How Does Urbanization Affect Farmland Protection? Evidence from China

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Abstract: China's urbanization and farmland protection problem has attracted attention from around the world. However, the relationship and mechanism between urbanization and farmland protection have not been yet fully understood. We address this gap by examining the impacts of urbanization on farmland area, based on Chinese prefecture-level cities' panel data over 1990-2013. We employ the instrumental variable method and satellite nightlight data for robust analysis. Our findings reveal that urbanization has significant negative effects on farmland area. Urbanization causes much higher rates of farmland loss in medium-sized cities and in the more developed eastern area of China. China's farmland dynamic balance policy has a significant positive effect on farmland area. We further test the impact channels and find that land financing and urban sprawl reinforce the negative impact of urbanization on farmland area. The problem of farmland quality loss or the contribution of different impact channels is needed to study in future research.

Keywords: urbanization, farmland protection, farmland change, land financing, urban sprawl, China

1. Introduction

Understanding how urbanization impacts farmland protection, and seeking a balance between urbanization and farmland protection, is a major challenge. The global urbanization level is over 50% and will increase by 60% in 2030 (UN-Habitat, 2010), which will have profound influences on the global environment and food security. Cities occupy only 0.3% of the total land area, while 3% is taken up by arable land (Bettencourt et al., 2007). The great loss of farmland (arable land) under rapid urbanization is causing alarm for the Chinese central government with respect to food security. In China, the urbanization level rose from 17.92% in 1978 to 52.57% in 2015[1], and will rise by 70% in 2030 (Bai et al., 2014). China was feeding a fifth of the global population with only 7% of global farmland land, and farmland protection and food security remains a challenge for Chinese leaders. In 2006, the Chinese central government set a target to protect 120 million hectares of **farmland** to ensure long-term **food security.** In 2014, the Chinese central government published the ambitious National New-Type Urbanization Plan (2014–2020), which aims to rectify existing problems including farmland loss and environmental problems under the rapid urbanization (Bai et al., 2011).

Urbanization and farmland protection have become hot topics recently as accelerating urbanization is increasingly threatening farmland protection. Most researchers who have considered the topic have employed case studies to analyze urbanization influences on farmland area, and the driving factors of farmland associated with rapid urbanization (Jiang et al., 2012; Xi et al., 2012; Huang et al., 2005). Fewer studies have attempted to examine the effect and impact of urbanization mechanisms on farmland protection over a long-term period, especially in developing countries.

In this paper, we aim to examine the impact of urbanization patterns on farmland area by employing econometric models based on panel data from Chinese prefecture cities. We also explore the mechanism through which urbanization impacts farmland.

Our study's contributions are threefold. First, our study contributes to the literature by offering new evidences regarding urbanization and farmland protection from China. Second, our study evaluates the effectiveness of farmland protection policy under urban expansion, which is quite rare in literature. Third, we contribute to the literature by studying the mechanisms through which urbanization impacts farmland. As the largest developing country in the world, China's challenges, experiences, and lessons about farmland protection under rapid urbanization could provide rich references for other developing countries.

The next section presents the context of farmland protection in China. The empirical framework section presents our empirical framework and data description. The empirical results section provides the empirical results and robust analysis. Concluding remarks and policy suggestions are provided in the final section.

2. Literature review

2.1 Theoretical expectations

We employ two kind of theories to frame our study of urbanization and farmland: urban bid-rent model (Alonso, 1964; Deng et al., 2008) and local government land supply behavior (Wang & Scott, 2008; Lichtenberg and Ding, 2008; Huang and Du, 2017b).

The urban bid-rent model, depicts the general urban land use pattern. It predicts the land use pattern by defining the distance to an urban center as location. It describes the trade-off of cheaper land rents with higher transportation cost owning to increasing distance to urban center. Land uses will vary with the increasing distance from urban center. Later scholars incorporate income, transportation, and natural resources to expand the bid-rent model (White, 1988). Based on the framework of the urban bid-rent model, scholars have analyzed the urban land use pattern and examined the impact of urbanization on the conversion of agricultural land (Seto and Kaufmann, 2003; Jiang et al., 2012; Deng et al., 2015). Brueckner and Fansler (1983) found that income, transportation cost and agricultural land rent, implicated by the bid-rent model, are important factors influencing urban growth. Deng et al. (2008) found that income and industrialization significantly drive urban land expansion, supporting the bid-rent mode. However, as their studies focus on the determinants of urban expansion, there is little conclusions about the impact of urbanization on farmland change.

The urban bid-rent model could partially explain the impact of urbanization on farmland due to non-market and unknown factors. As land allocations are heavily controlled by government, the application of a bid-rent model may be limited. Scholars have examined and realized local governments behavior's impact on urban land expansion (Huang and Du, 2018b; Huang and Du, 2017a; Tian, 2015).

Local government land supply behavior theory views the conversion of farmland to urban land under urbanization as the outcome of decision and supply behavior of local governments. Revenue-seeking behaviors of local governments (Wang & Scott, 2008).

