Study on Whether Urban Shrinkage Inhibits the Upgrading of Urban Industrial Structure based on the Empirical Study of 287 Prefecture-level Cities in China

Xiaona Yu

Department of Financial Mathematics, Beijing University of Chemical Technology, Beijing, 100029, China

Abstract. As China's urbanization process enters the middle and later stages, the phenomenon of urban shrinkage is gradually spreading in some cities. It is of great significance for China's urban development to rationally view the phenomenon of urban shrinkage and clarify the effect and mechanism of urban shrinkage on the upgrading of urban industrial structure. In this paper, we analyze the spatial characteristics of urban shrinkage in China based on the census data and panel data of Chinese cities from 2010 to 2019. On the basis of sorting out the impact mechanism of urban shrinkage on industrial structure upgrading, we construct instrumental variables and intermediary effects models to empirically test the relationship between urban shrinkage and industrial structure upgrading. The results show that urban shrinkage has a significant restraining effect on the level of industrial structure sophistication, and the level of industrial structure sophistication will decrease by 0.126 when the degree of urban shrinkage increases by 1%, but the impact of urban shrinkage on the level of industrial structure rationalization is not obvious. The mechanism analysis shows that the industrial structure upgrading is inhibited by reducing the accumulation of human capital stock and reducing the ability of scientific and technological innovation. Further research shows that the negative effects of urban shrinkage on urban industrial structure are more prominent in those less developed areas, old industrial bases and resource-based cities. The findings provide new insights for Chinese cities to cope with the problem of shrinkage and achieve sustainable development.

Keywords: Urban Shrinkage; Upgrading of Industrial Structure; Human-capital; Scientific and Technological Innovation; Mediating Effect.

1. Introduction

Urban contraction is a time-honored objective law of urban development, and the concept was first introduced in 1988 to describe the reality of persistent population outflow from urban areas (Häuβermann & Siebel,1988). According to statistics, more than 40% of densely populated cities in Europe and north America experienced persistent population loss in 1970-2005[1]; Since the 1970s, both major and minor U.S. cities have also experienced declines in population size to varying degrees. Due to the advancement of globalization and the structural break in urban transformation, urban contraction is sweeping the world, with a quarter of the world's large cities experiencing different degrees of sustained contraction by the beginning of the 21st century, and about 600 cities losing more than one-tenth of their resident population [2]. As China's economic development enters into new normalization and economic development becomes slower, the traditional model of urban development has been impacted and the phenomenon of urban contraction has gradually spread in some cities.

Most of the existing studies are statistical measurements and descriptive analyses, and there is not much literature that thoroughly discusses the externalities of urban contraction on urban economic development. Therefore, this paper uses urban panel data to examine the macroeconomic effects induced by urban population contraction and to investigate the effects and mechanisms of urban contraction on the upgrading of urban industrial structure.

2. Theoretical Mechanism and Research Hypothesis

Through a combing analysis of the literature, this paper finds that urban contraction affects industrial structure upgrading mainly via three paths: demand structure effect, human capital effect, technological innovation effect.

2.1 Demand Structure Effect

Se Yan et al. (2018) pointed out that the change in demand structure has significantly promoting effect on the upgrade of industrial structure [4]. Urban contraction, mainly characterized by population loss, may lead to an alteration of the local demographic structure. At the same time, as younger and healthier labor force tends to flow away more easily [3], it further exacerbates the degree of population aging in contracting cities, which leads to profound changes in the demand structure of contracting cities. From the resident consumption level, older consumers are more inclined to demand for healthcare and tourism products [10], which are high-quality consumption that will promote the quality upgrade of the consumption structure. From the enterprise level, the aging population leads to the upgrading of the level of consumption demand, and due to the profit-seeking of capital, a growing number of production sectors will increase the proportion of service output. As a result, the optimization of the demand structure will lead the elements to continuously gather in the service industry and eventually promote the upgrading of the industrial structure. This leads to the hypothesis:

Hypothesis 1: The optimization of demand structure arising from urban shrinkage will force the upgrading of industrial structure.

