sustainability

MDPI

Article

Modeling Urban Expansion and Agricultural Land Conversion in Henan Province, China: An Integration of Land Use and Socioeconomic Data

Li Jiang and Yonghui Zhang *

School of Economics, Renmin University of China, 59 Zhongguancun Street, Beijing 100872, China; li.jiang@ruc.edu.cn

* Correspondence: yonghui.zhang@hotmail.com; Tel.: +86-10-8250-0732; Fax: 86-10-6251-1091

Academic Editors: Federico Martellozzo and Beniamino Murgante
Received: 20 July 2016; Accepted: 3 September 2016; Published: 9 September 2016

Abstract: China has experienced rapid urban expansion and agricultural land loss, and the land conversion has accelerated in central provinces since the mid-1990s. The goal of this paper is to examine the relative importance of socioeconomic and policy factors on the urban conversion of agricultural land in Henan Province, China. Using panel econometric models, we examine how socioeconomic and policy factors affect agricultural land conversion at the county level across three time periods, 1995–2000, 2000–2005, and 2005–2010. The results show that both urban land rent and urban wages are essential factors that positively contribute to the conversion of agricultural land. It is also found that per capita GDP is correlated with more urban development and agricultural land loss. Consistent with expectations, agricultural financial support is negatively correlated with agricultural land conversion, suggesting a policy success. Finally, the decomposition analysis illustrates that urban wages are the most influential positive factor and agricultural financial support is the most influential negative factor affecting the urban conversion of agricultural land.

Keywords: urbanization; farmland loss; urban land-use change; land use sustainability; inland China; longitudinal data

1. Introduction

China has experienced rapid urban transformation since its economic reforms in the 1980s, represented by significant changes in the demographic composition and large-scale expansion of the urban landscape [1]. The proportion of urban population increased from 22% in 1983 to 47% in 2010 [2]. This trend is expected to continue, with a projected increase of 375 million in China's urban population over the next three decades [3]. Satellite imagery shows that the urban areas of China increased by almost 25% during the 1990s [4]. The resultant urban conversion of agricultural land has led to a significant loss of agricultural land [5,6]. Calculations derived from satellite imagery demonstrate that urban development occurred on more than 334 thousand ha of cultivated land between 1986 and 2003, accounting for 21% of the total loss of cultivated land in China [7]. Although urbanization was concentrated in coastal regions in the early period of the economic reforms, rapid urban land expansion began to take place in the vast inland region due to the "Go West" Policy, a policy shift propagated by the central government that aimed at directing industrial and economic development from the coastal areas to the interior regions since the mid-1990s [8]. This has further resulted in massive losses of agricultural land in the central provinces of the country [9,10]. In addition to the direct loss of agricultural land due to urban expansion, the diversification and westernization of dietary patterns are placing additional pressure on the country's agricultural land and production [11]. The combination of continued growth of Chinese cities, limited cultivated land, and changes in the

composition of domestic food demand puts existing agricultural land at risk for conversion to urban areas, and natural ecosystems at risk for conversion to farmland. Therefore, an understanding of the mechanisms and linkages of urban expansion and agricultural land loss is critical in order to alleviate the tension between urban and agricultural land uses, and to achieve the twin goals of urban growth and preservation of farmland and natural ecosystems.

Despite the magnitude of urban expansion and agricultural land loss in many areas of the country, there is limited understanding about the patterns and the underlying processes of urban conversion of agricultural land at the regional scale. A majority of the research on urban expansion in China has been devoted to studying the growth of individual cities or regions [8,12–14], especially coastal regions of the country. However, few of them quantitatively examine the urban conversion of agricultural land using systematic methods. There are exceptions. Using high-resolution remote sensing data, Seto et al. estimate econometric models of the socioeconomic drivers of urban land use change in the Pearl River Delta, China [15]. Unlike the previous studies looking at the spatial extent of cities, our study directly investigates the mechanism of the area of land conversion, and it focuses on central regions of China. On the other hand, most of the research on agricultural land conversion in China has focused on studying the temporal and spatial dynamics of agricultural land use change [16,17]. Very few studies have explicitly explained the processes and the shifting socioeconomic environments that drive the land use change [18,19]. Therefore, this study also contributes to the understanding about the mechanisms of the changes in China's agricultural land. Furthermore, this study simultaneously takes into consideration the legalization of the land leasing market, and the increasingly decentralized and unstructured nature of China's urban development. Because of this new trend of urbanization, socioeconomic factors and policies at the local level have exerted fundamental influences on the magnitude and the process of urban expansion. Incorporating local socioeconomic factors and exploring their impacts on urban conversion of agricultural land at the county level facilitate a better evaluation of the effectiveness of local land use management and planning.

This study examines the relative importance of socioeconomic factors in driving the urban conversion of agricultural land at the county level in Henan Province, China. Using the panel econometric method, we ask the following questions. What socioeconomic factors and policies drive the urban conversion of agricultural land at the county level in Henan Province? What is the relative importance of these factors? What are the impacts of key economic factors from the bid-rent model on the urban conversion of agricultural land? What is the impact of off-farm wages on the urban conversion of agricultural land? What is the impact of agricultural financial support on the urban conversion of agricultural land? The study intends to derive more insights about the underlying processes of urban expansion, and to provide policy implications regarding the efficiency and sustainability of land use.

