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Impact of urbanization on cultivated land changes in China

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ABSTRACT

This article aims to evaluate the impact of urbanization and different urbanization modes on cultivated land changes using an econometric model that incorporates socio-economic and policy factors in the eastern China, which experience the great urbanization in recent years. Based on land-use remote sensing data interpreted from Landsat Thematic Mapper/Enhanced Thematic Mapper digital images of Chinese Academy of Sciences and a unique set of socio-economic data, an econometric model is developed to empirically estimate the impacts on cultivated land changes. Although urbanization has an effect on the changes of cultivated land, its effect is marginal. Moreover, the expansion of built-up areas in different urbanization modes causes varying impacts on changes in cultivated land use in different regions. Assuming that other factors remain constant, compared with the expansion of villages or the development of small towns, in the periods of 1995–2000, the urbanization in the more developed eastern region alleviates the loss of cultivated land by 7%, while during 2000–2008 the rapid urbanization lead to the cultivated land loss increase by 29.2%. The policies designed to protect cultivated land by encouraging people move to small towns may actually accelerate the occupation of cultivated land.

Introduction

According to United Nations, from 2009 to 2050, 1.86 billion more people will live in urban areas and the level of urbanization is expected to rise from 50 to 69%. Although urbanized land area comprises just 2% of the earth's surface, more than half of the world's population lives in urban areas. In China, the urbanization rate, measured as urban population, rose from 17.92 to 52.57% between 1978 and 2012 (National Bureau of Statistics of China, 2013), with over half of the population in China living in urban areas in 2012.

As to the impacts of urbanization, it not only creates positive externalities through technological innovation and shared information, such as outstanding economic growth, increasing farming production, but also generates negative externalities such as problems in public safety, health, social equality, etc. (Bai et al., 2011; Wu et al., 2011). One of the major negative effects of urbanization for developing countries is the losing of cultivated land, for which researchers have various views. One view is that urbanization, especially the expansion of large cities and regions that have experienced rapid economic growth and urban development, causes the loss of cultivated land (Deng et al., 2009; Liu et al., 2014; Tan et al., 2005). On the opposite, many researchers conjecture that urbanization and the consequent population shift from agricultural to non-agricultural sectors can play an active role in promoting the conservation of cultivated land since the per capita land consumption in urban areas is much lower than in rural and town areas (Huang et al., 2005). For the impact of different urbanization modes on the changes in cultivated land, some state that the expansion of small towns and rural villages lacks sufficient focus and covers a large area of cultivated land, the leaders of small cities believe that urban land is more profitable than agricultural land, so they think that economic success is more likely to happen on urban land, which leads to a significant loss of cultivated land (Skinner et al., 2001), and more and more researchers identify that land occupied by rural settlements/residential land resulted in the loss of cultivated land (Tan et al., 2011; Xi et al., 2012). Others claim that the infrastructure built along with the expansion of cities occupies large amount of land, which leads to the large decrease in the cultivated land (Islam and Hassn, 2013).

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Accelerated development of urbanization and deputes about the impact of urbanization on cultivated land changes make the relationship between urbanization and cultivated land changes a hot topic in recent years. Most researchers conducted case studies to quantitatively analyze the changes of cultivated land along with urban expansion (Liu et al., 2012; Tang et al., 2008) and the driving forces and impact mechanism of urbanization and associated cultivated land conversion (Jiang et al., 2012). While less concerns had been focused on the growth of rural residential land, about 60% of the rural residential land was converted from farmland in China (Long et al., 2007; Tian et al., 2007), and more than 92% of the increased rural residential land was from farmland in economic developed region of coastal China (Long et al., 2009). Especially, researches that combine the sprawl of urbanization of cities and expansion of rural residential land in small villages and towns to study the impacts on cultivated land are much less.

In this article, we aim to explore the impact of different urbanization modes (“Village”, “Town”, “City”) on cultivated land changes using an econometric model that incorporates socio-economic and policy factors. Taking the fact that the urbanization is more obvious in the eastern China into account, we focus on the study in the eastern China, where experience the great urbanization in these recent years.