Revenue-seeking and promotional incentives shapes local governments' land supply behavior (Lichtenberg and Ding, 2008; Chen and Kung, 2016; Wang & Scott, 2008). In China, local governments are incentivized to lease out land for attracting investments, gaining land revenues and balancing fiscal deficit (Huang and Du, 2017b; Tao et al., 2010). Local governments convert farmland to urban land at low compensation and lease to developers at a much higher price (Huang and Du, 2017a). This type of local government land supply behavior significantly affects farmland change under rapid urbanization (Ding, and Lichtenberg, 2011). However, there are limited studies on urbanization and farmland change in China, especially from national scale.

2.2 Empirical evidences

The relationship between urbanization and farmland has not yet reached a consensus, although there are many studies on this topic. Although urbanization creates positive externalities through agglomeration, it also generates negative externalities, such as problems in environmental degradation and farmland loss (Bai et al., 2014). One of the major negative effects of urbanization for developing countries is the sudden conversion and loss of farmland (Deng et al., 2015; Tan et al., 2005). Researchers have posited various views about the impact of urbanization on farmland. One view, which has come mainly from urban economists, is that urbanization can promote intensive land use and thus is beneficial to farmland preservation (Huang et al., 2015; Glaeser, 2012). As per capita land consumption is much lower in cities than in rural areas, urbanization could benefit farmland protection. Urban growth may also enhance the economic returns to farmland expansion, and this stronger economic incentive may potentially increase farmland (Chamberlin et al., 2014).

Conversely, some scholars have argued that urbanization, especially rapid urban land expansion and urban sprawl, causes a great amount of farmland loss (Cheng et al., 2015; Liu et al., 2014; Deng et al., 2009).

The impacts of urbanization on farmland may depend on the different urbanization patterns and driving forces. In terms of urbanization patterns, large cities may have an agglomeration effect and consume less land per capita (Glaeser, 2012). Leaders of small and medium-sized cities believe that economic success is most likely to come from urban land and have thus converted large amounts of farmland for urban development. In addition, rural settlements occupied significant amounts of farmland, which resulted in a great loss of farmland (Tan et al., 2011; Long et al., 2009).

In terms of the driving forces of urbanization, urbanization could lead to the occupation of more farmland in a government-led urbanization development mode, wherein governments are ambitious to promote urbanization and depress farmland compensation prices. In China, this low cost of urban expansion has led to a significant loss of farmland in past two decades (Wang et al., 2010). In addition, China’s rapid urbanization consumes a great amount of high-quality farmland in the urban periphery (Cheng et al., 2015). It has also been suggested that infrastructure built along with urban expansion occupies large amounts of farmland (Islam and Hassn, 2013).

3. Context of Chinese farmland protection

3.1 China’s land management system and farmland conversion

China has a two-tiered land property rights system, including state-owned land and rural collective-owned land (Huang and Du, 2018a). In fact, local governments control urban land and monopolize the land supply by requisitioning rural land (mostly comes from farmland) for urban construction (Zhu, 2005). Without a clear definition and implementation of land property rights in this two-tiered system, local governments can easily convert rural land into state-owned land with low costs (Huang and Du, 2017a).

The 1994 centralized fiscal reform induced local governments' land financing behavior, which significantly influences farmland conversion. It drastically reduced local governments' budgetary fiscal revenue (Xu, 2011; Huang and Du, 2017b). Thereafter, local governments resorted land leasing for gaining extra revenue to finance urban construction and to balance fiscal expenditure (Cao et al., 2008). This extra local revenue from land leasing was about 33.7% of the local revenues over 2007–2012[2]. However, most land leasing comes from farmland conversion (Tao et al, 2010; Cheng et al., 2015). Although central government limits the total construction land quotas that local governments can lease to developers, with the aim of preserving agricultural land and food security, local governments still have enough autonomy to determine which parcel of land to lease out.

Farmland conversion and illegal farmland occupation have boomed with the rapid urbanization that has taken place since the 1990s. Urban development and construction demand for land have increased rapidly. Moreover, local governments could easily control land supply and convert farmland with low compensation to high value commercial use land for gaining extra budgetary revenue (Wang et al., 2012).

The huge profits from land leasing have spurred local governments to supply more land for urban use. As a result, urban built-up land in Chinese cities more than doubled from 1996–2014, increasing from 2.05–4.98 million square kilometers[3]. Most urban expansion areas come from the conversion of farmland, especially from high-quality farmland at the edges of existing urban areas. The massive occupation of high-quality farmland for urban expansion is threatening farmland preservation and food security. Land degradation always happens for the new replenished farmland which always has lower quality and productivity (Cheng et al., 2015).

3.2 China's farmland protection issues and policy

The rapid process of urbanization and urban expansion induced the conversion of farmland for non-agricultural use and the loss of ecological land (Wang et al., 2018;). Farmland is the main source of urban expansion. Rapid urbanization has resulted in the conversion of enormous amounts of farmland into urban construction land for residential, industrial, commercial, and infrastructural uses (Li et al., 2018). Urban construction had become the main source of farmland loss, over loss from disaster, conversion into land for ecological preservation, and agriculture structure adjustments (Zhang et al., 2014). Compared to the cost of redeveloping existing urban land, urban expansion into farmland is much cheaper due to its low compensation payments to farmers and circumvention of the need for resettlement. As a result, conversion of farmland has become a popular mean for providing land to accommodate urban development (Feng et al., 2015).

