Science in China Series D: Earth Sciences

Springer

Regional differences and determinants of built-up area expansion in China

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Based on remote sensing data on land use provided by the Chinese Academy of Sciences and socio-economic data collected by the authors, this paper analyzes the trends and regional differences in built-up area (BUA) expansion in China from the late 1980s to 2000, and empirically estimates the major determinants of BUA expansion in different regions in 1996—2000. In 1989—2000, although China's overall BUA expansion accelerated, the trends differed significantly among regions. BUA expansion in the central and western regions accelerated significantly, but it slowed down considerably in the eastern region. The estimation results from our econometric analysis reveal that BUA expansion in the eastern region reached a period when economic growth had no further significant impact on per capita BUA, the land utilization in this region has become more intensive with further expansion of the economy. In the central and western regions, the BUA has expanded remarkably due to the relatively more flexible land development policies and the relatively cheap land prices. Therefore, as the economy continues to grow rapidly, policies relating to BUA expansion and cultivated land reductions may face more serious challenges in the central and western regions.

built-up area, land use, regional difference, determinants, China

The expansion of built-up area (BUA) has become an increasingly hot issue in land use in China. The nation's huge population and scarce arable land per capita ensure that China will face increasing conflict between BUA expansion and cultivated land protection. Many studies have pointed out that because China's cities are commonly surrounded by lands with rich soil and high productivity, the expansion of cities will inevitably provoke the loss of quality cultivated land, and consequently may threaten national food security[1−3]. Therefore, the expansion of BUA, especially through urban land use, has become a focal issue for governments and academics[4,5].

The expansion of BUA is an unavoidable result of economic development. Since the implementation of the reform and opening policies, and with the acceleration of industrialization and urbanization and continuous population growth, land utilization in China, especially BUA, has reflected the demands of social and economic development to a certain extent[6]. Ongoing processes of industrialization and urbanization will surely bring about the transfer of production input factors and resources from agricultural to non-agricultural sectors, which of course will include agricultural land[7]. Further development of the society and economy and the acceleration of industrialization and urbanization will perpetuate current trends of conversion of cultivated land into BUA.

Received December 21, 2006; accepted June 13, 2007
doi: 10.1007/s11430-007-0117-6
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Sponsored by the Knowledge Innovation Project of the Chinese Academy of Sciences (Grant No.KSCX2-YW-N-039) and the Advantageous Group Project of the National Natural Science Foundation Commission (Grant No.70021001)

Economic growth clearly has a major effect on the expansion of BUA, but opinions differ significantly about the magnitude of its effect. Tan et al.[8] have analyzed the effects of population and economic growth and urban environmental improvement on the expansion of urban land, and have concluded that economic growth is the most significant and fundamental driving factor. A study of 145 cities in the 1990s has demonstrated that the growth of wages of employees best explains regional differences in the expansion of urban BUA[3]. In a case study of Ma'anshan Prefecture, Chen et al.[6] have econometrically estimated that per capita GDP has a positive and significant effect on the extent of urban BUA, with an elasticity coefficient of 0.26; if the annual per capita GDP grows at 8%, the BUA will have expanded by 100% after about 20 years. Zhu's[9] research on 14 provinces in eastern China also has shown that economic growth has a significantly positive effect on BUA, although with an elasticity coefficient of only around 0.002.

Differences in the times and places studied may account for the differing conclusions. First, each study generally has dealt with distinct regions, such as urban expansion in certain regions[6], large and medium-sized cities only[3], eastern regions with rapid economic growth[9], or less-developed western regions[10]. Secondly, they focused on different scopes of BUA. Some have examined only city core areas[3], whereas others have encompassed both city core areas and the counties around these cities[9]. Last but not least, the differing time periods covered in their analyses might explain their differing results. For example, some have concentrated on the expansion of BUA in the period since the mid-1980s[8], and some on the whole 1990s[3] or the period from the mid-1990s to the year 2000[9].

Many previous studies in this area in China have been descriptive; no quantitative BUA analysis has simultaneously taken into account different periods and different regions nationwide. Clearly, more extensive research is needed to better analyze the relation between economic development and BUA, and to understand the regional differences in the expansion of BUA in all of China. Therefore, this paper will analyze the trends and regional differences in BUA expansion in China over different periods, to quantitatively examine the effects of economic growth and other factors on the expansion of BUA in different regions, and to provide empirically based evidence for better policy advice on land-use planning.