Data

In this study, we use the built-up area as an index to distinguish the urbanization modes. The built-up area data comes from the land-use database of the Resources and Environment Scientific Data Center, Chinese Academy of Sciences (Deng et al., 2006; Liu et al., 2003, 2010). The land-use database is constructed from remotely sensed digital images by the US Landsat TM/ETM satellite with a spatial resolution of $30 \times 30\,m^2$. The land-use data analyzed by this study covers four periods: (1) the late 1980s, mainly including the data from 1986 to 1989 (henceforth, referred to as 1988 data for brevity); (2) the middle of 1990s, including the data from 1995 to 1996 (henceforth, 1995); (3) the late 1990s, including the data from 1999 to 2000 (henceforth, 2000); and (4) the late 2000s, including the data from 2005 to 2008 (henceforth, 2008). We used geographic information system (GIS) technology to aggregate the built-up areas with stable forms and spatially continuous patches to the level of county or city, which are the basic analysis units in this study. The summary statistics are presented in Table 1.

In order to analyze the effects of different urbanization modes on the changes in cultivated land, we divided the patches into three categories based on the calculation of built-up area. The first category includes all patches with a built-up area less than $0.5\,km^2$. In fact, as these patches are mostly equivalent to rural residential areas in the scale, they are defined as the built-up area in the “Village” mode. The second category includes all patches with a built-up area between 0.5 and $5\,km^2$, which is referred to as the “Town” mode urbanization because a typical large township area usually ranges between 1 and $5\,km^2$. The third category refers to all patches with a built-up area more than $5\,km^2$, which is defined as a built up area in the “City” mode in this study. These three categories of urbanization modes or build-up areas are not only closely related to the administrative levels of villages, towns and cities, but also ensure that the analyses of urbanization modes are comparable over time and space. On the basis of the classification of urbanization modes, we calculated a set of ratio variables, which are calculated as the ratio of the built-up area in each urbanization mode to the total built-up area in each county (city) as follows: $R_{ij} = \frac{A_{ij}}{A_j}$

where R is the ratio of built-up area to total built-up area, A represents the area, i represents the urbanization mode and j represents the county (city). This enables the analysis of the differences between the changes in built-up areas in rural regions and those in different urban districts.

The geophysical factors used in this study include geographical locations, average slope, plain area proportion, elevation, precipitation and air temperature of each county (city) (Table 1). The geographical locations include two variables: one is the distance to the provincial capital and the other is the distance to the nearest port city, which were calculated based on the topographic map of 1:250,000 scale obtained from the State Bureau of Surveying and Mapping of China. The data of slope and elevation of the counties (cities) were extracted from the national digital elevation model (DEM) of 1:250,000 scale. The data of precipitation and average air temperature were derived based on the data from the climatic stations affiliated with China Meteorological Administration from 1950 to 2008. Using the map algebra in GIS, we first interpolated the site-based climate records into the surface with a spatial resolution of 1 km by 1 km, and then aggregated the cell-based information on the air temperature surface to the administrative units in counties (cities) using GIS spatial analysis techniques (Deng et al., 2008, 2010). The socio-economic data such as GDP and population were obtained from the Social and Economic Statistical Yearbook of China’s counties (cities) (National Bureau of Statistics of China, 1996, 2000, 2005, 2008).

In order to better analyze the impacts of economic growth on cultivated land and expansion of built-up areas, we controlled for economic growth factors and a slew of land-use-related policy factors, including the non-agricultural population registered, upgrades of county to city, foreign direct investment per capita and whether the region is the development zones, which were obtained from Statistical Yearbook of China (National Bureau of Statistics of China, 1996, 2000, 2005, 2008).

Considering that rapid urbanization mostly occurs in the eastern China, our empirical analysis focuses on the expansion of built-up area in the eastern provinces. Further, due to China’s administrative division changes over time, we revisited 18 counties/cities within eastern 14 provinces or municipalities (Heilongjiang, Jilin, Liaoning, Beijing, Tianjin, Hebei, Shandong, Shanghai, Jiangsu, Zhejiang, Fujian, Guangdong, Guangxi and Hainan) based on the neighborhoods of residential polygons with the reference of year 2005. Finally, we prepared the panel data of land use, policy, economic and geophysical factors for the total 1738 valid samples (counties or cities/districts) of year 1988, 1995, 2000 and 2008, to investigate the impact of urbanization on cultivated land changes in China.