2. Study Area

Situated in central China, Henan Province has the largest population and is the first major agricultural province in China [20]. With an area of 167,000 km^2, Henan Province covers a large part of the fertile and densely populated Central Plains region. The Yellow River, the river with the highest sediment concentration in the world, flows through the province [21]. The region has a semi-humid to humid continental climate, with extensive monsoonal influence. Winters are cold and dry, while summers are warm and in many areas hot. The average annual temperature ranges from 12 °C to 16 °C. The average annual precipitation varies between 500 mm and 900 mm and 50% of the rainfall is concentrated during the summer in the form of storms [20]. The growing season for wheat and rice extends from March until late October, which implies that double cropping is possible provided that the second round of crops is planted. Vegetables can be cultivated throughout the year.

Henan Province is the first of the thirteen major grain producing areas designated by the central government in 2003 [20]. In 2014, the output of grain in Henan Province reached 57.5 million tons, accounting for 9.5% of the total output of the country. During the past several decades, Henan Province

has experienced rapid rates of urban and economic growth. The proportion of urban population increased from 15.4% in 1989 to 38.8% in 2010 [20]. This has resulted in both the decline of cultivated land and rising labor shortage in the agricultural sector. From 1989 to 2010, the urban area of Henan Province increased by 223,713 ha, equivalent to 15.7% of the urban area in 1989. During the same period, the cultivated land area of Henan Province decreased by 161,169 ha, equivalent to 1.9% of the total in 1989, according to calculations based on the land use data set from the Chinese Academy of Sciences (CAS). The combination of the continued growth of cities, limited arable land, great population pressures, and unsustainable agricultural practices has led to severe environmental degradation in the province. How to balance the pressure between urban growth and agricultural land use and preservation while improving the sustainability of land uses becomes a real challenge.

3. Literature Review on Theories of Urban Land Use Change

The literature on urban land use change provides explanations about major factors contributing to the expansion of urban areas. We use two categories of theories to frame our study of urban expansion and agricultural land conversion: the microeconomic theory of land use change [22,23] and the urban bid-rent model [24].

The microeconomic theory of land use change describes the urban development of agricultural land as the outcome of decisions made by individual land users who attempt to maximize the expected profits of individual land parcels. Spatially-explicit land use models based on microeconomic theory are powerful tools for understanding the spatial and temporal dynamics of land use decisions among individual agents. However, they do not provide information about the cumulative amount of land use change [25]. Moreover, with little connection to the macro-environment, these land use models do not take account of the institutional and socioeconomic factors that are exogenous to the micro-environment of individual land users.

The urban bid-rent model is the basis of urban economic theory, and it explains the accumulated outcome of urban land use change. The classical bid-rent model theoretically defines the distance to a city center as the single determinant of land rents and the spatial distribution of different land uses. Expansions of the bid-rent model further incorporate the influence of income [26], transportation [27], and spatial heterogeneities in terms of soil quality, climate, natural resource endowments, etc. [28]. Under the guidance of the bid-rent model, aspatial land use models have been developed and empirically implemented in order to understand the change in spatial scale of cities [29,30], industrialization and urban expansion [31], and urbanization and the conversion of agricultural and natural land covers [15]. Relying on empirical evidence in the U.S., Brueckner and Fansler found that the fundamental factors identified by the bid-rent model, including population, income, transportation costs, and agricultural land rent, are of primary importance in determining urban spatial scales. McGrath reinforced the former argument, and found that unknown factors beyond those from the bid-rent model also contribute to urban expansion.

The presence of those unknown factors indicates that the bid-rent model can only explain the increase of urban areas to certain extent. Since the late 1980s, China's central government has been taking a cautious and gradual approach to reforming the land markets. Although the land-use rights system is established and land prices have started to rationalize land-use allocation and land use, the state holds stringent control of land supply through its monopolization of the first level of land markets [32]. Given the lesser maturity of the land leasing market, there are additional reasons why the bid-rent model may be limited. Researchers have highlighted the role of policy intervention and the shifts of macroeconomic environments on urban land-use change in China, including the importance of foreign direct investment and off-farm wages [15], the relaxation of the "hukou" system of residency permits [33], and governance decentralization and the profit-seeking behaviors of local agents [6]. In terms of rural policies, notably, the Chinese government has consistently increased the amount of funds and investment allocated to agriculture in order to improve agricultural productivity [34]. Moreover, there has been a major shift from taxing agriculture before 2004 to subsidizing grain

farming since then [35]. Agricultural land conversion has probably been affected by these rural policy interventions through relaxing liquidity constraints and influencing land use choices of farmers.

4. Data

With the objective to understand the underlying process that drives urban expansion and agricultural land conversion at the regional scale, high resolution, spatially explicit data on land-use changes are required. Aggregated land use data that are available in provincial statistical yearbooks lack the adequate temporal and spatial resolution for the study. Moreover, land use data published by the Chinese government have been questioned for underestimating the quantity of agricultural land and its rate of loss [5].

