \mu_i + \varepsilon_{it}, \text{where } \varepsilon_{it} \sim N(\mu = 0, \sigma^2 = \mathrm{I}) \end{aligned} \quad (7)$$

where q is the threshold variable, *γ* is the threshold value that needs to be estimated, *I* is the indicator function, when the condition in parentheses is met, its value is 1, otherwise it is 0, θ is the threshold coefficient, *n* is the number of thresholds, and the rest of the variables are the same as in Equation (1).

Table 3. Baseline regression results.

Variables	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Industrialization	0.56^{**}(81.89)	-	0.13^{**}(27.69)	0.33^{**}(63.03)	-	0.14^{**}(34.88)
Industrial upgrading	-	0.76^{**}(190.48)	0.65^{**}(116.93)	-	0.64^{**}(106.72)	0.51^{**}(77.53)
Marketization	-	-	-	0.26^{**}(0.26)	0.11^{**}(13.55)	0.09^{**}(12.85)
Technological progress	-	-	-	0.20^{**}(35.92)	0.01^{*}(2.21)	0.03^{**}(8.32)
Agricultural resources	-	-	-	-0.01^{**}(−5.28)	-0.01^{**}(−9.16)	-0.01^{**}(−8.59)
Medical level	-	-	-	0.17^{**}(27.69)	0.10^{**}(23.35)	0.10^{**}(25.22)
Infrastructure	-	-	-	0.05^{**}(27.98)	0.03^{**}(24.17)	0.03^{**}(30.29)
Environmental pollution	-	-	-	-0.13^{**}(−21.67)	-0.06^{**}(−13.31)	-0.08^{**}(−20.18)
Hausman test	H0: Difference in coefficients not systematic			Chi2(8) = 2204.35, Prob ≥ chi2 = 0.000		
N	3835	3835	3835	3835	3835	3835
R^2	0.64	0.90	0.92	0.86	0.93	0.95
F-statistic	6706.25^{**}	36281.46^{**}	22148.99^{**}	3431.46**	7213.70^{**}	8468.68^{**}

Significance: +, $p < 0.1$; *, $p < 0.05$; ** $p < 0.01$; ns, not significant.

To further examine the existence of different population thresholds in different regions of China, we divided the 295 cities into three major geographic regions according to the regional economic development level for the Eastern, Central, and Western regions (**Figure 1**).

3. Results

From the perspective of the whole city (i.e., not just the urban area), Model 1 and Model 2 in **Table 4** respectively present the regression coefficients of the impact of industrialization and industrial upgrading on regional economic level in different population density ranges under the consideration of other control variables. The coefficients of industrialization changed from 0.31 to 0.44, indicating that the regional economic level increased significantly with increasing industrialization when the population density exceeded 173 km^{-2} (**Table 4**). The impact of industrial upgrading on the level of regional economy decreased with increasing population density higher than 866 km^{-2} for the city as a whole. These results suggest that once cities grow beyond an optimal size (the threshold), further population growth decreases the contribution of emerging industries to economic development.

Table 4. Regression results of the threshold models based on data for all parts of a city combined for the 295 Chinese cities.

Variables	Model 1	Model 2
Threshold	173^{**}	866^{**}
Industrialization (0)	0.31^{**}(31.03)	-
Industrialization (1)	0.44^{**}(46.02)	-
Industrial upgrading (0)	-	0.65^{**}(103.33)
Industrial upgrading (1)	-	0.53^{**}(63.27)
Marketization	0.26^{**}(22.03)	0.12^{**}(15.21)
Technological progress	0.13^{**}(27.20)	0.37^{**}(10.50)
Agricultural resources	$–0.01^{**}$(–2.89)	$–0.00^{ns}$(–0.59)
Medical level	0.21^{**}(29.71)	0.14^{**}(29.02)
Infrastructure	0.03^{**}(6.49)	0.04^{**}(14.34)
Environmental pollution	$–0.28^{**}$(–29.70)	$–0.10^{**}$(–15.49)
N	3835	3835
R^2	0.85	0.93
F statistic	3136.31^{**}	8083.55^{**}

Significance: +, $p < 0.1$; *, $p < 0.05$; ** $p < 0.01$; ns, not significant.