The loss of farmland in the face of rapid urban expansion has aroused Chinese governments' concern. The central government is concerned about the ability of China's farmland production to keep food security under the rapid loss of farmland (Anderson and Strutt, 2014). Local governments' land financing incentives are also of concern, for local officials have enthusiasm to requisition farmland for gaining revenue. Converted farmland in nearby suburban areas comprises the main sites for urban development and expansion.

Considering the significant farmland loss under rapid urbanization, the Chinese central government has implemented its most restrictive farmland policy to date, along with strong regulations restricting the conversion of farmland for non-farm use. On January 1, 1999, the central government amended the Land Administration Law 1998, which aims to protect farmland in the face of rapid urbanization and economic development. It includes a series of farmland protection provisions with the goal of zero loss of farmland. This dynamic balance policy was first published in 1994. It requires local governments to offset the loss of farmland occupied by construction by providing the same amount of farmland, adjusted for quality, through land reclamation, consolidation, and rehabilitation (Ding, 2003). This dynamic balance policy has been the main tool used by central government to restrain local governments for protecting farmland. In practice, however, some local governments have converted high-quality farmland for non-agricultural use and offset this loss through the conversion of other land within same province to low-quality farmland (Cheng et al., 2015).

China's farmland protection policy is implemented through a hierarchical top-down approach. Central government oversees and designates provincial-level governments' farmland protection responsibilities. Provincial-level governments, meanwhile, allocate responsibility and farmland protection quotas to prefecture-level cities. The same logic applies to county and township governments. Low-level governments' conversion of farmland into urban land must abide by the land use master plan (which includes setting a long-term farmland protection quota and farmland conversion quota) and annual land use plan (including breaking down the long-term farmland conversion quota into an annual land use quota) (Wang et al., 2010). Moreover, low-level governments' conversion of farmland for nonagricultural use must be approved by higher governments.

4. Empirical Framework

4.1 Econometric specifications

First, we present the baseline empirical specification. Our empirical analysis aims to examine the impacts of urbanization on farmland. Based on the theoretical framework of the urban bid-rent model and local government land supply behavior discussed in section 2.1, conversion of farmland to urban land in China is driven by urbanization, industry development, population, and other factors. According to the literature (Deng et al., 2015; Jiang et al., 2012; Huang et al., 2005), we control relevant impact factors and set the following baseline empirical equation.

$$Farmland_{it} = \alpha + \beta_1 Urbanization_{it} + \gamma X_{it} + u_i + v_t + \varepsilon_{it} \quad (1)$$

Where the dependent variable is farmland area in equation (1). *Urbanization*, our interested variable, is represented by urban population share or urban built-up land share. X_{it} is a set of controls, including per capita GDP, share of secondary industry, share of tertiary industry, population density and the geophysical factors. The geophysical factors including temperature and precipitation could influence farmland through the supply side (Deng et al., 2015). For example, areas with high temperature and precipitation could provide more arable land. u_i and v_t are city and year fixed effect, respectively.

We also use alternative measurements for urbanization and to check for robustness. We use the average annual stable night lights data composited from DMSP/OLS over 1992–2013 to measure the urbanization of Chinese prefecture-level cities. Compared to statistical data, remote-sensed luminosity data has the advantages of being low cost, up-to-date and less manipulated, and has been successfully used to measure urban areas or urbanization (Small et al., 2005; Small et al., 2011; Liu et al., 2012; Gibson et al., 2015). We use 75% and 50% of the maximum value (DN=63) as thresholds, consistent with Liu et al. (2012), to calculate the share of urban pixels in each prefecture city and generate two time-series of urbanization (Urban light75 for a 75% luminosity threshold, urban light50 for a 50% luminosity threshold).

Second, we further examine the farmland protection policy's impact on farmland area, and exploit the variation of time taken by local government to implement the dynamic balance policy to estimate its effect. We employ the difference-in-difference method (Angrist and Pischke, 2008), and set the estimating equation as follow:

$$Y_{it} = \alpha + \beta Policy_t * Treat_i + \gamma X_{it} + u_i + v_t + \varepsilon_{it} \quad (2)$$

Where Y_{it} is the outcome variable, farmland area. The variable X_{it} is set of control variables. $Policy_t$ is an indicator for the farmland dynamic balance policy period, which is set equal to 1 after 1998 (when the national 1998 Land Administration Law and dynamic balance policy implemented) and 0 otherwise. $Treat_i$ is a dummy for the city after implementing the farmland dynamic balance policy. Our difference-in-differences estimates are captured via the coefficient for the interaction term Policy*Treat.

Third, we also explore the underlying impact mechanisms of urbanization on farmland. Based on the behavior of local governments, which plays an important role in promoting urbanization and farmland conversion, we lay out two hypotheses. The first hypothesis concerns to the role of "land financing". Local governments' high reliance on land leasing revenue for financing urban construction induced a great amount of farmland loss (Huang and Du, 2017a; Lichtenberg and Ding, 2008；Tao et al., 2012). As a result, the impact of urbanization on farmland area might be larger in regions with a higher share of land-leasing revenues.

Hypothesis 1: The impact of urbanization on farmland area is negatively related with local governments' land financing dependence.