Therefore, the study used a land use data set that was derived from the U.S. Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM) sensors, and analyzed by the Chinese Academy of Sciences (CAS) [36]. This national data set, which has undergone extensive development and testing, contains moderate resolution and spatially explicit information about the extent of urban and cultivated land for the years 1995, 2000, 2005, and 2010. Specifically, the cultivated land used in the study consists of two land use categories—dry land and paddy land. The urban land comprises two categories of built-up areas—the urban core and the other built-up area. The urban core is defined as all built-up areas that are contiguous to urban settlements. The other built-up areas refer to roads, mines, and development zones that are not contiguous with the urban core. Using data from these years as baselines, we further calculated the amount of cultivated land loss resulting from urban conversion for the periods 1995–2000, 2000–2005, and 2005–2010. We obtained a land use data set on cultivated land area, urban land area, and conversion land area for all 108 counties of Henan Province.

It is hypothesized that the urban conversion of agricultural land is due to the effects of two key determinants of urban extent from the bid-rent model (land rents and income) and other important socioeconomic factors documented in empirical studies (off-farm wages and agricultural financial support). In addition to the land use data, the study used socioeconomic data on total and sector gross domestic products (GDP) for individual counties, total population for individual counties, average urban wages of staff and workers for individual counties, and expenditure of government for supporting agricultural production and operation for individual counties as measures to test the aforementioned hypotheses. All the data were collected from the Henan Statistical Yearbooks [20].

The study included a group of biophysical variables in order to capture the geographical heterogeneities across space. The second data source was used to test how biophysical factors including relative location, terrain conditions, and climate characteristics affect urban expansion and cultivated land conversion. The distance of each county seat to the provincial capital, and the distance of each county seat to the nearest highway were calculated by Deng et al. using data from the CAS data center [31]. The data reflecting terrain attributes were generated from China's digital elevation model data set by the CAS. The climate data were created by Deng et al. using the site-based observations from the China Meteorological Administration [31]. The biophysical data set was also combined with the list of counties of Henan Province.

5. Empirical Models and Variable Specifications

We followed guidelines from the literature on urban land-use change to select the variables and construct the panel econometric models about the amount of urban conversion of agricultural land for all of the 108 counties across three time periods. In the panel econometric models, the dependent variable is *ConvertedLand*, the amount of cultivated land in a county that has been converted to urban uses for each of the three time intervals: 1995–2000, 2000–2005 and 2005–2010 (Table 1). The urban bid-rent model identifies land rents and income as important determinants of urban extent. At the same time, empirical studies report that off-farm wages and agricultural financial support are important factors that drive urban expansion and agricultural land conversion in China. Combining these two arguments, we select four socioeconomic variables at the county level to construct the model.

Table 1. Description of variables.

Variable	Description
Dependent variable	
ConvertedLand	Area of land converted from agriculture to urban uses in a county within 1995–2000, 2000–2005, or 2005–2010 intervals (hectare)
Independent variables	
LandRentRatio	$\frac{\text{GDP in agricultural sector/area of agricultural land}}{\text{GDP in industrial and service sectors/area of urban land}}$ (ratio)
UrbWage	Average urban wages of staff and workers (thousand yuan)
GDPpct	GDP per capita (thousand yuan)
AgExp	Per capita expenditure of government for supporting agricultural production and operation (yuan)
DistPvcap	Distance from the county seat to the provincial capital (km)
DistHighw	Distance from the county seat to the nearest highway (km)
PlainRatio	Ratio of land with an average slope of less than eight degrees (ratio)
Elevation	Average elevation (km)
Sun	Annual average sunshine hours (hour)
Humudity	Annual average relative humidity (%)

Note: 1 Chinese yuan ≈ 0.15 US dollars.

The study intends to explain the change in *ConvertedLand* as a function of land rents, income, off-farm wages, agricultural financial support, and a range of environmental conditions. *LandRentRatio* is defined as the ratio between agricultural land rent and urban land rent in a county for a given year (1995, 2000 or 2005). The conversion of cultivated land to urban land is affected by land rents and land prices associated with individual land uses. Since there is no consistent information about land rent across counties in Henan Province, we use the value of GDP of agricultural sector divided by cultivated land area as a proxy for agricultural land rent and the value of GDP of industrial and service sectors divided by urban land area a proxy for urban land rent [15]. *UrbWage* is average urban wages of staff and workers for a county in a given year. High urban wages, which indicate greater off-farm opportunities, are expected to increase the opportunity costs of farming, and result in labor scarcity in the agricultural sector [37]. *GDPpct* is the gross domestic output per capita of a county for a given year and is used as an indication of income level for the county. *AgExp* represents per capita expenditure of government for supporting agricultural production and operation in a county for a given year. Agricultural investments and funds from the national and provincial governments, which are allocated at the county level, are aimed at enhancing agricultural productivity and promoting rural economic development and farmland preservation. This variable is used to test the effect of rural policy intervention on the conversion of agricultural land to urban uses.