Model

The main objective of our empirical analysis is to investigate the determinants of different urbanization modes and their impacts on the changes in cultivated land in time and space. The selection of underlying factors that drive urban expansion and cultivated land conversion is important for our analysis, based on previous studies (Jiang et al., 2012; Long et al., 2007; Xie et al., 2005) and the three urbanization modes, we select relevant driving factors and propose the following empirical models:

Cultivated land area = *Fc* (urbanization mode, social and economic variables, geophysical variables, other control factors, *random error term*)

The dependent variable cultivated land area is the total area of cultivated land presented in hectares and the urbanization mode is represented by ratio variable R_i. In total, we constructed four regression models. We used data of four years 1988, 1995, 2000, 2008, which were computed at the county (or city) level.

The explanatory variables in model *Fc* are defined as follows. The social and economic variables include GDP, Agricultural GDP,

Table 1
Descriptive statistics of the main variables.

Variables	1995		2000		2008	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Cultivated land area (ha)	69277	66091	68250	67952	66062	68643
Cultivated land area (1988) (ha)	66630	61212	66630	61212	66630	61212
Cultivated land area (1995) (ha)	69277	66091	69277	66091	69277	66091
Build-up area						
Village land ratio (%)	67.16	22.01	65.71	21.78	60.54	22.36
Town land ratio (%)	12.00	11.57	12.66	11.87	15.96	12.97
City land ratio (%)	20.84	20.84	21.63	22.21	23.50	23.50
Policy factors						
Non-agricultural population registered($t-1$) (%)	23.76	20.38	25.19	20.43	45.51	34.83
County upgrading to city (yes = 1)	0.24	0.43	0.26	0.44	0.29	0.45
Foreign direct investment per capita (yuan per capita)	2212	2314	3911	3894	5200	5019
Development zone (exist = 1)	0.36	0.48	0.37	0.48	0.41	0.5
Economic factors						
GDP($t-1$) (million yuan[a])	4331.98	9603	6567.68	16370	9467	18823
Agriculture GDP($t-1$) (million yuan)	825.86	591.79	986.72	696.27	1338.68	962.11
Secondary industry GDP($t-1$) (million yuan)	2004.27	4980.47	3043.47	8167.19	4324.11	11028
Tertiary industry GDP($t-1$) (million yuan)	1501.85	4647.55	2537.49	8225.31	3804.21	13123
Population($t-1$) (person)	631933	607333	653616	628337	731665	821621
Geophysical factors						
Slope (degree)	2	2	2	2	2	2
Distance to the nearest port (km)	467	342	467	342	467	342
Distance to the capital city (km)	164	96	164	96	164	96
DEM (m)	233	255	233	255	233	255
Plain area proportion (%)	0.53	0.38	0.53	0.38	0.53	0.38
Average precipitation (mm)	1016	510	1016	510	1016	510
Average temperature (°C)	13	6	13	6	13	6
Observations	1738		1738		1738	

[a] At the price of 2000.

Secondary Industrial GDP, Service Industrial GDP and Population. To avoid possible endogenous problems, we used GDP data from the previous year, i.e., a one year lag in the measurement of GDP. The geophysical factors may all significantly contribute to regional differences in the use of cultivated land and expansion of built-up area and are therefore used as the control variables in this study. Although there are some geophysical factors in the model to control the regional differences, it is still difficult to control differences between regions in the analysis, thus we further take the cultivated land area of year 1988 as the control factor to better control on the regional difference, and we call it the “base-period dependent variable”.

In the model *Fc*, except the economic variables, some other factors also changes over time may be neglected and have not been included in the model *Fc* due to data availability problems, while those factors are related with urbanization mode and will further lead the urbanization mode variable to be related with the random error term in the model *Fc*, namely that there may exist endogenous problems in the urbanization mode variable. As the urbanization mode is an important variable used to identify the impacts of different urbanization modes on cultivated land changes, thus in order to accurately estimate the influence of different urbanization modes on cultivated land, we adopt the instrumental variable method to solve the endogenous problem, we established the urbanization mode model *Fu* as follows:

Urbanization mode = *Fu* (instrumental variables for urbanization mode, social and economic variables, geophysical variables, other control factors, *random error term*)