We repeated our analysis for only the urban part of each city (**Table 5**). We found that the economic level increased significantly with increasing industrialization in the urban areas (the coefficients increased from 0.31 to 0.40). However, when the population density exceeded 15,131 km^{-2} in the urban part of Chinese cities, the impact of industrial upgrading on the level of regional economy increased (the coefficients increased from 0.61 to 0.65). What's more, the regression coefficients of technological progress on economic level increased increasing population density higher than this threshold. This suggested that an optimal population concentration in the urban areas could stimulate the development of emerging technologies and industries, ultimately promoting the evolution of a more advanced economy.

Table 5. Regression results of the threshold models based on data from only the urban areas of 295 Chinese cities.

Variables	Model 1	Model 2
Threshold	8327**	15131**
Industrialization (0)	0.31**(30.28)	-
Industrialization (1)	0.40**(50.52)	-
Industrial upgrading (0)	-	0.61**(97.55)
Industrial upgrading (1)	-	0.65**(90.27)
Marketization	0.28**(23.02)	0.13**(16.19)
Technological progress	0.13**(28.87)	0.24**(6.86)
Agricultural resources	–0.01**(–2.61)	–0.00^{ns}(–0.89)
Medical level	0.21**(28.64)	0.15**(29.74)
Infrastructure	0.04**(7.47)	0.04**(13.53)
Environmental pollution	–0.28**(–29.82)	–0.10**(–14.83)
N	3835	3835
R^2	0.84	0.93
F Statistic	3134.86**	7743.55**

Significance: +, $p < 0.1$; *, $p < 0.05$; ** $p < 0.01$; ns, not significant.

There are differences in population density thresholds among eastern, central, and western regions (**Table 6**). The results showed that the impact of industrialization in promoting the regional economic level increased gradually with increasing population density in eastern, central, and western regions, with population density thresholds of 473, 5, and 66 km^{-2}, respectively. However, when population density was higher than 967 km^{-2} in eastern region, the effect of industrialization on economic level decreased. The impact of industrial upgrading on economy decreased after the population density in eastern region exceeds 1050 km^{-2} and central region exceeds 33 km^{-2}. In central region, the impact of industrial upgrading on regional economy showed a trend of first increasing and then decreasing, with corresponding population density thresholds of 195 km^{-2} and 888 km^{-2}, respectively.

Table 6. Regression results of the threshold models based on data for all parts of a city for the 295 Chinese cities divided into three regions.

Variables	Eastern		Central		Western	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Threshold	473^{+} and 967*	1050**	5**	195* and 888*	81^{ns} and 66^{+}	33^{+}
Industrialization (0)	0.39**(20.47)	-	0.13**(5.95)	-	0.46**(23.14)	-
Industrialization (1)	0.54**(30.77)	-	0.35**(30.52)	-	0.30**(15.45)	-
Industrialization (2)	0.41**(21.76)	-	-	-	0.45**(22.63)	-
Industrial upgrading (0)	-	0.62**(56.70)	-	0.59**(51.54)	-	0.75**(40.21)
Industrial upgrading (1)	-	0.49**(43.16)	-	0.69**(54.65)	-	0.66**(55.86)

Table 6. (*Continued*).

Variables	Eastern		Central		Western	
	Model 1	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**
Industrial upgrading (2)	-	-	-	0.56^{**}(26.21)	-	-
Marketization	0.10^{**}(5.57)	0.08^{**}(6.61)	0.34^{**}(17.02)	0.15^{**}(11.36)	0.09^{**}(5.92)	0.04^{**}(4.00)
Technological progress	0.15^{**}(20.15)	0.06^{**}(10.94)	0.08^{**}(11.11)	0.00^{**}(0.13)	0.25^{**}(15.25)	0.04^{**}(3.61)
Agricultural resources	$–0.53^{**}$(–3.63)	$–0.28^{**}$(–2.70)	0.06^{**}(3.09)	0.04^{**}(3.38)	$–0.01^{**}$(–3.18)	$–0.00^{ns}$(–0.03)
Medical level	0.03^{**}(19.19)	0.02^{**}(15.10)	0.02^{**}(21.68)	0.16^{**}(21.98)	0.01^{**}(9.41)	0.01^{**}(14.95)
Infrastructure	0.04^{**}(4.41)	0.05^{**}(7.84)	0.04^{**}(6.32)	0.04^{**}(9.75)	0.04^{**}(4.63)	0.05^{**}(7.94)
Environmental pollution	$–0.29^{**}$(–17.99)	$–0.12^{**}$(–10.49)	$–0.28^{**}$(–20.96)	$–0.05^{**}$(–5.46)	$–0.28^{**}$(–15.86)	$–0.11^{**}$(–9.22)
N	1235	1235	1482	1482	1118	1118
R^2	0.88	0.95	0.82	0.91	0.77	0.87
F Statistic	1332.65^{**}	3145.23^{**}	1238.26^{**}	2788.95^{**}	660.49^{**}	2170.78^{**}

Significance: +, $p < 0.1$; *, $p < 0.05$; ** $p < 0.01$; ns, not significant.