Since spatial heterogeneities and environmental conditions affect urban growth, a group of biophysical variables are specified and used to account for heterogeneities across space. Specifically, *DistPvcap* represents the distance from the county seat to the provincial capital and *DistHighw* represents the distance from the county seat to the nearest highway. Together, they provide information about the relative location of a county and they do not change over time. *PlainRatio* is the ratio of land in a county with a slope of less than eight degrees and *Elevation* is the average elevation of a county. These two time-invariant variables measure the average terrain condition or suitability for urban construction in a county. Finally, Sun is the annual average sunshine hours, and Humidity is the annual average relative humidity in a county for a given year. These two time-variant variables are included as controls for climatic characteristics.

Table 2 presents the descriptive statistics for all variables used in the model. Through the whole study period, the amount of conversion of agricultural land to urban uses in Henan province increased steadily from 37,734 ha for the 1995–2000 interval to 38,122 ha for the 2000–2005 interval, and to 39,270 ha for the 2005–2010 interval. Between 1995 and 2005, land rent ratio declined dramatically from 0.12 to 0.08, due to the rise of urban land rent and the decrease of agricultural land rent. During the same period, average urban wages increased from 3395 yuan to 8491 yuan, while GDP per capita increased nearly three-fold from 2876 yuan to 8573 yuan, according to the price level of 1995. Per capita expenditure of government for supporting agricultural production and operation increased substantially from 9.30 yuan in 1995 to 49.39 yuan in 2005, according to the price level of 1995.

Table 2. Description statistics for variables used in the study.

Variable	Number of Observations	Mean	Standard Deviation	Maximum	Minimum
ConvertedLand	324	355.33	149.92	780.35	85.59
LandRentRatio	324	0.099	0.056	0.29	0.0029
UrbWage	324	5.61	2.39	15.30	2.38
GDPpct	324	3.84	4.79	25.23	1.33
AgExp	324	24.99	25.60	208.67	3.02
DistPvcap	324	144.47	60.74	275.09	30.30
DistHighw	324	88.64	62.54	220.012	6.43
PlainRatio	324	0.66	0.36	1	0.012
Elevation	324	0.20	0.23	1.11	0.034
Sun	324	5.58	0.58	7.13	4.20
Humudity	324	67.89	4.30	75.38	57.38

The simplest linear panel econometric model for the relationship between the amount of conversion of agricultural land to urban uses and its socioeconomic and biophysical determinants can be specified as

$$Log(ConvertedLand)_{it} = \mathbf{X}_{it}\beta + u_{it}, \quad (1)$$

where $Log(ConvertedLand)_{it}$ is the log of urban conversion of agricultural land for county i in year t. $\mathbf{X}$ is a matrix of explanatory variables. β is a vector of regression coefficients to be estimated. u is a random disturbance term with mean 0. This standard linear pooling model assumes that β is the same for all counties and all time periods. Next, we implement the Lagrange multiplier test of individual effect based on the result of the pooling model [38], and we reject the null hypothesis that variances across entities are zero (Chisq = 231.18, df = 1, p-value < 0.00001). With evidence of significant differences across counties, a treatment of the individual effects has to be incorporated into the model in order to capture county-specific heterogeneities that may bias the coefficient estimates.

Either the fixed effects model or the random effects model can be specified to account for the spatial heterogeneities and stable unobservable characteristics associated with individual counties [39]. Assuming that the random disturbance term in Equation (1) has two separate components, the resulting model can be described as

$$Log(ConvertedLand)_{it} = \mathbf{X}_{it}\beta + u_i + \varepsilon_{it} \quad (2)$$

where u is the individual error component specific to each county, and ε is the idiosyncratic error that is assumed to be independent of both the regressors and the individual error component. The choice between the fixed and random effects specifications for Equation (2) depends on the properties of the individual error component. If u is correlated with the regressors, the fixed effects model in which u is treated as a set of fixed but unknown constants, is used to derive consistent estimates. A disadvantage for the fixed effects model is that it does not allow for estimating the coefficients of the time-invariant regressors. Alternatively, in a situation in which u is uncorrelated with the regressors, the random effects model is used. This specification assumes u is drawn from a normal distribution with a zero

mean and a variance of σ_{μ}^{2}. In the study, both the fixed effects and random effects models are estimated, and their estimation results are compared using the Hausman test.

6. Results

Models for the amount of conversion of agricultural land to urban uses for the 108 counties across three time periods are estimated using both the fixed and random effects models as specified in Equation (2). The estimation results show that, in both models, each of the explanatory variables is significantly correlated with the urban conversion of agricultural land (Table 3). Furthermore, the coefficient estimates of all the socioeconomic determinants have consistent signs with minor differences in their magnitudes between the fixed effects and random effects specifications. However, based on the result of the Hausman test ($p < 0.0001$), we reject the null hypothesis of no significant differences between estimates from the two specifications. This indicates that the fixed effects model, which generates consistent estimates even when the individual error component is correlated with the regressors, is a more appropriate specification. The fixed effects model is then used to illustrate the effect of each of the socioeconomic variables.