The second hypothesis relates to urban sprawl (low urbanization efficiency). Rapid urban sprawl of many Chinese cities has caused the rate of urban land expansion to exceed that of population expansion (Ye and Wu, 2014). As Chinese local governments have incentives to expand urban land areas, they request a great mount of farmland for urban construction (Huang and Du, 2017b; Lichtenberg and Ding, 2008; Xi et al, 2012), which induce the decrease of farmland area. Thus, the impact of urbanization on farmland area might be more significant in cities with higher urban sprawl.

Hypothesis 2: Urban sprawl negatively affects the impact of urbanization on farmland area.

To test the above two hypotheses, we set the empirical specification as follows.

$$Farmland_{it} = Urbanization_{it} + Urbanization_{it} * Land\ revenue\ dependence_{it} + \beta X_{it} + u_i + v_t + \varepsilon_{it} \quad (3)$$

$$Farmland_{it} = Urbanization_{it} + Urbanization_{it} * Urban\ sprawl_{it} + \beta X_{it} + u_i + v_t + \varepsilon_{it} \quad (4)$$

Where, *Farmland*$_{it}$, and *Urbanization*$_{it}$ are as previously defined. *Land revenue dependence*$_{it}$ is the share of land revenue in local budget revenue. *Urban sprawl* is defined as a dummy variable for whether urban built-up land expansion is proceeding faster than population expansion. X_{it} is a set of controls, as used before.

4.2 Data description

We employ Chinese prefecture-level cities' panel data from 1990–2013, which is sourced mainly from the China City Statistical Yearbook and China Land and Resource Yearbook. The definition and descriptive analysis of variables are provided in Table 1. We also use remote-sensed nightlights data from the Defense Meteorological Satellite Program's Operational Linescan System (DMSP/OLS), sourced from the United States Geographic Service (USGS), to derive alternative measurement of urbanization.

Table 1 Description of main variables

Variables	Definition	Period	Obs.	Mean	Std. dev.
Farmland	Arable land area, in hectares	1995–2013	6453	294.73	272.09
Urban population share	Share of urban population in total population	1990–2008	4751	0.31	0.15
Built-up land share	Share of built-up land in total city land	1990–2013	6284	0.012	0.025
Social economic factors					
Per capita GDP	Per capita GDP (10^4 Yuan)	1995–2013	6274	7405.74	10200.0
Share of secondary industry	Share of secondary-industry output in GDP (%)	1995–2013	5120	47.12	11.60
Share of tertiary	Share of tertiary industry output in	1995–	5120	35.14	7.96

industry	GDP (%)	2013			
Population density	Ratio of population to total city land (person/km^2)	1995–2013	6297	425.83	334.61
Land revenue dependence	Share of land revenue in budgetary revenue	2003–2013	3007	0.61	0.43
Per capita FDI	Per capita foreign direct investments (Yuan/person)	2003–2013	2960	328.21	655.05
Geophysical factors					
Temperature	Average temperature (℃)		7075	14.02	5.62
Precipitation	Average precipitation (m)		7075	0.90	0.48
Slope	Average slope (degree)		6925	18.49	9.89
DEM	elevation (1000 m)		6875	0.53	0.66
Provincial capital distance	Distance to the provincial capital city (1000 km)		6950	0.22	0.19
Port distance	Distance to the nearest large port (1000 km)		6950	0.66	0.42
land suitability index	ratio of land that is safe for urban development, below the slope of 15 degrees		6700	0.54	0.26
Others					
Urban light75	Ratio of urban areas using 75% of the maximum luminosity value as thresholds to classify a pixel as urban land	1992–2013	6116	0.02	0.07
Urban light50	Ratio of urban areas using 50% of the maximum luminosity value as thresholds to classify a pixel as urban land	1992–2013	6116	0.04	0.10
Policy	Dummy variable, 1 for after 1998	1990–2013	7075	0.64	0.48
Treat	Dummy variable, 1 for the city after implementing the farmland dynamic balance policy	1990–2013	6792	0.56	0.50
Urban sprawl	Dummy variable, 1 for urban built-up land expansion over population expansion	1990–2008	4491	0.48	0.50

4.3 Descriptive analysis

Fig. 1 portrays the spatial distribution of urban land expansion (land urbanization) and farmland change over 2000-2007. Cities in coastal areas, in the middle and lower reaches of

Yangtze River and in Yellow River areas, which experienced most rapid urban expansion, have significant loss in farmland.