1 Data description and processing

This study encompasses urban and rural BUA, as well as transportation, industrial and mining lands that are spatially separated from urban and rural BUAs. BUA data are from the land-use database of the Resources and Environment Scientific Data Center, Chinese Academy of Sciences, and were interpreted from digital satellite images of the US Landsat TM/ETM with a spatial resolution of 30 m×30 m[11]. We considered three periods: (1) the late 1980s, mainly including data from 1988 to 1989 (henceforth referred to as 1989 data for brevity); (2) the mid-1990s, including data from 1995 to 1996 (henceforth, 1996); and (3) the end of the 20th century, including data from 1999 to 2000 (henceforth, 2000). We used geographic information system (GIS) technologies to aggregate the stable-form, spatially adjacent patches of BUA to the county level, the basic unit of analysis in this study. For cities at the prefecture or province level, we use the city instead of the county as the level of analysis. To control the effects of counties (cities) of different areas and populations, and to facilitate comparisons among different regions, we used per capita BUA in our empirical analysis.

The data on GDP and population derive from official statistics. GDP by county (city) in 1996 are from the *Statistical Yearbooks* of the respective provinces[12]; similar data in 2000 are from the *Social and Economic Statistical Yearbook of China's Counties* (*Cities*)[13]. The data on population are taken from the *Population Statistics of China's Counties* (*Cities*)[14].

In order to better analyze the impacts of economic growth on BUA, this paper also tries to control all time-varying variables. Such measures can include land-use-related policies that vary among different periods. However, as these variables can seldom be quantified and their trends are highly related to time, we simply used a set of year dummy variables to control and represent their effects on BUA over time.

Our geophysical factors include geographical locations, average slopes, elevations and air temperatures of each county (city). Geographical locations comprise 2 variables, the distance of the county (city) center to the nearest provincial capital and the distance to the nearest port city; these 2 variables were calculated from the 1∶250000 topographic maps published by China's State

Bureau of Surveying and Mapping. The slopes and elevations of the counties (cities) were extracted from the national digital elevation model (DEM). Average air temperatures were based on the data managed by climate stations affiliated with the China Meteorological Administration. Using the map Algeria in GIS, we first interpolated the site-based air temperature records onto surface data with a spatial resolution of 1 km×1 km. We then aggregated the cell-based information on surface air temperatures over the administrative units of counties (cities) using GIS spatial analysis techniques[15].

Data on the GDP of most counties (cities) of the Tibet Autonomous Region and on the GDP of certain provinces detailed to the county (city) level in the late 1980s were not available, so our empirical analysis was focused on the expansion of BUA in the 30 provinces, excluding the Tibet Autonomous Region, Hong Kong, Taiwan and Macao. The total valid sample size (counties or cities) was 2246 for each year.

2 The expansion of BUA in China

For China as a whole, the average annual growth of BUA has accelerated with rapid economic growth. In 1989, the total BUA in the sample counties (cities) was 156381 km^2; it increased to 165885 km^2 in 1996 and to 173070 km^2 in 2000 (Table 1). Thus the average annual growth of BUA rose from 0.85% in 1989—1996 to 1.07% in 1996—2000.

For different regions, BUA expansion rates differed significantly. Firstly, during the whole period covered by this study, the highest BUA expansion rate was found in the eastern region, where annual growth reached 1.32% in 1989—2000. This exceeded the national average of 0.93% and growth in the western region (1.02%) and the central region (0.48%) (Table 1). Secondly, although the eastern region had the highest expansion rate in 1989—2000, in other periods, its annual BUA growth rates had declined significantly, from 1.49% in 1989—1996 to 1.03% in 1996—2000. Thirdly, annual growth rates of BUA in the western and central regions have climbed. Moreover, the annual growth rate of BUA in the western region in 1996—2000 reached 2.11% (Table 1), exceeding that of the eastern region in the same period.

What are the causes of the increasing rate of BUA expansion nationwide and of the significant regional differences? Why did rates in the central and western regions rise significantly while in the eastern region rates declined? In the rest of this paper, we will try to answer these questions using both simple descriptive and in-depth econometric analyses. Previous studies have indicated that economic growth, as well as regional spatial variations, historical development legacy and policy changes have had important effects on BUA expansion in different regions. Our analysis will focus especially on the effects of economic growth on per capita BUA.