Table 3. Results from panel econometric models for the urban conversion of agricultural land.

	Dependent Variable: *Log(ConvertedLand)*	
	Fixed Effects Model	**Random Effects Model**
Intercept		7.298 ***
		(14.93)
LandRentRatio	−0.115 *	−0.153 **
	(−1.67)	(−1.99)
Log(UrbWage)	0.033 **	0.037 **
	(1.98)	(2.03)
Log(GDPpct)	0.023 **	0.020 *
	(2.20)	(1.73)
Log(AgExp)	−0.015 **	−0.015 **
	(−2.25)	(−2.12)
Log(Sun)	−0.108 ***	−0.123 ***
	(−2.78)	(−2.88)
Log(Humidity)	−0.266 ***	−0.272 ***
	(−5.08)	(−4.76)
Log(DistPvcap)		−0.299 ***
		(−2.61)
Log(DistHighw)		−0.260 ***
		(−4.27)
PlainRatio		0.545 ***
		(3.15)
Log(Elevation)		−0.202 ***
		(−3.03)
Observations	324	324
R-squared	0.52	0.42

Note: t statistics in parentheses. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

LandRentRatio, a proxy of the ratio of agricultural land rent relative to urban land rent in a county, is negatively correlated with the urban conversion of agricultural land. This indicates that relatively high returns to agricultural uses could make it less desirable to convert agricultural land to urban uses. *LandRentRatio* is one of the key economic factors identified by the urban bid-rent model. Its estimated effect conforms to the prediction of the theory that increasing land rent associated with urban uses relative to agricultural uses fundamentally triggers the conversion of agricultural land into urban areas. However, caution needs to be taken about this interpretation given that the land leasing market in China is far from mature and the proxy that we use can only roughly capture the information about land rents. *Log(UrbWage)*, average urban wages of staff and workers in a county, is positively

correlated with the urban conversion of agricultural land. This is reasonable because, as wages increase in non-agricultural sectors, the opportunity costs of farming increase, which can lead to agricultural labor scarcity, farmland abandonment and a higher risk of the conversion of agricultural land into non-agricultural uses. This result agrees with previous studies arguing that urbanization and increasing off-farm employment opportunities drive farmland abandonment and increase the mobility of agricultural land in China [40,41].

As anticipated, *Log(GDPpct)* has a positive effect on the urban conversion of agricultural land. This means that counties with a higher per capita GDP tend to experience more agricultural land loss due to urbanization. Since per capita GDP is also a measure of income level, the result indicates that income increase, which is largely driven by urban economic development, in turn can stimulate urban development and agricultural land conversion of the same area. There is likely a certain degree of dynamics and interactions between income increase, urban development, and agricultural land conversion at the local level. *Log(AgExp)* has a negative effect on the urban conversion of agricultural land. The goal of agricultural financial support, in the form of agricultural investments, funds, and subsidies, is to increase agricultural productivity and to keep farmland in agricultural production. The results suggest that there is a policy success: agricultural financial support reduces agricultural land conversion at the county level. This is reasonable because liquidity constraints and access to credit are crucial for capital input in agricultural production [42]. With greater financial support and subsidies from the government, farmers are more capable of increasing the level of capital input and then enhancing land productivity. The increase in agricultural productivity raises the returns to agricultural land, which makes it less desirable to convert land to urban uses. This result implies that policies aimed at subsidizing agricultural production have great potential for boosting agricultural productivity and slowing the land conversion, especially for the central provinces where the opportunity costs of farming are not as high as the coastal regions. The policy success identified by the model conforms to the empirical evidence shown by most case studies in central and western China, while the case studies in eastern China are on the opposite: agricultural investments lead to agricultural land conversion.

In addition to the socioeconomic variables, the results of the fixed effects model provide coefficient estimates for two time-variant biophysical variables. Both *Log(Sun)* and *Log(Humidity)* are negatively correlated with the urban conversion of agricultural land and both of their coefficients are significant. As environmental conditions constrain the use of land, areas with good climate characteristics are generally more attractive for urban development. Both investors and real estate developers consider environmental amenities when determining where to allocate their investments. It is expected that counties with less sun exposure and lower humidity will experience more urban conversion of cultivated land. In the random effects model, we include a group of biophysical variables that do not change over time. Both *Log(DistPvcap)* and *Log(DistHighw)* are negatively correlated with the urban conversion of agricultural land. This result indicates that counties closer to the provincial capital and counties closer to highway are more prone to agricultural land loss as a result of urban expansion. Proximity to the provincial capital is associated with many locational advantages: good transportation and infrastructure, better market access, and better labor market, all of which matter for urban development. Proximity to highway represents good transportation, which affects decisions on urban development. *PlainRatio* is positively related to the amount of cultivated land conversion, while *Log(Elevation)* is negatively related. This result indicates that countries with relative lower and flatter terrain tend to have more urban conversion of agricultural land. This is consistent with the expectation that good terrain conditions facilitate land development and urban construction.