As to the instrumental variables for urbanization mode, a slew of land-use-related policy factors that basically influence the cultivated land changes through influencing the urbanization mode rather than directly exerting impact on cultivated land are chosen, including household registration policy (represented by the non-agricultural population registered), urban development policy (represented by upgrades of county to city, dummy variable, yes = 1, zero = 0), foreign direct investment policy (represented by per capita foreign direct investment in stock) and regional development policy (dummy variable, if the region is development zone, yes = 1, otherwise, no = 0). And to be explicit, the economic factors, geophysical factors and the other factors are the same in the *Fc* and *Fu* model. And here we use the three-stage least-squares (3SLS) method to estimate the model *Fc* and *Fu*. The 3SLS method is the most common estimation method in the literature and it accounts for the endogeneity issue and the disturbance correlation across equations for a given time period. It considers information on the complete structure of the model and is asymptotically more efficient when the structural disturbances are correlated and accounts for all exogenous and endogenous variables (AlDakhil, 1998). As the sum total of the three ratio variables (the built-up area ratios in “Village” mode, “Town” mode and “City” mode respectively) is 1, we take the “Village” mode as benchmark to identify the impacts of “Town” mode and “City” mode on cultivated land-use changes. (Note: the 3SLS method goes one step further by using the two-stage least-squares estimated moment matrix of the structural disturbances to estimate all coefficients of the entire system simultaneously. The method has full information characteristics to the extent that, if the moment matrix of the structural disturbances is not diagonal (that is, if the structural disturbances have nonzero “contemporaneous” covariance), the estimation of the coefficients of any identifiable equation gains in efficiency as soon as there are other equations that are over-identified. Further, the method can take account of restrictions on parameters in different structural equations. And it is very simple computationally, apart from the inversion of one big matrix).

Results and discussions

We estimate the regression models using the samples of counties from the eastern China. First, we analyze the factors that affect three urbanization modes, then estimate the cultivated land model to detect the impact of different urbanization modes and socio-economic factors on cultivated land changes using 3SLS method. The explicit analyses are as follows.

The estimation result of urbanization modes

Overall, the estimated effects of socio-economic, geophysical and other factors on urbanization modes are consistent with our expectations and most of them are significant. Here we only discuss the most important effects.

Firstly, the household registration policy has significant different impacts on different urbanization modes. On the one hand, according to the results of model estimation (Table 2), the influence coefficient of household registration policy to the "Town" mode is −0.025 (the second column) at 5% significance level. It indicates that the increase in non-agricultural population will have a negative effect on the "Town" mode urbanization. However, the household registration policy has significant positive influence on "City" mode urbanization. This is consistent with the result we expected, as the registration constraint was loosened in the past three decades, the population gradually migrated from villages and small towns to larger urban areas, which then leads to the expansion of urban districts.

Meanwhile, according to the results of our empirical estimates (Tables 2 and 3), in the period of 1995–2000, the implementation of urban development policy to upgrade the county to city (or district) has a negative but not significant effect on "Town" mode urbanization, while it has a significant positive effect on "City" mode urbanization, the influence coefficient of estimation is 0.013 at the significant level of 1%. In the period 2000–2008, the estimation results show that the development of county to city (district) also has an effect on "Town" mode and "City" mode, but both are not significant. This is intuitively reasonable because the policy of county to city (district) transition was mostly implemented in city and designed to promote the expansion of cities.

Further, the effects of the per capita foreign direct investment on both "Town" mode and "City" mode urbanization are not significant in the period 1995–2000 (Table 2), but the effect was significant in "City" mode in 2000–2008 (Table 3), more specifically, the influence coefficient of per capita foreign direct investment on "City" mode urbanization is 0.008 at the significant level of 1%. In addition, the regional development policy has a significant negative effect on "Town" mode urbanization, but has a positive effect on "City" mode urbanization, and this is because the development zones are generally set up around the town and consequently promote its expansion. Most of these instrumental variables have significant effect on the relative proportion of urbanization change, which indicates that the selected instrumental variables are effective.