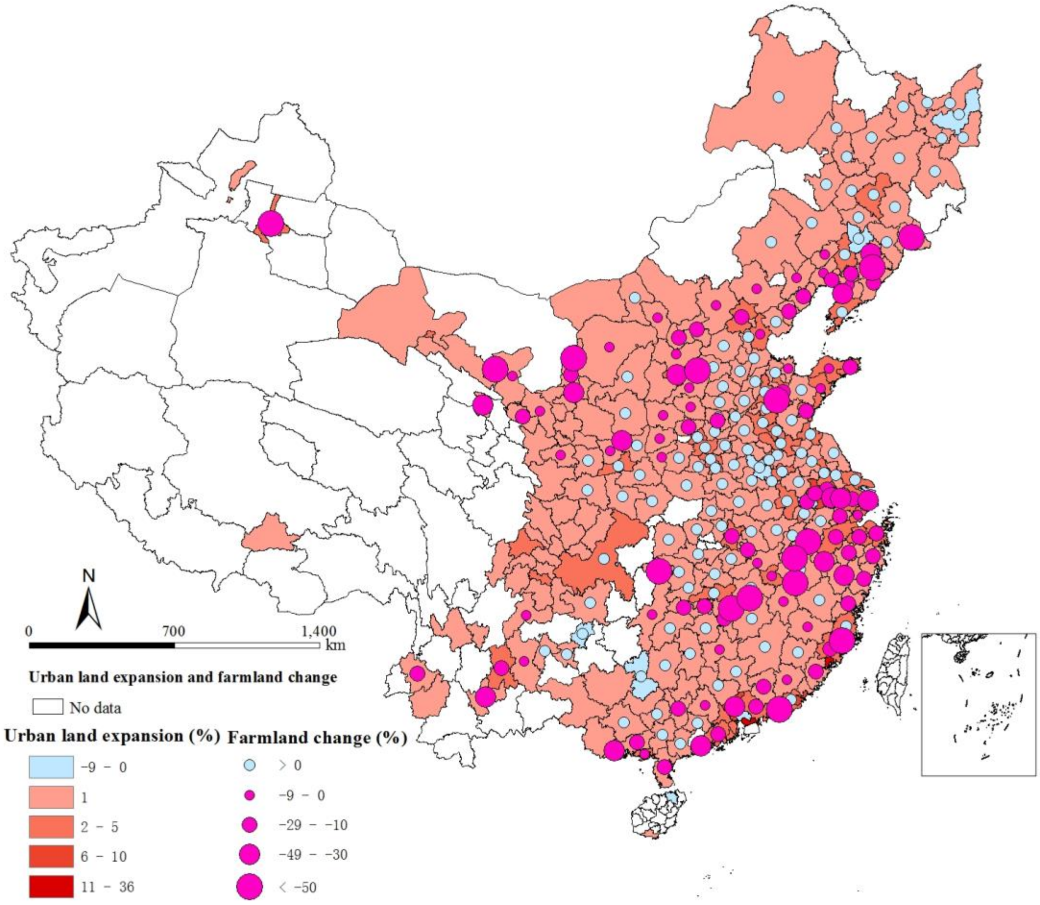

Fig. 1. Spatial pattern of urban land expansion and farmland change (2000-2007)

Fig. 2 shows the relationship between land urbanization (ratio of urban built-up land in total city land) and farmland over 1990-2013. There is a clear and negative relationship between land urbanization and farmland. That is, urban land expansion reduces the amount of farmland.

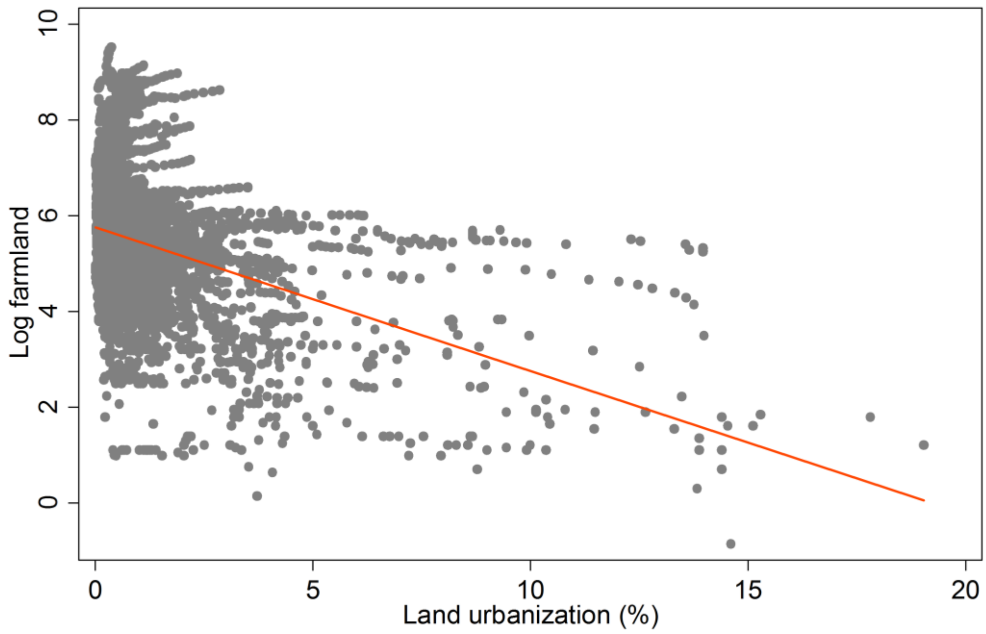

Fig. 2. Urban land expansion and farmland (1990-2013)

5. Empirical Results

5.1 Baseline Empirical Results

Table 2 reports our baseline estimation results for farmland. The first three columns show our baseline estimates for models with city and year fixed effects. The regression in column 4 further includes controls for social economic factors, including log per capita GDP, industry ratio, service industry ratio, and population density. The estimated effect of urbanization on farmland becomes less, but is still statistically and quantitatively significant. The regression in column 5 further includes geophysical factors and the coefficient of urban population share is close to that in column 4. The results in columns 4 and 5 imply that a 1% increase in urbanization level is associated with a 3% decrease in farmland. Alternatively, a one standard deviation increase in urban population share is associated with decrease in farmland of 1%.