Table 1 Regional expansion of BUA in China in 1989—2000

	Western a) region	Central b) region	Eastern c) region	Whole China
BUA (km^2)				
1989	21212	66912	68257	156381
1996	21818	68388	75678	165885
2000	23718	70506	78846	173070
Annual growth rate (%)				
1989—1996	0. 40	0.31	1.49	0.85
1996—2000	2.11	0.77	1.03	1.07
1989—2000	1.02	0.48	1.32	0.93

Data source: Remote sensing land-use data for 2246 sample counties (cities). a) Western region includes Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Ningxia, Qinghai and Xinjiang. b) Central region includes Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei and Hunan. c) Eastern region includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan.

3 Regional differences in per capita BUA

To better compare the relation between BUA and economic growth among regions and over different periods in the same region, we chose two indicators: per capita BUA and per capita GDP. Based on their per capita GDP in 1996, all the counties (cities) were divided into 4 groups with per capita GDP of 0—2500 RMB Yuan, 2500—5000 RMB Yuan, 5000—10000 RMB Yuan and more than 10000 RMB Yuan. We examined the changes in per capita BUA in 1996—2000 at national and regional levels as well as by income group. Table 2 illustrates the following interesting patterns of per capita BUA change with income.

(1) For the country as a whole, economic development appears to promote the expansion of per capita BUA until income reaches a certain level. Table 2 shows that the economic growth of 1996—2000 was accompanied by a per capita BUA increase from 151 m^2 to 153 m^2. This positive relationship between economic development and per capita BUA was also generally found in

comparisons of the per capita BUA across income groups in either 1996 or 2000. In 1996, where the per capita GDP was less than 2500 RMB Yuan, the per capita BUA was only 115 m^2, but where the per capita GDP reached 5000－10000 RMB Yuan, the per capita BUA reached 184 m^2; this relationship is what we might expect. However, interestingly, in the counties (cities) with per capita GDP exceeding 10000 RMB Yuan, the per capita BUA was no more than that in the counties (cities) with a per capita GDP of 5000－10000 RMB Yuan. This demonstrates that factors beyond economic growth (e.g., local policies in land control or land prices) might also have had significant effects on BUA expansion.

Table 2 Per capita GDP and per capita BUA in 1996－2000

Region[a)]	Per capita GDP (RMB Yuan)[b)]	Sample size	Per capita BUA (m^2/person)	
			1996	2000
Western		800	94	99
	0－2500	487	63	66
	2500－5000	232	127	130
	5000－10000	64	160	185
	>10000	17	285	325
Central		788	188	186
	0－2500	332	176	177
	2500－5000	331	201	200
	5000－10000	102	198	184
	>10000	23	131	121
Eastern		658	176	178
	0－2500	67	194	191
	2500－5000	288	165	167
	5000－10000	208	185	188
	>10000	95	177	179
Whole China		2246	151	153
	0－2500	886	115	117
	2500－5000	851	169	170
	5000－10000	374	184	187
	>10000	135	183	187

a) Regional definitions are the same as in Table 1. b) GDP is in constant 2000 prices.

(2) A comparison across regions confirmed that other factors beyond economic growth may also have had significant effects on per capita BUA. In 1996, the per capita BUA in the western, central and eastern regions were 94 m^2, 188 m^2, and 176 m^2, meaning that the eastern and central regions each had about twice the per capita BUA of the western region; similar differences were evident in 2000. The level of economic development can explain some, but not all, of these differences. For example, in both 1996 and 2000, per capita BUA of the much more developed eastern region was less than that of the central region. We also found, by comparing the per capita BUA of different regions for the same income groups large differences among regions, further illustrating the importance of factors other than economic growth.

(3) Different regions displayed different relations between income levels and per capita BUA. In the western region, the counties (cities) with higher incomes also had higher per capita BUA (Figure 1). However, this kind of positive correlation was not obvious in the eastern and central regions, suggesting that differences in local policies, scarcity of land resources (i.e., high land prices) and geographical locations may also have significantly affected the expansion of BUA. After the economy reached a certain level, the per capita BUA began to decrease, perhaps because of resource availability and the relatively high land prices in the developed regions.

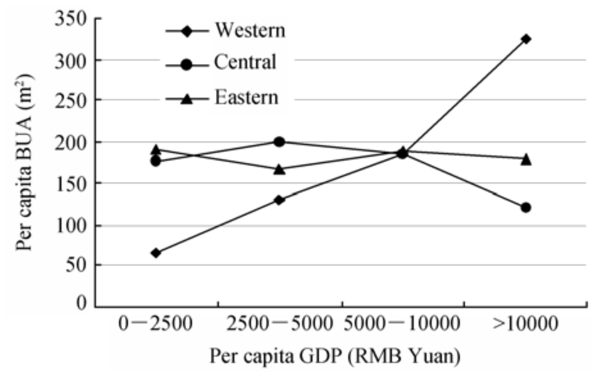

Figure 1 Relation between per capita GDP and per capita BUA in 2000.