2.2 Human Capital Effect

Hasumann (2007) pointed out that human capital is an essential foundation for industrial structural upgrading and a core determinant of economic growth [5]. The core problem of urban contraction is population loss, which not only reduces the local labor supply but also weakens human capital accumulation [6], which has a dampening effect on industrial structural upgrading. First, shrinking cities confront labor shortage, which reduces the productivity of labor-intensive industries significantly, while the remaining elderly labor force cannot shift to the technological and knowledge-intensive industries. This degrades the overall labor efficiency in cities and stagnates industrial structural upgrading [10]. Moreover, high quality human capital is more likely to flow out under the siphoning effect of large cities, and the migration barriers on the basis of the household registration system reinforce this selection outcome [7]. Human capital loss caused by population loss has a direct inhibitory effect on the upgrading of urban industrial structure, which leads to the following hypothesis:

Hypothesis 2: Human capital loss due to urban contraction will inhibit industrial structural upgrading.

2.3 Technological Innovation Effect

Technological innovation is an important driver of industrial structure upgrading [8], on the one hand, technology can directly promote the improvement of production efficiency, on the other hand, Baumol (1997) stated that technological progress will also affect industrial structure by leading to changes in the relative prices of products [9]. First, human capital is a prerequisite for innovation, and the loss of labor force accompanied by a decrease in high-quality human capital will directly inhibit the technological innovation capacity of cities; Second, technological innovation is a complex mental work, which is affected by many factors such as strength, energy, and cognition[10], and the creativity of aging workers is weakening; at the same time, the increase of aging population ratio enlarges the pension expenditure, this will occupy part of fiscal expenditure and social resources[11], which is not conducive to enhancing the technological innovation capacity . Based on the above analysis, the third hypothesis in this paper is given:

Hypothesis 3: The decline of technological innovation capacity due to urban contraction will inhibit industrial structure upgrading.

3. Model Construction, Variable Selection and Data Description

3.1 Model Construction

3.1.1. Regression Model

This paper aims to explore the effect of urban contraction on industrial structure upgrading, whose core idea is to analyze the effect of urban contraction by comparing how much the industrial structure has altered with the change in the degree of urban contraction. Based on the above analysis, this paper constructs the following model.

$$SH_{it} = \alpha_0 + \alpha_1 Shrink_{it} + \delta Z_{it} + \lambda_i + \nu_t + \varepsilon_{it} \quad (1)$$

Among which, SH_{it} denotes the prefecture-level city-i's industrial structure level in year-t, specifically including two indicators of sophistication and rationalization; The core explanatory variable $Shrink_{it}$ denotes the contraction degree of city-i in year-t, its parameter α_1 represents the effect of urban contraction on the industrial structure; λ_i is city fixed effect; ν_t is year fixed effect; Z_{it} is control variable, ε_{it} is disturbance.

3.1.2. Exploration of Endogeneity

Overall, there are two possible endogeneity problems in this paper: one is the omission of variables, since the impact of urban contraction on urban economy is comprehensive, the influence mechanism is more complex, and there are multiple unobservable factors affecting industrial structure upgrading, hence the probing of the relationship between the two may suffer from a serious omission of variables. Second is the two-way cause and effect, on the one hand, the shift of demand structure, the loss of human capital and the weakening of technological innovation capacity caused by urban contraction will be detrimental to the upgrading of industrial structure; on the other hand, the adjustment of industrial structure will further lead to the loss of urban population and intensify the contraction.

In order to try to overcome the estimation bias caused by the endogeneity problem, this paper refers to previous studies [3], selects the natural population growth rate in municipal areas as an instrumental variable, and uses two-stage least squares (2SLS) to identify the influence of urban contraction on industrial structure upgrading. In order to verify the validity of the instrumental variable, a under identification test and a weak identification test are also conducted below.

3.1.3. Mediating Effect Model

To test the mechanism by which urban contraction affects industrial structure upgrading, this paper constructs a model below, drawing on the research method of Zhonglin Wen [12].

$$SH_{it} = \alpha_0 + \alpha_1 Shrink_{it} + \delta Z_{it} + \lambda_i + \nu_t + \varepsilon_{it} \quad (2)$$

$$MV_{it} = \beta_0 + \beta_1 Shrink_{it} + \delta' Z_{it} + \lambda_i + \nu_t + \varepsilon_{it} \quad (3)$$

$$SH_{it} = \gamma_0 + \gamma_1 Shrink_{it} + \varphi_1 MV_{it} + \delta' Z_{it} + \lambda_i + \nu_t + \varepsilon_{it} \quad (4)$$

Among which, MV_{it} denotes mediating variables, specifically demand structure DS, human capital HC, and science and technology innovation ST.