The estimated coefficients on urban population share are robust to the addition of more controls. The regressions in columns 1–5 confirm a negative relationship between urbanization and farmland, indicating that urbanization leads to significant farmland loss. Compared to the coefficient of urban population share, the effect of build-up land share has large negative effects on farmland, suggesting that land urbanization could cause much more farmland loss than population urbanization. This is because the Chinese urbanization development strategy depends heavily on large-scale urban land expansion and farmland conversion, which confirms the studies such as Jiang et al. (2012), and Wang and Scott (2008).

For the effects of socio-economic characteristics, the coefficient on log per capita GDP is negative, indicating that economic growth has a negative effect on farmland. A 1% in economic growth is associated with a 0.4% decrease in farmland. This implies that the current extensive economic development mode is inefficient and consumes too much land, especially farmland. If we compare this with Japan, in the same rapid economic growth period, the effect of economic growth on farmland is almost as much as 8 times larger[4] (Dang, 2010). Regarding the effects of industry structure, secondary and tertiary industry share both have negative effects on farmland, which is contracted to urban economists' prediction that agglomeration economics would intensively use land and thus save land. This suggests the extensive economic development model in China. The coefficient on population density is negative and significant, indicating that geographical concentration of a population deceases with farmland. This result suggests that the land-based urbanization development mode is to occupy more farmland in suburban rather than in other areas.

To check the possible collinearity between variables, we use VIF (variance inflation factor) test and found the VIF of variables are less than 5, which indicates no serious multicollinearity problem.

Table 2 Baseline estimation results for farmland

Variables	(1)	(2)	(3)	(4)	(5)
Urban population share	-6.54***		-5.19***	-2.61***	-2.76***
	(0.26)		(0.36)	(0.38)	(0.34)
Built-up land share		-16.31***	-10.03***	-4.13***	-5.52***
		(6.09)	(2.12)	(1.43)	(1.63)
Log per capita GDP				-0.40***	-0.35***
				(0.08)	(0.07)
Secondary industry share				-0.01*	-0.00
				(0.00)	(0.00)
Tertiary industry share				-0.02***	-0.02***
				(0.00)	(0.00)
Log population density				-0.92***	-0.69***
				(0.16)	(0.11)
Temperature					-0.03**
					(0.02)
Precipitation					-0.31*
					(0.16)
Slope					-0.03***
					(0.01)
DEM					-0.55***
					(0.20)
Provincial capital distance					-0.08
					(0.31)
Port distance					-0.50**
					(0.25)
Constant	7.78***	5.83***	7.43***	16.39***	16.45***
	(0.09)	(0.09)	(0.11)	(0.94)	(0.81)
Year fixed effect	Yes	Yes	Yes	Yes	No
City fixed effect	Yes	Yes	Yes	Yes	No

N	4462	5926	4449	3471	3393
R^2	0.735	0.455	0.762	0.735	0.734

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are clustered at prefecture city level.

We further explore the heterogeneous effects of urbanization on farmland. Here we are primarily interested in the relationship between urbanization and farmland area across city size, time and region, so we do not add all controls. Table 3 presents the estimation results across city, region, and period. First, columns 8 and 9 show that urbanization consumes more farmland in the middle and western areas than in eastern area. This is because the middle and western areas experienced rapid urbanization and farmland loss recently. In addition, disasters and the policy of returning farmland to grassland and forests may also significant induce more farmland loss in middle and west areas. Second, columns 1–5 show that medium-sized cities (1-5 million people) consume much more farmland than larger cities do. This result is consistent with Deng et al. (2015), which found that small town urbanization accelerates the occupation of farmland. No significant relationship was found between urbanization and farmland loss in megacities (population over 10 million). This indicates that city size has significant impact on the relationship between urbanization and farmland loss. Larger cities have a higher agglomeration economics effect, and thus consume less farmland for urban expansion. Finally, urbanization had a much larger effect on farmland before the year 2000. This is because the accelerated urbanization and weak regulation before 2000 led to higher levels of farmland loss.

Table 3 Estimation results for farmland across city, region, and time

Variables	Across city (Population million)					Across time		Across region	
	>10	5–10	1–5	0.5–1	<0.5	1990–1999	2000–2013	East	Middle–west
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Urban	-0.55	-0.72	-	-1.31	-0.22	-4.87***	-0.41*	-	-5.30***

population share			2.19***					1.78**	
Urban land share	(0.39)	(0.53)	(0.43)	(0.91)	(0.42)	(0.66)	(0.24)	(0.79)	(0.59)
Constant	- 16.42**	-2.44	-6.03	- 14.24*	- 10.47***	-10.78***	-2.88	-4.88	-10.48***
	(5.48)	(1.78)	(4.01)	(8.18)	(2.95)	(2.84)	(3.07)	(3.46)	(3.02)
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	63	1140	2742	273	231	2155	2412	1684	2711
R^2	0.695	0.151	0.258	0.236	0.551	0.777	0.102	0.327	0.801

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are clustered at prefecture city level.