We further explore the estimation results in order to derive more information on the nature and the ranking of the importance of each socioeconomic variable in determining the urban conversion of agricultural land. Previous studies on the determinants of the spatial scale of cities have used two approaches—ranking the importance of factors according to the size of their elasticities [30] and decomposition analysis [34]. Elasticities represent measurements of the marginal effects. Using elasticities as indicators of the importance of factors can be misleading considering the fact

that X may be less relevant to the change in Y if X changes very little over the period when the change in Y is measured, even if the elasticity of Y relative to X is large. We therefore implement the decomposition analysis that accounts for both the size of the marginal effects and the size of the change of the predictors. The results of the decomposition analysis based on the estimation results of the fixed effects model display the relative importance of the four socioeconomic variables on the urban conversion of agricultural land (Table 4). The total effects associated with land rent ratio, urban wages, and per capita GDP, which incorporate the marginal effect of each predictor and the change in the predictor, are positive. Among these three variables, the urban wages is the most important factor, and it induces 59.8% of the change in agricultural land conversion. Without the involvement of other factors, the converted land area would have increased by 4.9% with the 150% increase of urban wages. The per capita GDP exerts less but still substantial influence, accounting for 56.1% of the change in agricultural land conversion, while the total impact of land rent ratio is small. The total effect associated with agricultural financial support is negative and substantial. This indicates that agricultural financial support largely contributes to the decrease of agricultural land conversion. Without the involvement of other factors, the converted land area would have decreased by 6.4% with the 431% increase of agricultural financial support. As a consequence, urban wages is identified as the most influential positive factor and agricultural financial support is identified as the most influential negative factor for the urban conversion of agricultural land.

Table 4. Decomposition analysis of the socioeconomic determinants of land conversion, 1995–2005.

Variables	(a) Estimated Parameter	(b) Percentage Changes in Variables	(c) Impact on Converted land Area	(d) Contribution
LandRentRatio	−0.115	−0.035	0.004	0.049
UrbWage	0.033	1.50	0.049	0.598
GDPpct	0.023	1.98	0.046	0.561
AgExp	−0.015	4.31	−0.064	−0.780
ConvertedLand		0.082		1

Note: Column (a) represents the coefficient estimate of each variable based on the fixed effects model. Column (b) corresponds to the change in percentage of the mean of each variable between 1995 and 2005 (except that change in ratio is calculated for *LandRentRatio*). Multiplying Column (a) and Column (b) for each variable arrives at Column (c). The contribution of each variable to the change in converted land area in Column (d) is derived by dividing each element in Column (c) by the percentage change in *ConvertedLand* (0.082).

7. Conclusions and Discussion

In this paper, we used panel econometric models to examine the socioeconomic and policy factors that drive the urban conversion of agricultural land at the county level in Henan Province, China. The results show that both urban land rent and urban wages are essential factors that positively contribute to the conversion of agricultural land. It is also found that per capita GDP is correlated with more urban development and agricultural land loss. Consistent with expectations, agricultural financial support is negatively correlated with agricultural land conversion, suggesting a policy success associated with its performance. Finally, the decomposition analysis illustrates that urban wages is the most influential positive factor and agricultural financial support is the most influential negative factor affecting the agricultural land conversion due to urban expansion.

The panel econometric model allows us to take account of the decentralized trend of urban development and test differences in urban land rents and other socioeconomic factors across counties. The results reveal that local socioeconomic factors have exhibited fundamental influences in determining urban expansion. These are also the proximate drivers that are immediately responsible for the observed urban land-use change. Moreover, the study sheds some light on the control of future urban expansion and agricultural land loss, particularly for the central provinces where the opportunity costs of farming are not as high as the coastal regions. The negative effect of land rent ratio indicates that it may be less desirable to convert land to urban uses if the returns to agricultural uses are high. The negative effect of agricultural financial support implies that agricultural financial

support, with the purpose of raising the returns to agricultural land, has great potential for slowing the land conversion.

The study provides important implications for the sustainability of land use. As the first major agricultural province and one of the thirteen major grain producing areas in China, Henan Province has played a pivotal role in stabilizing grain supply and ensuring the country's food security. The preservation of agricultural land in Henan Province is of great importance for maintaining its agricultural production capacity. Furthermore, agricultural land loss in Henan Province means that more land reclamation in the northern provinces is required to offset the resulting lost production capacity, given the inferior soil and climate conditions in the northern provinces. In this sense, farmland preservation in Henan Province and the other major grain producing provinces also reduces pressures on the country's natural land resources.

On the other side, the rate of urban growth in Henan Province is likely to accelerate in the future. The proportion of urban population in Henan Province is 43.8% in 2013, which is much lower than the national level of 53.7% [2,20]. In 2012, the State Council promulgated the Central Plains Economic Zone Planning, which designated Henan Province and its peripheral regions as the Central Plains Economic Zone, and proposed that the proportion of urban population in Henan Province would reach 56% by 2020. Examples from other parts of the world reveal that land conversion is necessary for urbanization and economic development [43]. Projected rapid urbanization and urban land expansion in the Central Plains region will generate continuing pressure on the country's agricultural land and natural land resources.