4 Empirical model of per capita BUA

Previous studies and the discussion above suggest two categories of factors affecting per capita BUA: those factors that vary with time (e.g., economic growth and other non-economic growth factors), and those that do not vary with time or only vary across spaces (e.g., geophysical variables, historical situations, or other regionally fixed factors). We adopted the following general form for a per capita BUA model for 1996 and 2000:

Per capita BUA = *f* (factors with time variation; factors without time variation)
= *f* (economic development and other factors with time variation;
geophysical factors, historical legacy and other regional fixed factors).

All data were computed at the county (or city) level. Explanatory variables are defined as:

Economic development was measured by per capita

GDP. To avoid a possible endogeneity problem, we used the per capita GDP of the previous year. To estimate how the impact of per capita GDP on the per capita BUA might differ among regions, we created interaction terms by multiplying per capita GDP by 3 regional dummy variables.

Some other time-varying factors, such as policy factors, were difficult to quantify. In our empirical analysis, we set up a year dummy variable (1 for the year 2000, zero otherwise). Because the effects of time-varying factors on per capita BUA might differ among regions, we created a set of variables by generating interaction variables from the year dummy variable and regional dummy variables. If the estimated coefficients of these interaction variables differed significantly among regions, we could conclude that these time-varying factors had different effects on the per capita BUA of different regions.

Geophysical factors included slope, distances from the nearest port and provincial capital, elevation, and average air temperature, as discussed in section 2. Any of these factors might significantly contribute to regional differences in the per capita BUA and therefore were control variables in this study.

We selected per capita BUA in 1989 as a control variable to control and measure the impacts of the historical legacy of BUA development on BUA expansion. Given that no data were available on the per capita BUA by county (city) prior to 1996, we used 1989 as a base year and included the level of BUA in 1989 in our econometric model.

We also included regional dummy variables to control the effects of unobserved and regionally characterized factors. The regional dummy variables were specified in two ways: by introducing 2 regional dummies to identify the differences among western, central and eastern regions, with the western region as the basis for comparison; and by including all county (city) dummy variables in the model.

All variables in the model with continuous values (see Table 3) were expressed in logarithmic form. The Appendix displays means and standard errors for each variable.

5 Estimated results of the model and discussions

We applied two different sets of dummy variables to controlling either regional fixed effects, i.e., 2 regional dummies, or dummies for each of 2245 counties (cities), and estimated two sets of results for the econometric model discussed in section 4. The results under specification (1) of Table 3 correspond to the regional dummy model, and the results under specification (2) are in accordance with the county (city) dummy model. Since the county dummy variables control all fixed effects at the county level, the model under specification (2) excludes all individual variables that are time-invariant. We found that these models fit well and that most of the estimated coefficients were statistically significant. The variable for the historical level of per capita BUA has a significant positive effect on per capita BUA in 1996—2000, which indicates that the variable has controlled well the regional variations in per capita BUA, due to their base-level difference (Table 3, column 1). In the following discussions, we will focus on the major results drawn from our econometric estimates of the determinants of per capita BUA.

Effects of economic development. Economic development had a significant effect on the expansion of per capita BUA; however, the effect was not as strong as the previous literature has often suggested. Estimation results from specifications (1) and (2) both revealed that economic growth, in general, has increased per capita BUA. But neither the results of specification (1) for the central region nor those of specification (2) for the eastern region were statistically significant. We favor the results from specification (2), because specification (1) does not fully control spatial variations among counties (cities).

According to the estimation results of specification (2), in the western region, the coefficient of per capita GDP or the elasticity of per capita BUA with respect to per capita GDP was 0.094. This implies that if the per capita GDP increased by 8% annually, per capita GDP would double in 9 years, and per capita BUA would increase by about 9.4%. If the per capita GDP continued to grow at this rate for 20 years, per capita BUA would increase by about 35%. If we applied this estimated parameter for decomposition analysis in the western region, we would find that of a total increase of 5.69% in per capita BUA in 1996—2000, economic growth would have accounted for 2.91%. This is consistent with the trend of noticeable growth of per capita BUA accompanied by the growth of per capita GDP in the western region, as described in section 3. In the western region, economic growth (especially the growth of industry and service sectors) not only was accompanied by a large expansion of infrastructure and associated service facilities, but also was related to the fact that the region had relatively low urbanization and a relatively extensive (or not intensive) use of land.