The impact of social and economic factors, geophysical factors and other factors on the urbanization pattern are almost the same with our expectations. Quite a few of the variable coefficients have reached the significant level which shows that the estimated urbanization model has good explanation ability. As explained, the effect of urbanization mode is not the research emphasis of this article; here we only made a brief description to explain the effectiveness of the instrumental variable and the overall estimated results of urbanization mode and mainly focus on the econometric analysis results of the impact of different urbanization modes on cultivated land.

The estimation results of the cultivated land model

First of all, according to the estimation results of the cultivated land model (the forth column of Tables 2 and 3), most of the coefficients reached the significant level on statistics, and the R^2 values reached 0.99 and 0.97 in the periods 1995–2000 and 2000–2008, respectively; thus, the estimated results show that the cultivated land model can explain the changes in quantity of cultivated land well in the eastern 14 provinces or municipalities of China.

Secondly, the historical levels of the cultivated land area in 1985 and 1995 have significant positive effects on the cultivated land area in 1995–2000 and 2000–2008, which indicates that these variables have sufficiently controlled for the regional variations due to their initial differences in land areas. Also the effect of urbanization mode on cultivated land in the estimated model shows that in the period 1995–2000, the influence coefficients of the "Town" mode and "City" mode are 0.117 and 0.036 at the significant level of 1 and 10%, respectively (Table 2, column 4). As the "Village" mode is taken as benchmark to identify the impacts of "Town" mode and "City" mode on cultivated land-use changes, it indicates that assumed that other variables are constant, compared to the effect of the "Village" mode, the cultivated land occupied by urbanization in the "Town" mode and "City" mode will be 11.7 and 3.6% respectively, less than that occupied in the "Village" mode. This is because the level of intensified utilization of land in city and town is higher than in rural areas, thus with the same increase in construction land area, the cultivated land used in towns and cities will be less than in the rural areas. So, it shows that relative to the construction land in rural areas, the land areas used for "Town" mode and "City" mode urbanization is more economical and also play an important role in alleviating cultivated land loss.

While in the period 2000–2008, the result has taken place a great change, the influence coefficients of the "Town" mode and "City" mode are negative at the significant level of 1 and 10%, respectively (Table 3, column 4). It indicates that in case other variables are constant, the cultivated land that will be occupied more in the "Town" mode and "City" mode than in the "Village" mode, namely the urbanization level increases by every one unit, the cultivated land being occupied by construction land in "Town" mode and "City" mode will be 14.6 and 6.7%, respectively, more than that occupied in the "Village" mode.

As to the difference in the impacts of urbanization modes on the changes in cultivated land before and after 2000, it can be explained by the Chinese government's urban development policy reform. In the mid-1980s of the last century, along with economic reform to market economy, "small towns" concept put forward by the famous sociologist Fei Xiaotong was accepted by the government. State Council of China set up an office for "small town" construction to promote the development of medium and small cities (Wang, 1994). The policy means give priority to development of small cities and towns with development of medium and big cities as supplement. During 1978–2000, the general trend of urban development in China has been to control the scale of large- and medium-sized cities, to release rural surplus labor and to develop rural enterprises, which resulted in emerging of small cities and towns. Urbanization rate increased from 17.9% in 1978 to 36% in 2000, with an average annual growth of 1.05%. And not only the scale of cities was enlarged, the number of small towns also reached 20,000 (Liu, 2012). Thus, "Village" mode exerted more impacts on cultivated land loss before 2000. Since 2000, the urban development policy transformed from "strictly control the growth of large cities, rationally develop medium-sized cities and vigorously promote the development of small cities and towns" to "coordinated development of towns and cities of various scale taking large cities as the center, and development of urban agglomeration and urban belt" (Liu, 2012), which leads to a rapid development of urbanization, lots of considerable urban district construction plans were formulated and implemented from the provincial capitals to small town. According to national statistics yearbook in recent years, the rate of urbanization in China increased 1.3% per year, by the

Table 2
Estimation results, for the eastern region, the decision factors of urbanization mode and cultivated land, 1995–2000 (3SLS).