The UN Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development provide guidance and strategies that promote economic prosperity while protecting the environment [44]. In order to achieve the twin goals of urban growth and preservation of farmland and natural ecosystems, effective land use management is critical. Integrated land use management that incorporates urban planning into the formulation of farmland preservation policy could improve the overall land use efficiency and alleviate the tension between urban growth and farmland preservation. In addition, the development of yield-increasing technologies, investments in rural infrastructure and institutions, and subsidies in labor-saving input and extension services, which can enhance the economic returns from farming, are important for maintaining the agricultural land use intensity. Agricultural intensification may reduce the need of land conversion from natural ecosystems into agricultural land, hence preventing excessive exploitation of land resources. Finally, policies aimed at ensuring sustainable consumption and production patterns have great potential for reducing the use of land and other natural resources. These include decreasing per capita food waste at the retail and consumer levels, reducing food losses along production and supply chains, and improving people's awareness for sustainable development and lifestyles.

Acknowledgments: This research was supported by National Natural Science Foundation of China (Grant No. 71503252) and National Natural Science Foundation of China (Grant No. 71401166). The land use data were supported by the National Key Programme for Developing Basic Science of China (Grant No. 2010CB950904).

Author Contributions: Li Jiang conceptualized and designed the study, analyzed the data, and wrote the paper. Yonghui Zhang jointly designed the study and collected the data. All authors read and approved the final manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Pannell, C.W. China's continuing urban transition. *Environ. Plan. A* **2002**, *34*, 1571–1590. [CrossRef]
2. National Bureau of Statistics of China (NBSC). *China Statistical Yearbooks (2010-2013)*; China Statistics Press: Beijing, China, 2011–2014.
3. United Nations. *The 2013 Revision of World Urbanization Prospects*; United Nations: New York, NY, USA, 2014.
4. Liu, J.; Zhan, J.; Deng, X. Spatio-temporal patterns and driving forces of urban land expansion in China during the economic reform era. *Ambio* **2005**, *34*, 450–455. [CrossRef] [PubMed]

5. Seto, K.C.; Kaufmann, R.K.; Woodcock, C.E. Landsat reveals China's farmland reserves, but they're vanishing fast. *Nature* **2000**, *406*, 121. [CrossRef] [PubMed]
6. Wang, Y.; Scott, S. Illegal farmland conversion in China's urban periphery: Local regime and national transitions. *Urban Geogr.* **2008**, *29*, 327–347. [CrossRef]
7. Chen, J. Rapid urbanization in China: A real challenge to soil protection and food security. *Catena* **2007**, *69*, 1–15. [CrossRef]
8. Schneider, A.; Seto, K.C.; Webster, D.R. Urban growth in Chengdu, western China: Application of remote sensing to assess planning and policy outcomes. *Environ. Plan. B Plan. Des.* **2005**, *32*, 323–345. [CrossRef]
9. Lichtenberg, E.; Ding, C. Assessing farmland protection policy in China. *Land Use Policy* **2008**, *25*, 59–68. [CrossRef]
10. Yue, T.; Wang, Q.; Lu, Y.; Xin, X.; Zhang, H.; Wu, S. Change trends of food provisions in China. *Glob. Planet. Chang.* **2010**, *72*, 118–130. [CrossRef]
11. Pingali, P. Westernization of Asian diets and the transformation of food systems: Implications for research and policy. *Food Policy* **2007**, *32*, 281–298. [CrossRef]
12. Cheng, J.; Masser, I. Urban growth pattern modeling: A case study of Wuhan city, PR China. *Landsc. Urban Plan.* **2003**, *62*, 199–217. [CrossRef]
13. He, C.; Okada, N.; Zhang, Q.; Shi, P.; Li, J. Modelling dynamic urban expansion processes incorporating a potential model with cellular automata. *Landsc. Urban Plan.* **2008**, *86*, 79–91. [CrossRef]
14. Long, H.; Tang, G.; Li, X.; Heilig, G.K. Socio-economic driving forces of land use change in Kunshan, the Yangtze River Delta economic area of China. *J. Environ. Manag.* **2007**, *83*, 351–364. [CrossRef] [PubMed]
15. Seto, K.C.; Kaufmann, R.K. Modeling the drivers of urban land use change in the Pearl River Delta, China: Integrating remote sensing with socioeconomic data. *Land Econ.* **2003**, *79*, 106–121. [CrossRef]
16. Deng, X.; Huang, J.; Rozelle, S.; Uchida, E. Cultivated land conversion and potential agricultural productivity in China. *Land Use Policy* **2006**, *23*, 372–384. [CrossRef]
17. Tan, M.; Li, X.; Xie, H.; Lu, C. Urban land expansion and arable land loss in China—A case study of Beijing-Tianjin-Hebei region. *Land Use Policy* **2005**, *22*, 187–196. [CrossRef]
18. Wan, S.C.; Wang, L.J.; Liu, M. An analysis for the driving factors of agricultural land conversion in China based on spatial econometric. *Econ. Geogr.* **2012**, *7*, 021.
19. Xie, Y.; Yu, M.; Tian, G.; Xing, X. Socio-economic driving forces of arable land conversion: A case study of Wuxian City, China. *Glob. Environ. Chang.* **2005**, *15*, 238–252. [CrossRef]
20. National Bureau of Statistics of China (NBSC). *Henan Statistical Yearbooks (1995-2014)*; China Statistics Press: Beijing, China, 1996–2015.
21. Xu, J. River sedimentation and channel adjustment of the lower Yellow River as influenced by low discharges and seasonal channel dry-ups. *Geomorphology* **2002**, *43*, 151–164. [CrossRef]
22. Bockstael, N.E. Modeling economics and ecology: The importance of a spatial perspective. *Am. J. Agric. Econ.* **1996**, *78*, 1168–1180. [CrossRef]
23. Rosenthal, S.S.; Helsley, R.W. Redevelopment and the urban land price gradient. *J. Urban Econ.* **1994**, *35*, 182–200. [CrossRef]
24. Beckmann, M.J. On the distribution of urban rent and residential density. *J. Econ. Theory* **1969**, *1*, 60–67. [CrossRef]
25. Verburg, P.H.; Schot, P.P.; Dijst, M.J.; Veldkamp, A. Land use change modelling: Current practice and research priorities. *GeoJ.* **2004**, *61*, 309–324. [CrossRef]
26. Barlowe, R. *Land Resource Economics*; Prentice-Hall Inc.: Englewood Cliffs, NJ, USA, 1978.
27. White, M.J. Location choice and commuting behavior in cities with decentralized employment. *J. Urban Econ.* **1988**, *24*, 129–152. [CrossRef]
28. Moses, L.; Williamson, H.F. The location of economic activity in cities. *Am. Econ. Rev.* **1967**, *57*, 211–222.
29. Brueckner, J.K.; Fansler, D.A. The economics of urban sprawl: Theory and evidence on the spatial sizes of cities. *Rev. Econ. Stat.* **1983**, *65*, 479–482. [CrossRef]
30. McGrath, D.T. More evidence on the spatial scale of cities. *J. Urban Econ.* **2005**, *58*, 1–10. [CrossRef]
31. Deng, X.; Huang, J.; Rozelle, S.; Uchida, E. Economic growth and the expansion of urban land in China. *Urban Stud.* **2010**, *47*, 813–843. [CrossRef]
32. Ding, C. Land policy reform in china: Assessment and prospects. *Land Use Policy* **2003**, *20*, 109–120. [CrossRef]