5.2 Robustness analysis and additional evidences

5.2.1 Endogeneity problems

Endogeneity problems may exist with respect to urbanization variables for two reasons. First, some omitted variables, such as uncontrolled local city characteristics that change over time, may be correlated with urbanization and lead the urbanization variable to be correlated with the error term. Second, urbanization and farmland may impact each other. On the one hand, farmland may impact urbanization through providing a place for urbanization to take place. On the other hand, urbanization may affect farmland by inducing to the conversion of farmland for urban development.

To solve such problems, we adopt the instrumental variable (IV) method. We employ city-level IVs which are correlated with urbanization but not correlated with the unobserved determinants of a city's farmland. First, following Saiz (2009) and Chen and Kung (2016), we construct a similar land suitability index—share of land below the slope of 15 degrees—to measure the ratio of land that is suitable for urban development, based on China's digital elevation model data at the 30 meters resolution[5]. Second, we use foreign direct investment (FDI) policy (represented by per capita FDI). This land use-related policy factor basically influences farmland through impacting urbanization development modes (Deng et al., 2015). We use the city's per capita FDI as an IV for FDI, as it is most likely to influence on farmland area through urbanization. Third, we use a 10-year lagged urbanization variable as another IV for past urbanization as these influence the current urbanization development but are unlikely to directly impact the city's farmland area. The rationale for using lagged urbanization as an instrument is that this persistence is unrelated to current farmland area.

Table 4 reports the IV regression results for farmland. The F-statistics are all significant in Columns 1, 3 and 5, suggesting that these instruments are not weak and satisfy the relevance requirement. In addition, our instruments are just identified and do not have overidentifying restriction problems. The results in Columns 1, 3 and 5 suggest that the IVs are significantly correlated with urbanization (urban population share). Columns 2, 4 and 6, reported the second-stage results, indicates that the coefficients of urban population share are negative and statistically significant for the different IVs. The coefficients of the IV estimate, local average treatment effect, vary somewhat across instruments, but are close to and consistent with the fixed effects estimation from Table 2. These results reassure us that our estimate are robust.

Table 4 IV estimation results for farmland

Variables	First stage	Second stage	First stage	Second stage	First stage	Second stage
	Urbanization	Log farmland	Urbanization	Log farmland	Urbanization	Log farmland
	(1)	(2)	(3)	(4)	(5)	(6)
Urban population		-2.101***		-2.025***		-1.345***

share		(0.462)		(0.225)		(0.206)
Land suitability	-0.407***					
index	(0.033)					
Log capita FDI			0.051***			
			(0.002)			
Urban population					0.457***	
share 10 years lag					(0.016)	
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes
N	3319	3319	1472	1472	2011	2011
F-statistic	146.13***		125.60***		202.40***	
R^2	0.284	0.436	0.436	0.488	0.477	0.458

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are clustered at prefecture city level

Other controls include secondary industry share, log population density, temperature, precipitation, slope, DEM, provincial capital city distance and port distance.

5.2.2 Using DMSP/OLS data

China's urbanization statistics are based on the population of permanent residents, who are considered those who have resided in one city for more than six months. Rural migrant workers are thus also included in the urban population, which may bias the urbanization level. Table 5 presents the estimation results using DMSP/OLS data. The coefficients of Urban light75 and Urban light50 are all statistically significant and negative, which confirms that urbanization has a negative impact on farmland area. The estimated effect of urbanization on farmland is close to 1, which is similar as the results in columns 4 and 5 of Table 2.

Table 5 Estimation results using DMSP/OLS data

Variables	Log farmland	Log farmland
	(1)	(2)
Urban light75	-0.87**	
	(0.43)	
Urban light50		-1.11***
		(0.32)

Log farmland		
Log per capita GDP	-1.09***	-1.08***
	(0.13)	(0.13)
Constant	16.06***	16.02***
	(1.23)	(1.22)
Year fixed effect	Yes	Yes
City fixed effect	Yes	Yes
Controlled variables	Yes	Yes
N	5595	5595
R^2	0.456	0.459

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are clustered at prefecture city level

5.2.3 Impact of farmland protection policy on farmland

The 1998 Land Administration Law (farmland dynamic balance policy) released on January 1, 1999. However, local governments gradually implemented this dynamic balance farmland policy and revised their land use regulations in accordance with it. Farmland area is expected to have increased more following the farmland dynamic balance policy in more rapidly urbanized areas. To consider the heterogeneous effects across different urbanization areas, we further interacted Policy*Treat with urbanization in equation (4). Data on the years in which the local province started to implement the dynamic balance policy was drawn from an internet search.

Table 6 reports the estimated results for the impacts of dynamic balance policy on farmland area. Column 1 shows that the dynamic balance policy had a significant positive effect on farmland. Implementation of this dynamic balance policy induces a 4% increase in farmland area. Column 2 further shows that the dynamic balance policy has a larger effect on farmland area in rapid urbanization areas. These results suggest that the farmland dynamic balance policy have positive influences on farmland area, especially in rapid urbanized areas. Although our study found that farmland dynamic balance policy is significantly able to retain farmland area loss under urbanization, there remains a risk that farmland quality maybe lowered. In fact, some scholars suggest that the new replaced farmland has lower quality or productivity than the old ones, which may harm food security (Cheng et al., 2015).