Explanatory variables	"Town" mode proportion	"City" mode proportion	Cultivated land area
Explained variables in 1988			1.018 (199.39)***
"Town" mode proportion	0.084 (77.85)***		0.117 (4.25)***
"City" mode proportion		0.853 (64.85)***	0.036 (1.80)*
Policy instrumental variables			
Non-agriccultural population registered($t-1$)	−0.025 (2.36)**	0.087 (5.96)***	
County upgrading to city (yes = 1)	0.004 (−1.22)	0.013 (3.02)***	
Foreign direct investment per capita	0.001 (−0.82)	−0.003 (1.30)	
Development zone (exist = 1)	−0.01 (2.83)***	0.011 (2.50)**	
Socio-economic factors			
Agriculture GDP($t-1$)	−0.006 (1.98)**	0.002 (0.42)	0.021 (3.25)***
Secondary industry GDP($t-1$)	0.002 (−0.65)	0.005 (1.45)	−0.009 (1.66)*
Tertiary industry GDP($t-1$)	0.003 (−0.87)	0.014 (3.00)***	−0.025 (3.66)***
Population($t-1$)	−0.003 (−0.71)	−0.022 (4.85)***	−0.006 (0.80)
Geophysical factors			
Slope	−0.002 (2.15)**	−0.002 (1.88)*	−0.001 (0.30)
Distance to the nearest port	0.001 (−0.87)	−0.004(2.70)***	0.007 (2.83)***
Distance to the capital city	−0.000 (0.02)	−0.007 (2.96)***	0.02 (5.48)***
DEM	−0.000 (0.33)	0.002 (2.66)***	−0.000 (0.06)
Plain area proportion	−0.001 (0.22)	−0.012 (1.53)	−0.043 (3.44)***
Average precipitation	−0.007 (1.17)	−0.057 (7.97)***	0.041 (3.89)***
Average temperature	0.000 (1.06)	0.005 (9.34)***	−0.004 (4.58)***
R^2	0.78	0.91	0.99
Observations	1738	1738	1738

*Significance at 10%. **Significance at 5%. ***Significance at 1%.

end of 2008, the rate of urbanization in China's major cities such as Shanghai, Beijing and Tianjin was more than 70%, and the rate was over 60% in Guangdong province and Liaoning province. Moreover, the quick acceleration of the urbanization rate and process, especially extensive expansion of urbanization, would inevitably lead to the rapid expansion of construction land and has brought a huge challenge to villages, towns, especially to medium-sized cities, which will accelerate the decrease in cultivated land area. Further, the results of the period 2000–2008 indicated that the policies designed to protect cultivated land by encouraging people move to towns and cities may actually accelerate the occupation of cultivated land. Since 2000, the government also issued some policies to protect cultivated land area, such as the implementation of 'increasing vs. decreasing balance' land-use policy, which seeks to balance increases in urban construction land with a reduction in rural construction land to alleviated the cultivated land loss. The policy implementation has achieved some successful examples, such as at Huantai county, Shandong province, in the area around Maqiao town, a process of resettlement will release over 660 ha (10,000 mu) of former rural housing land, most of which will be converted into farmland. With the people moving to towns and cities, land consolidation by rejuvenating disperse, abandoned, idle and low-efficient used rural housing land will increase the area of local farmland (Long, 2014; Long et al., 2012). However, to a greater extent, the policies designed to protect cultivated land have not been well implemented, thus with the urbanization development,

Table 3
Estimation results, for the eastern region, the decision factors of urbanization mode and cultivated land, 2000–2008 (3SLS).