3.2 Variable Selection

3.2.1. Explained Variable

In this paper, the industrial structure sophistication indicator SH and the rationalization indicator SR are selected as proxy variables for industrial structure upgrading. Borrowing from Wei Liu et al. (2008) and Yonghui Han et al. (2017), the product of the output share and labor productivity of each industrial sector is applied to measure SH [13], and the industrial structure deviation adjusted by output weighting is used to represent SR [14].

3.2.2. Core Explanatory Variable

This paper refers to Murdoch (2018), which uses the negative logarithm of relative population change to measure the degree of urban contraction [15].

3.2.3. Control Variables and Mediating Variables

Table 1. Variable description

Variable Type	Variable Name	Variable Definition
Control Variable	PGDP	gross regional product per capita
	SG	government public finance expenditure to regional GDP
	FDI	actual amount of foreign investment used to regional GDP
	UR	urban non-farm population to total resident population
	INF	urban road area per capita
Intermediary Variable	DS	residents medical consumption per capita to total consumption
	HC	number of college students in the city
	ST	S&T expenditure to total public fiscal expenditure

3.3 Data Description

In this paper, the sample is limited to the panel data of 287 prefecture-level cities in China from 2010-2019, where all price data involved are deflated accordingly and missing values are filled in using regression interpolation.

4. Empirical Result

4.1 Instrumental Variable Test

Ensuring the validity of the instrumental variables is an inevitable prerequisite. In this section, the under-identification test and the weak identification test is conducted for the selected instrumental variables, and the results are shown below.

Table 2. First stage regression and instrumental variables test

Explanatory Variable	Shrink
Tool Variable	-0.067***
	(-0.001)
Control Variable	YES
Fixed Effect	YES
Sample Size	2870
Kleibergen-Paap rk LM	15.020**
Cragg-Donald Wald F	197.300**

The results indicate that the instrumental variable, natural population growth rate, satisfies the rank condition and is not a weak instrumental variable.

4.2 Regression Result

In this section, the impact effect of urban contraction is estimated using fixed-effects model and 2SLS, respectively. First, the results of the fixed-effects model are shown in columns (1) and (2) of the table below, where the effect of urban contraction on industrial structure sophistication is negative (-0.144), but the effect on rationalization is not significant (-0.049). Nevertheless, the results obtained above are not reliable due to the possible bidirectional causality between shrinkage and structure upgrading with the problem of severe omission of variables.

To mitigate the endogeneity caused by omitted variables and two-way causality, instrumental variables are selected and a series of estimations are performed using 2SLS. Corresponding estimation results are in columns (3) and (4), where each 1% increase in urban shrinkage is followed by a 0.126 decrease in industrial structure sophistication level, but the regression coefficients remain insignificant at the rationalization level. Analysis of the control variables shows that the economic development level is significantly positive (0.001) at the 1% level, which further confirms that urban economic development will promote the upgrading of local industrial structure; government size is significantly positive(0.006) at the 1% level, probably because the larger the government is, the more efficient the regulation of resource allocation is, which can promote the upgrading effectively; urbanization rate is significantly positive(0.003) at the 1% level, which is consistent with the results of many literatures; infrastructure is significant(0.004) at the 1% level. In contrast, the effect of the level of external opening is negative, but not statistically significant overall.

Table 3. Regression result

Variable	SH	SR	SH	SR
	(1)	(2)	(3)	(4)
Shrink	-0.144***	-0.049	-0.126**	-0.055
	(0.048)	(0.040)	(0.051)	(0.042)
PGDP	0.010***	0.001	0.010***	0.001
	(0.003)	(0.001)	(0.003)	(0.001)
SG	0.006***	0.001***	0.006***	0.001***
	(0.001)	(0.000)	(0.001)	(0.000)
UR	0.003***	0.001***	0.003***	0.001***
	(0.001)	(0.000)	(0.001)	(0.000)
FDI	-0.001	0.003***	-0.001	0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
INF	0.004***	0.001***	0.004***	0.001***
	(0.001)	(0.000)	(0.001)	(0.000)
Method	FE	FE	2SLS	2SLS
Fixed Effect	YES	YES	YES	YES
N	2870	2870	2870	2870
R^2	0.446	0.080	0.446	0.079

(Note: Values in brackets denote robust standard errors for clustering to the city, same below)

4.3 Intermediation Effect Test

Previously, this paper identifies the inhibition effect of urban contraction on the industrial structure sophistication. The more interesting question to investigate, however, is the mechanism of inhibition, and here, the mediating effect models (2)-(4) above are tested. The results are shown in Table 4, where column (1) is the regression estimated using 2SLS, corresponding to equation (2) above; columns (2), (4), and (6) serve to test the effect of urban contraction on each mediating variable, corresponding to equation (3); and columns (3), (5), and (7) are for testing the existence of mediating effects, corresponding to equation (4).