In the central region, where economic growth also significantly and positively affected per capita BUA, the estimated coefficient was as high as 0.097 (see Table 3, column 2). This means that after controlling other factors, if per capita GDP increased by 1%, per capita BUA would expand by 0.097%. Based on this coefficient and the growth of per capita GDP, we estimated that economic growth led to a 3.77% expansion of per capita BUA in 1996−2000. However, the actual per capita BUA recorded a decrease of 1.20% in the central region in this period, which suggests that per capita BUA was also related to other important factors.

In the eastern region, the estimation results show that whereas economic growth had a positive effect on per capita BUA, the effect was not statistically significant (Table 3, column 2). This implies that the eastern region has been gradually moving to more intensive land uses.

Effects of other time-varying factors. The other time-varying factors also had significant effects on BUA expansion, but their effects differed greatly among regions. Whereas we were not able to exactly tell what

Table 3 Estimation results of determinants of per capita BUA in 1996−2000

Variables	Ln (per capita BUA)	
	(1)	(2)
Economic development		
Ln (per capita GDP_{t-1} in the western region)	0.064	0.094
	(7.39)***	(2.87)***
Ln (per capita GDP_{t-1} in the central region)	–0.001	0.097
	(0.13)	(3.08)***
Ln (per capita GDP_{t-1} in the eastern region)	0.073	0.045
	(7.53)***	(0.97)
Regional dummy×T_{2000} dummy (1996 as base year)		
Western region×T_{2000}	0.081	0.072
	(7.55)***	(5.46)***
Central region×T_{2000}	0.010	–0.029
	(0.86)	(1.93)*
Eastern region×T_{2000}	–0.010	–0.000
	(0.84)	(0.01)
Geographic factors		
Ln (average slope)	–0.010	
	(3.30)***	
Ln (distance from the nearest port)	0.005	
	(2.67)***	
Ln (distance from the nearest provincial capital)	–0.016	
	(4.51)***	
Ln (elevation)	–0.006	
	(2.59)***	
Average air temperature	–0.005	
	(5.33)***	
Ln (per capita BUA)$_{1989}$	0.937	
	(236.75)***	
Regional dummies (western region as base region)		
Central region	0.563	
	(5.59)***	
Eastern region	0.006	
	(0.06)	
County dummies	Excluding county dummies	Including 2245 county dummies
Intercept	–0. 568	–3.104
	(5. 61)***	(18.13)***
Adj R^2	0. 97	0.98

The figures in parentheses are absolute t-statistics; ***, ** and * indicate statistically significant at 1%, 5% and 10%, respectively; (t–1) indicates that the variables were lagged by one year; the number of samples is 4492 from 2246 counties (cities).

these time variation factors were in 1996—2000, they may have included policy changes in land management, land prices, regional development, finance and taxation, foreign direct investment, or urban development. The estimated coefficients of the interaction terms from the regional dummy and time dummy for the year 2000 showed that the factors with time variations had significant and positive effects on BUA expansion in the western region, but negative effects in the central region and no effect in the eastern region (Table 3, column 2). These findings agree with the trends of BUA expansion for each region, discussed in section 3.

In the western region, the rapid expansion of BUA was closely related to China's regional development policies as well as to economic growth. In the late 1990s, the central government initiated the "Western Development Program". Since then, the government's investment in the western region has increased substantially, with many investments in urban and rural infrastructures. The "Western Development Program" and the relatively low land prices in the western region[16] are probably two of several major factors that have driven BUA expansion in the region.

In the central region, after controlling the impacts of all other factors, per capita BUA declined by 2.9% in 1996—2000 (note the coefficient for the central region× T_{2000} of –0.029, in column 2 of Table 3). We suggest two possible explanations: First, the central government provided no specific and significant supportive development policies for the central region. The eastern region has enjoyed preferential policies since the 1980s when China opened its economy to the rest of the world, and the western region has enjoyed a preferential regional development policy since the late 1990s, but the central region has lacked similar preferential policies. Secondly, since the 1990s, the Ministry of National Land and Resources has released a series of regulations on cultivated land protection. Because the central region is a major grain production area, the regulations have been more rigidly executed there. These two explanations, together with a general increase in land prices, may account for the decreasing per capita BUA in the central region since the mid-1990s, which is also consistent with the data set in Table 2.