Explanatory variables	"Town" mode proportion	"City" mode proportion	Cultivated land area
Explained variables in 1995			1.023 (128.84)***
"Town" mode proportion	0.826 (54.23)***		−0.146 (2.92)***
"City" mode proportion		0.793 (64.47)***	−0.067 (2.01)*
Policy instrumental variables			
Non-agricultural population registered($t-1$)	0.021 (2.10)*	0.037 (3.51)***	
County upgrading to city (yes = 1)	−0.005 (−0.95)	−0.001 (−0.13)	
Foreign direct investment per capita	0.003 (1.14)	−0.008 (−2.88)***	
Development zone (exist = 1)	0.000 (0.03)	−0.005 (−0.95)	
Socio-economic factors			
Agriculture GDP($t-1$)	0.015 (3.59)***	−0.018 (−4.24)***	0.014 (1.38)
Secondary industry GDP($t-1$)	0.004 (1.04)	0.012 (2.75)***	−0.003 (0.34)
Tertiary industry GDP($t-1$)	−0.015 (−2.69)***	0.022 (3.82)***	−0.037 (3.25)***
Population($t-1$)	−0.012 (−2.07)*	−0.007 (−1.25)	0.038 (3.06)***
Geophysical factors			
Slope	0.004 (3.03)***	−0.001 (−0.46)	0.005 (1.38)
Distance to the nearest port	−0.011 (−3.49)***	−0.001 (−0.36)	0.002 (0.39)
Distance to the capital city	−0.000 (−0.13)	0.004 (1.28)	−0.003 (−0.41)
DEM	−0.001 (0.89)	−0.000 (−0.30)	−0.008 (−3.42)***
Plain area proportion	0.017 (1.77)	0.001 (0.13)	0.009 (0.43)
Average precipitation	0.008 (1.01)	−0.012 (−1.47)***	−0.091 (−5.42)***
Average temperature	−0.000 (−0.60)	0.004 (5.37)***	0.000 (0.06)
R^2	0.56	0.85	0.97
Observations	1738	1738	1738

*Significance at 10%. **Significance at 5%. ***Significance at 1%.

Table 4
Decomposition analysis of cultivated land loss, 1995–2000.

Variable	Estimated parameter[1]	Variation (%)[2]	Influence[3] = [1] × [2]	Rate of contribution (%)[4] = [3]/(−1.48)*100
Urbanization (construction land area ratio)				
"Village"(Rural residential)				
Town	0.117	0.66	0.08	−5
City	0.036	0.79	0.03	−2
Agriculture GDP*(t − 1)	0.021	18.08	0.37	−25
Secondary industry GDP*(t − 1)	−0.009	40.45	−0.35	24
Tertiary industry GDP*(t − 1)	−0.025	50.07	−1.27	86
Population*(t − 1)	*−0.006*	3.12	−0.02	*1*
Other variables			−0.32	21
Change of cultivated land area (%)		−1.48		100

Note: Italicized values represent that the coefficient based on the decomposition analysis is not significant.

Table 5
Decomposition analysis of cultivated land loss (2000–2008).

Variable	Estimated parameter[1]	Variation (%)[2]	Influence[3] = [1] × [2]	Rate of contribution (%)[4] = [3]/(−2.1)*100
Urbanization (construction land area ratio)				
"Village"(Rural residential)				
Town	−0.146	3.33	−0.486	23.2
City	−0.067	1.87	−0.125	6.0
Agriculture GDP*(t − 1)	*0.014*	35.67	0.499	*−23.8*
Secondary industry GDP*(t − 1)	*−0.003*	42.08	−0.126	*6.0*
Tertiary industry GDP*(t − 1)	−0.037	49.92	−1.847	88
Population*(t − 1)	0.038	11.94	0.454	−21.6
Other variables			1.150	77.7
Change of cultivated land area (%)		−2.1		100

Note: Italicized values represent that the coefficient based on the decomposition analysis is not significant.

the areas with "Town" mode and "City" mode urbanization will experience more cultivated land loss.

Thirdly, geophysical factors are also the important factors to explain regional differences of cultivated land. Among the seven geophysical factors which are considered, there are five variables whose coefficients reached 1% significant level, including the nearest distance to the province capital, the nearest distance to the port, the ratio of plain area, precipitation and average temperature, and the effects of these factors are consistent with previous research results (Huang et al., 2005).

Fourthly, economic and social development has a significant effect on cultivated land change. According to the estimation results, the impact of the economic development of various sectors on cultivated land is significantly different. We can found from the results in Table 3, the development of the primary industry has a positive influence on cultivated land, which shows that in the case of other variables unchanged, from 2000 to 2008, when the agricultural GDP increases by 1%, the cultivated land will increase (or save) by about 0.014%. This is because agriculture development needs a large number of cultivated land, the more agriculture develop, the more cultivated land used for farming. At the same time, we found from Table 3 that, in the period 2000–2008, the development of the secondary industry and the tertiary industry have significant negative effects on cultivated land, and the influence coefficient of tertiary industry GDP reached 1% significant level. It shows that in case other variables unchanged, as secondary industrial GDP or tertiary industry GDP increases by 1%, the cultivated land will reduce by about 0.003 and 0.037%, respectively. The estimated results agree with the theoretical values, basically, due to the development of the secondary industry and tertiary industry need to build a large number of infrastructure and service facilities, etc., which will directly affect the areas of cultivated land and have very significant influence on cultivated land loss. According to the results of the estimated model, in the periods 1995–2000, the influence coefficient of population is negative, but not significant (Table 2). This may be explained that as the non-agricultural employment population increase, the demand for construction land in rural areas may reduce, and increase in the same amount of construction land in urban areas may occupied less cultivated land than in rural areas, so the influence of population increase on cultivated land is not significant.