33. Shen, J.; Wong, K.; Feng, Z. State-sponsored and spontaneous urbanization in the Pearl River Delta of south China, 1980–1998. *Urban Geogr.* **2002**, *23*, 674–694. [CrossRef]
34. Deng, X.; Huang, J.; Rozelle, S.; Uchida, E. Growth, population and industrialization, and urban land expansion of China. *J. Urban Econ.* **2008**, *63*, 96–115. [CrossRef]
35. Heerink, N.; Kuiper, M.; Shi, X. China's new rural income support policy: Impacts on grain production and rural income inequality. *China World Econ.* **2006**, *14*, 58–69. [CrossRef]
36. Liu, J.; Liu, M.; Deng, X.; Zhuang, D. The land use and land cover change database and its relative studies in China. *J. Geogr. Sci.* **2002**, *12*, 275–282.
37. Conelly, W.T. Population pressure, labor availability, and agricultural disintensification: The decline of farming on Rusinga Island, Kenya. *Hum. Ecol.* **1994**, *22*, 145–170. [CrossRef]
38. Breusch, T.S.; Pagan, A.R. The Lagrange multiplier test and its applications to model specification in econometrics. *Rev. Econ. Stud.* **1980**, *47*, 239–253. [CrossRef]
39. Hausman, J.A. Specification tests in econometrics. *Econometrica* **1978**, *46*, 1251–1271. [CrossRef]
40. Xie, H.; Wang, P.; Yao, G. Exploring the dynamic mechanisms of farmland abandonment based on a spatially explicit economic model for environmental sustainability: A case study in Jiangxi Province, China. *Sustainability* **2014**, *6*, 1260–1282. [CrossRef]
41. Deininger, K.; Jin, S. The potential of land rental markets in the process of economic development: Evidence from China. *J. Dev. Econ.* **2005**, *78*, 241–270. [CrossRef]
42. Yi, F.; Lu, W.; Zhou, Y. Cash transfers and multiplier effect: Lessons from the grain subsidy program in China. *China Agric. Econ. Rev.* **2016**, *8*, 81–99. [CrossRef]
43. Ramankutty, N.; Foley, J.A.; Olejniczak, N.J. People on the land: Changes in global population and croplands during the 20th century. *Ambio* **2002**, *31*, 251–257. [CrossRef] [PubMed]
44. United Nations General Assembly. *Open Working Group Proposal for Sustainable Development Goals (A/68/970)*; United Nations: New York, NY, USA, 2014.