4. Discussion

Humans are both consumers and producers. When the human population grows greater than the Earth's carrying capacity and greater than new technological and economic innovations can support, the unsustainable population begins causing real harm to both people and their environment (Cao et al., 2007; Crist et al., 2017; Ehrlich and Holdren, 1971; Gamelon et al., 2017; Gilles, 2019). However, it is precisely the pressure created by this harm that motivates us to move toward a more advanced economy through technological innovation and industrial evolution (Bettencourt et al., 2007; Klasen and Nestmann, 2006; Simon, 1980). The present results reveal the existence of trade-offs between population density and economic development, and are consistent with the results of Bekele et al. (2024) and Liu and Zhu (2023). They therefore confirm the existence of a threshold effect for population density in terms of its impact on economic development, especially in terms of the impact of industrial upgrading on a city's or region's economy (Forbes and Kirsch, 2011).

As industrialization and urbanization progress, and as the population density increases, the concentration of people in cities can increase their income and improve other economic characteristics. The increased population density in cities can not only provide opportunities for more effective division of labor, but also (and more importantly) can reduce the investment cost to construct urban infrastructure and develop new technologies and new industries (Berliant and Konishi, 2000; Ortman et al., 2015). Our findings are similar to those of Carillo (2024), Ni et al. (2023) and Prego (2021): An increased population can promote industrial development and technological innovation in urban areas. However, unlike this previous research, our results suggest the possibility of specific population thresholds beyond which the development response to population changes. Being able to identify these thresholds would support the development of more targeted recommendations for how to achieve advanced regional development. Urbanization can reduce the economic cost of evolution to a more advanced economy. However, neither natural nor economic values can increase forever; that is, there are limits to growth. We found that when the population density of the whole city exceeded 866 km^{-2}, it became increasingly likely (depending on the socioeconomic indicator and region of China) that the impact of industrial upgrading on the regional economy would begin to decrease.

The evolution of a civilization is influenced by multiple factors, and the population and the economy that sustains it are two key factors (Henriques et al., 2019; Nekola et al., 2013; Schäfer, 2001). Therefore, different regions may have different thresholds for the optimal urban population. For example, the thresholds differed among the three regions of China. Possibly due to its climate, its geography, and historical factors, China's less-developed and more remote western region, with a lower population, showed trends in the opposite directions as those for the eastern and central regions for the relationships between its population variables and economic development (Hui, 2006; Liu et al., 2011; Zhang et al., 2018). Our results are consistent with those of Fraumeni et al. (2019) and Li et al. (2021); that is, due to the differences in the background conditions of different regions, a given population density will have different effects on a region's economic development. However, the present study builds on these previous results by demonstrating the existence of population thresholds and of differences among cities and regions in these thresholds. It will therefore be necessary to study these cities and regions in more detail to learn what factors are responsible for these differences so that provincial and urban managers can seek solutions.

5. Conclusion

We confirmed our research hypothesis that it would be possible to detect a population density (a threshold) that can promote economic transition to a more advanced stage, and that this threshold density would vary among cities and regions based on differences in their historical, demographic, and industrial characteristics. In this paper, we found thresholds that represented a trade-off between population density and economic development (i.e., the impact of key factors on regional economy). Although the impact of industrial upgrading on the economy may decrease when population density exceeds a certain threshold, emerging industries may advance rapidly and create a new, more advanced economy in the urban areas. What's more, different regions may have different thresholds for the optimal urban population. These differences should guide the development of population and development policies.

In future research, it will be necessary to replicate the present results for other countries and to determine whether the economic efficiency permitted by large cities can improve non-economic aspects of a civilization, such as human health and happiness. It will also be important to determine what aspects of population density (e.g., the number of schools per unit area) create conditions suitable for economic advancement.

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SC and WL; project administration, SC; funding acquisition, SC. All authors have read and agreed to the published version of the manuscript.

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