Decomposition analysis of cultivated land change

According to the decomposition analysis result of cultivated land change in the period 1995–2000, no matter how urbanization develop, the social economic factors play the most important decision role in deciding the range of cultivated land change (Table 4). In general, although urbanization is an important factor affecting the change of cultivated land, the influence of urbanization on cultivated land is not significant and not as terrible as it was in imagination. Among the factors that affect the cultivated land changes, economic growth (GDP), especially the development of the secondary industry and services industry, play the important decision roles in the change of cultivated land (Table 4). The decomposition result in Table 4 suggests that the development of the secondary industry and tertiary industry explains 110% of the cultivated land loss (24% plus 86%, rows 4 and 5), especially, the development of the tertiary industry plays a leading role in the cultivated land change. At the same time, we found that the urbanization let the loss of cultivated land decrease by 7% (5% plus 2%, rows 1 and 2).

While in the period 2000–2008, great changes have taken place, the computed results show that among all the factors that affect the change of cultivated land, the development of urbanization changes significantly. During 1995–2000, urbanization alleviated the loss of cultivated land by 7%, while in the period 2000–2008, the urbanization make the cultivated land loss increased by 29.2% (23.2% plus 6%, rows 1 and 2). It shows that with the continuous development of urbanization, the impact of urbanization on cultivated land gradually become more important (Table 5). Of course, the secondary and tertiary industry still play the decisive influence to cultivated land changes, in which the impact of the tertiary industry on the cultivated land is most obvious and the contribution rate is as high as 88%. This indicates that by the end of year 2008, the economic development is still the main influencing factor that results in the cultivated land loss, and the influence of the urbanization on cultivated land change is particularly increasing.

Conclusions

This article documents the changes and features of the built-up areas of different urbanization modes and their impacts on cultivated land changes in the eastern China from the late 1980s to 2008. To avoid endogenous problems, we apply the 3SLS method with some land-use-related policy factors as instrumental variables to estimate the impacts on cultivated land changes. The results of function *Fu* show that the instrumental variables, including household registration policy, urban development policy, per capita foreign direct investment, etc. significantly exert effects on the urbanization modes. We also find that social, economic and geophysical factors, such as industrial structure, population growth, the location of built-up areas, etc. played an important role in influencing urbanization modes.

The estimation results of function *Fc* and decomposition analysis of cultivated land loss show although urbanization has an effect on the changes of cultivated land, its effect is marginal, and economic growth is the major determinant of any changes in cultivated land use. In the more developed eastern region, assuming that other factors remain constant, in the period 1995–2000, the urbanization alleviates the loss of cultivated land by 7%, while during 2000–2008 the rapid urbanization lead to the cultivated land loss increased by 29.2%. While the economic development explain more part of the cultivated land loss, 110 and 88%, respectively, in the periods 1995–2000 and 2000–2008. And the above results indicate that with the continuous development of urbanization, the impact of urbanization on cultivated land gradually become more important, while economic development is still the main influencing factor. Moreover, the expansion of built-up areas in different urbanization modes causes varying impacts on changes in cultivated land use. For example, compared to the effect of the "Village" mode, in the period 1995–2000, the cultivated land occupied by urbanization in the "Town" mode and "City" mode will be 11.7 and 3.6%, respectively, less than that occupied in the "Village" mode, while in the period 2000–2008, the urbanization level increases by every one unit, the cultivated land being occupied by construction land in "Town" mode and "City" mode will be 14.6 and 6.7%, respectively, more than that occupied in the "Village" mode. The results indicate that the policies designed to protect cultivated land by encouraging people move to towns and cities may actually accelerate the occupation of cultivated land.

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