At present and in the coming years, the western region is expected to continue to accelerate its BUA expansion in general and its urban area expansion in particular. The eastern region, in contrast, may have reached a stage in which further expansion of per capita BUA has become difficult and may turn to a strategy of more intensive use of its limited land. This region is relatively more developed, with a higher level of urbanization and more constraints on land resources, and therefore higher land prices. Therefore, except for the positive impacts of economic growth on BUA, the combined effects of all other time variation factors may have no effects on per capita BUA in 1996—2000 (Table 3, column 2).

Effects of geophysical factors. Geophysical factors also had significant effects on per capita BUA (Table 3), providing further clues for understanding the remarkable differences in BUA among regions. Almost all of the signs for all of their regression coefficients agreed with our expectations and also with the results of other similar studies[17,18]. Since these factors are not the focus of this paper, we will not present a more detailed discussion.

Regression results. Last but not least, the regression results identified large regional per capita BUA differences, even after controlling all factors included in the model. The significant coefficient of 0.563 (Table 3, column 2) for the regional dummy variable for the central region indicates that per capita BUA in 1996 in the central region was 56.3% higher than that in the western region, which is consistent with the regional differences in per capita BUA of Table 2. In 1996, per capita BUA in the central region was 188 m^2, or 94 m^2 more than that of the western region (94 m^2), of which 52.9 m^2 (94×0.563) is explained by the regional fixed effect in our regression. The much higher per capita BUA in 1996 in the central region than in the western region may be partially explained by large mineral reserves and consequently a higher mining BUA in the central region; also, rural houses often occupy more land in the central region (usually there is a courtyard in front of a house) than in the other regions. The estimation results also revealed no significant difference in per capita BUA in the base year for the eastern and western regions, which also agrees with the descriptive analysis in Table 2.

6 Conclusions

This paper demonstrates that, for the nation as a whole from the late 1980s to 2000, the total BUA has been increasing. This BUA expansion even accelerated after the mid-1990s. Although BUA expansion in the eastern region was the fastest, its growth rate has decreased significantly over our study periods. On the other hand, the overall BUA growth rates were relatively low in the western and central regions, but have been increasing. By the late 1990s, the BUA growth rate in the western region exceeded that of the eastern region.

The empirical econometric estimates reveal that the decrease in BUA growth rates in the eastern region during 1996—2000 was mainly because the effect of economic growth on per capita BUA had become insignificant. Due to the rather high economic growth rates in earlier stages, further economic growth in the eastern region will probably bring about a significant increase in land price. The BUA expansion in the eastern region seems to have moved from a horizontal sprawl pattern in early stages towards a vertical expansion pattern with a somewhat more intensive utilization of land (e.g., higher buildings and more careful land-use planning). With further land-price increase and population growth, per capita BUA in the eastern region can be expected to continue to decrease. Our study also finds that the acceleration of per capita BUA in the central and western regions in 1996—2000 was mainly attributable to the significant positive effect of economic growth. Economic growth in these regions has favored the horizontal over vertical expansion of urban spaces. This pattern of BUA expansion may be related to local development policies and the relatively cheap land price in the central and western regions. Therefore, the conflict between regional economic growth and national cultivated-land protection policies will face increasingly serious challenges in these two regions.

We would like to thank the Resources and Environment Scientific Data Center, Chinese Academy of Sciences for providing some basic data for this study. We also would like thank two anonymous referees for their constructive and valuable comments.

Appendix Means and standard errors for all variables

Variables		1996		2000	
		Mean[a)]	Std error	Mean	Std error
Per capita BUA	(hm^2)	0.151	0.169	0.153	0.165
Per capita BUA in 1989	(hm^2)	0.159	0.180	0.159	0.180
Per capita GDP in western region	(RMB Yuan)	2778	3064	3732	3636
Per capita GDP in central region	(RMB Yuan)	3440	2598	5052	3699
Per capita GDP in eastern region	(RMB Yuan)	6393	5692	9214	8088
Average slope	(°)	2.8	2.8	2.8	2.8
Distance from the nearest port city	(km)	631	566	631	566
Distance from the nearest provincial capital	(km)	195	145	195	145
Elevation	(m)	743	876	743	876
Average air temperature	(℃)	12	6	12	6
Number of samples [b)]		2246		2246	

a) The mean values reported are the average values for the samples in this study; b) the number of samples (counties or cities) is 2246 each year.

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