The result of stepwise regression suggests that urban shrinkage will further inhibit the industrial structure by lowering the human capital level, science and technology innovation (STI) assumes part of the mediating effect at the same time, and demand structure does not mediate the effect of urban shrinkage on industrial structure upgrading.

In addition, Sobel test is conducted in this paper, which shows that human capital and STI play mediating effects of 11.7% and 5.5%, respectively, while demand structure has no significant mediating effect. This finding is consistent with the conclusion of the stepwise regression above.

Table 4. Intermediation effect test

Variable	SH	HC	SH	ST	SH	DS	SH
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
HC			0.003***				
			(0.001)				
ST					0.003*		
					(0.002)		
DS							0.009***
							(0.001)
Shrink	-0.126**	-5.813**	-0.107**	-2.374**	-0.118**	0.806	-0.133***
	(0.051)	(2.322)	(0.052)	(1.144)	(0.051)	(0.205)	(0.047)
PGDP	0.010***	0.274***	0.009***	0.100***	0.010***	0.0850***	0.009***
	(0.003)	(0.095)	(0.003)	(0.025)	(0.003)	(0.029)	(0.003)
SG	0.006***	0.021	0.006***	-0.012***	0.007***	0.056***	0.006***
	(0.001)	(0.014)	(0.001)	(0.004)	(0.001)	(0.012)	(0.001)
UR	0.003***	0.072***	0.003***	0.015**	0.003***	0.012	0.003***
	(0.001)	(0.028)	(0.001)	(0.006)	(0.001)	(0.008)	(0.001)
FDI	-0.001	0.051	0.001	0.062***	0.001	-0.020	-0.001
	(0.001)	(0.051)	(0.001)	(0.021)	(0.001)	(0.032)	(0.001)
INF	0.004***	0.081***	0.004***	0.016**	0.004***	0.0240**	0.004***
	(0.001)	(0.024)	(0.001)	(0.007)	(0.001)	(0.012)	(0.001)
Fixed Effect	YES	YES	YES	YES	YES	YES	YES
N	2870	2870	2870	2870	2870	2870	2870
R^2	0.446	0.149	0.455	0.094	0.447	0.066	0.473

Table 5. Result of Sobel test

	Sobel Quantity	Percentage of Intermediary Effect
HC	-0.017***	0.117
	(0.004)	
ST	-0.008**	0.055
	(0.003)	
DS	0.008	-0.056
	(0.005)	

4.4 Robustness Test

4.4.1. Substitution of Explanatory Variable

In this part, this paper refers to Yuan Hang's (2018) research method and uses the weighted score TS of the share of three industries to replace the original indicator at the sophistication level, and the Thiel index TL to replace the original indicator at the rationalization index [16].

4.4.2. Deletion of Special Samples

Given that the industrial upgrading in some provinces is much faster or slower than the average level, which may affect the estimation results significantly. Therefore, this paper removes the provinces with abnormal industrial structure development levels, i.e., Beijing, Shanghai and Xinjiang, based on the box line diagram, and conducts the estimation again.

Table 6 shows the robustness tests of the regression part, columns (1)(2) and (3)(4) are the results of fixed-effects model and 2SLS, respectively, showing that the regression results in this paper remain robust after removing the special city sample or replacing the industrial structure indicators.

Table 6. Robustness Test-Regression Section

Model	Variable	SH	SR	SH	SR
		(1)	(2)	(3)	(4)
Regression Model	Shrink	-0.144***	-0.049	-0.126**	-0.055
		(0.048)	(0.040)	(0.051)	(0.042)
Deletion of Special Samples	Shrink	-0.147***	-0.046	-0.126**	-0052
		(0.049)	(0.041)	(0.052)	(0.042)
Substitution of Explanatory Variable	Shrink	-0.119***	2.474	-0.101**	2.656
		(0.045)	(2.109)	(0.050)	(2.182)

Tables 7 and 8 report intermediation effect test results after removing the special city samples or replacing the industrial structure indicators, respectively. The test results of the intermediation effect are also consistent with the previous paper, indicating that the findings are robust.