Table 6 Results for the impacts of farmland protection policy on farmland area

Variables	Log farmland	Log farmland
	(1)	(2)
Urban population share	-4.91***	-2.91***
	(0.36)	(0.47)
Urban land share	-11.46***	-5.82***
	(2.16)	(1.96)
Policy	0.33***	0.18***
	(0.02)	(0.02)
Policy*Treat	0.33***	0.16***
	(0.02)	(0.02)
Other controls	No	Yes
City fixed effect	Yes	Yes
N	4688	3471
R^2	0.725	0.665

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are clustered at prefecture city level. Other controls include log per capita GDP, secondary industry share, tertiary industry share, log population density.

5.2.4 Understanding the mechanism of urbanization and farmland change

Table 7 presents the estimations results for equations (4)-(5). Column 1 shows that the coefficient of the interaction term, land financing dependence*urbanization, is statistically significant and negative. This result implies that urbanization has a larger negative effect in cities that rely more heavily on land-leasing revenue, which is consistent with Hypothesis 1. The results in column 2 shows that the interaction term, urban population share* sprawl, is significantly negative. This suggests that the impact of urbanization on farmland is larger in areas with more significant urban sprawl or less urbanization efficiency, which consistent with hypothesis 2. Overall, the above two hypotheses are both confirmed. Compared to coefficients on the interaction terms, Hypothesis 1 is more important. This is because that local governments' land finance dependence behavior has more profound negative effect on farmland than urban sprawl. Local governments prefer to convert farmland to urban land for gaining land revenue and urban development, which significantly induces farmland loss.

Table 7 Estimation results for the impact mechanism of urbanization and farmland area

Variables	Log farmland	Log farmland
	(1)	(2)
Urbanization	0.63*	-0.27
	(0.325)	(0.555)
Land revenue dependence	-0.01	
	(0.013)	
Urbanization*Land revenue dependence	-0.47**	
	(0.230)	
Urban sprawl		0.01
		(0.011)
Urbanization*Urban sprawl		-0.41**
		(0.192)
Other controls	Yes	Yes
Year fixed effect	Yes	Yes
City fixed effect	Yes	Yes
Observations	2,845	3,439
R-squared	0.154	0.666

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. We use urban light 75 defined as before to measure urbanization. Standard errors are clustered at prefecture city level. Other controls include log per capita GDP, secondary industry share, tertiary industry share, log population density.

6. Conclusions

Over the past few decades, China’s farmland loss problem in the face of rapid urbanization has become a topic of increasing concern. We examine the impact of different urbanization modes on farmland area using Chinese prefecture cities’ panel data. To avoid problems of endogeneity, we explore the variation of land revenue dependence, land suitability index, and FDI as instrumental variables to estimate the impacts of urbanization on farmland area. We find that urbanization has a significant influence on farmland area, such that a 1% increase of urban population share is associated with a 3% decrease of farmland.

We also find heterogeneous effects of urbanization on farmland area. Land urbanization, the expansion of urban built-up land, has a larger effect on farmland area than population urbanization. Urbanization has much more influence in the more developed eastern areas, and after the year 2000. Moreover, the urban population and built-up land expansion have varying impacts on farmland loss across different urbanization modes. Compared to the effects of the large cities (urban population over 1 million), farmland loss due to urbanization in medium-sized and small cities has been much more significant than that in large cities. The results suggest that policies should be designed to promote the efficient development of urbanization and to regulate farmland conversion in medium-sized and small cities, which would help alleviate farmland loss.

China has implemented the world’s strictest farmland protection policy. Our empirical results found that China’s farmland protection policy, which has been in place since 1998, has had a significant positive effect on farmland area. To protect farmland in the new urbanization era in China, the government should keep the current farmland protection policy in place and strive to balance the relationship between urbanization development and farmland preservation. As land urbanization cause much more farmland loss than population urbanization, measures of regulating urban land expansion and promoting intensive urbanization is needed to protect farmland. In addition, local governments' incentive should be transformed from land revenue centered to ecological protection centered, protecting the ecological function and services of land use, for better preserving farmland under rapid urbanization development. The government should advance medium-sized and small cities' urbanization efficiency, promote the efficient use of rural land for construction and township business activities and save farmland under rapid urbanization.

Due to the data limitation, we evaluate the net effect of urbanization on farmland, and cannot decompose the source of farmland loss due to different impact channels of urbanization, including agglomeration and sprawl channels. More accurate data and methods for evaluating the contribution of different channel to farmland land loss are needed in the future research. Moreover, further work should explore the underlying processes between urbanization and farmland changes across different countries and different urbanization stages.

Notes:

1. Calculated from Statistical Yearbook of China (1979-2015).
2. Calculated from China Land and Resources Statistical Yearbook (2008–2013), and China City Statistical Yearbook (2008–2013).
3. Calculated from China City Statistical Yearbook (2001-2015).

4. See http://news.xinhuanet.com/2011-02/17/c_121090691.htm.

5. Water bodies is subtracted from the land with a slope below 15 degrees, as it is not suitable for development.

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