Table 7. Robustness Test - Intermediation Effect 1

Model	Variable	*SH*	*HC*	*SH*	*ST*	*SH*	*DS*	*SH*
		(1)	(2)	(3)	(4)	(5)	(6)	(7)
Delete Special Samples	*HC*			0.003***				
				(0.001)				
	ST					0.003*		
						(0.002)		
	DS							0.009***
								(0.001)
	Shrink	-0.126**	-5.920**	-0.107**	-2.376**	-0.119**	0.347	-0.129***
		(0.052)	(2.469)	(0.053)	(1.197)	(0.053)	(0.629)	(0.049)

Table 8. Robustness Test - Intermediation Effect 2

Model	Variable	TS	HC	TS	ST	TS	DS	TS
		(1)	(2)	(3)	(4)	(5)	(6)	(7)
Replace Explanatory Variable	HC			0.003***				
				(0.001)				
	ST					0.002*		
						(0.001)		
	DS							0.008***
								(0.001)
	Shrink	-0.101**	-5.813**	-0.082**	-2.374**	-0.096*	0.806	-0.107**
		(0.050)	(2.322)	(0.042)	(1.144)	(0.051)	(0.804)	(0.046)

4.5 Heterogeneity Analysis

On average, urban shrinkage has a significant inhibitory effect on urban industrial structure upgrading, whereas the effect may vary in view of the different economic development status, resource endowment conditions and industrial structure types of diverse cities. This paper will explore the heterogeneous effects of urban shrinkage in the above three aspects separately.

Firstly, this paper divides the 287 prefecture-level cities into eastern economically developed cities and central and western economically less developed cities [16]. The results in columns (1) and (2)

of Table 8 reveal that the coefficient of urban contraction is negative regardless of economic development, but the contraction coefficient of developed cities is not significantly.

Secondly, 287 cities are classified as resource-based cities and old industrial base cities, respectively, with reference to the "National Sustainable Development Plan for Resource-based Cities (2013-2020)" and Qingyun Wang's (2007) study [17]. As shown in columns (3)(4) and (5)(6) of Table 9, the coefficient estimates for resource-based cities are smaller than those for non-resource-based cities, those for old industrial bases are smaller than those for non-old industrial bases, and all of them are significantly negative.

Table 9. Heterogeneity Test

Variable	Developed	Less Developed	Resource	Non-Resource	Industrial Base	Non-base
	(1)	(2)	(3)	(4)	(5)	(6)
Shrink	-0.041	-0.140**	-0.174***	-0.049**	-0.193***	-0.111*
	(0.072)	(0.063)	(0.044)	(0.027)	(0.094)	(0.060)
Method	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS
Fixed Effect	YES	YES	YES	YES	YES	YES
N	2870	2870	2870	2870	2870	2870
R^2	0.5769	0.422	0.375	0.509	0.496	0.438

4.6 Countermeasure

By empirical analysis, this part uncovers that the impact of shrinkage on industrial structure is mainly expressed in the inhibition of structure upgrading, mainly acting via the two pathways of human capital and STI, the policy implications are as follows.

- Since population migration is the main reason for the shrinkage of some cities, causing the loss of human capital, which has a negative impact on both labor-intensive and technology-intensive industries in the cities. Therefore, shrinking cities should pay more attention to human capital accumulation, on the one hand, they should enhance the investment in local education to cultivate high quality talents for the local area; on the other hand, they should boost the construction of high-tech zones to create more employment opportunities.
- STI is the inexhaustible driving force of urban development and a powerful motive force of shrinking city rejuvenation. Enterprises are the main subject of promoting technological innovation, and government departments should refine the policy support system for new economic development, stimulating enterprises to increase investment in research and innovation.
- Some cities should face up to the shrinkage phenomenon, change the concept of urban development, avoid blind land development and disorderly urban expansion, and advocate smart urban shrinkage.

5. Conclusion

On the basis of panel data of 287 prefecture-level cities in China from 2010-2019, this paper constructs a fixed-effect model to explore the effect of urban contraction on urban industrial upgrading using the instrumental variable of natural growth rate of population. It is found that urban shrinkage has a significant dampening effect on the level of industrial structure sophistication, and the regression results of the instrumental variables show that a 1% increase in urban shrinkage is associated with a decrease of about 0.126 in the sophistication level, which remains robust after replacing the explanatory variable and deleting the special samples. Furthermore, by mechanism analysis and intermediary effect test, this paper uncovers that the impact of shrinkage on industrial structure is mainly expressed in the inhibition of structure upgrading, mainly acting via the two pathways of human capital and STI.

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