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**INDUSTRIALIZATION, URBANIZATION, AND LAND USE IN
CHINA**

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ABSTRACT

Rapid industrial development and urbanization transfer more and more land away from agricultural production, threatening China's capability to feed itself. This paper analyzes the determinants of land use by modeling arable land and sown area separately. An inverse U-shaped relationship between land use intensity and industrialization is explored both theoretically and empirically. The findings highlight the conflict between the two policy goals of industrialization and grain self-sufficiency in the end. Several policy recommendations are offered to reconcile the conflict.

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Industrialization, Urbanization, and Land Use in China

Xiaobo Zhang, Tim D. Mount and Richard N. Boisvert^{*}

1. INTRODUCTION

Land scarcity has become an increasingly important issue in China. Because of rapid industrial development and population growth, the land base for agricultural production has been shrinking steadily. Since 1952, more than 13 million hectares of arable land have been lost.¹ With the growing population and only about 7 percent of the world's arable land, some Malthusians, such as Brown (1995), have questioned China's capacity to feed its 1.25 billion people over the long haul. Despite these persistent pessimistic forecasts by the Malthusians, China has been rather successful in maintaining grain self-sufficiency over the past two decades.

One factor that Malthusians fail to consider is the increase in land use intensity.² In contrast to the decline of arable land, the sown area, a product of arable land area and

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¹ Arable land area and cultivated area are often used interchangeably. Sown area or cropping area is equal to the multiplication of arable land area and multiple-cropping index. It has been noted that the official arable land area might be under-reported (P. 368, SSB, 1997; Ash and Edmonds, 1998; Smil, 1999). In spite of the shortcomings of the official statistics, they are the only source for land stock at the provincial level that are readily available and consistently compiled. The trends of land use may not be severely affected by this problem considering that most under-reporting of arable land occurred in hilly and mountainous regions (Ash and Edmonds, 1998).

² For instance, Brown (1995) predicted a decline in both arable land and multiplying cropping.

the multiple-cropping index, has increased by more than 13 million hectares since 1952. As the total grain output is more related to the total sown area rather than the total arable land area, unrealistic predictions will result from ignoring the role of increased multiple cropping. Therefore, understanding the driving forces behind the growth in sown area is crucial for analyzing China's future grain production and trade situation. The question is: can China sustain the upward trend of sown area in the long run by continually offsetting the farmland loss with increasing intensity?

To address this question, an analytical framework based on policy and historical details is developed in this paper. Compared with previous studies on China's land use, this study has at least two unique features. First, land intensity is modeled separately from arable land area. Most previous studies (Heilig, 1997; Li and Sun, 1997; Fischer, Chen, and Sun, 1998) have just focused on arable land area, thus understating China's grain production capacity. In China, local governments have much authority to procure land for non-agriculture use, whereas the central government responds to the overall food situation by setting policy guidelines for local governments and farmers. Since land is nominally owned by the collective, individual farm, households are not allowed to convert their land to non-agriculture use, but they do have the right to cultivate their land and use multiple cropping. Therefore, it is sensible to model the different decision processes separately.

Second, using a thirty-three year (1965-97) panel data set at the provincial level, we can quantify the driving forces behind the changes in arable land and land use intensity. This is an improvement over previous studies on land use, which generally are qualitative or just based on time series data (Brown, 1995; Heilig, 1997; Zhang, Huang,

and Rozelle, 1997; Ash and Edmonds, 1998). Using the panel data set, we can also study the interplay between governments and farmers.

The paper is organized as follows. We provide a historical review of Chinese agricultural land use policy in section 2. Then, we develop an analytical framework to model arable land area and land intensity in Section 3. Section 4 presents the econometric results based on a panel data set. The conclusions and policy implications are provided in Section 5. A detailed description of the data is presented in the appendix.

2. AN HISTORICAL REVIEW OF CHINA S AGRICULTURAL LAND USE

Arable land area per capita in China is now less than 0.08 hectare (SSB, 1998), which ranks among the lowest in the world. Table 1 presents the basic information about land use (arable land and sown area), industrialization, urbanization, and grain trade balance. The time paths for these variables are also plotted in Figure 1.

Three features are apparent from Figure 1. First, it appears that there is a negative relationship between arable land area and industrialization and urbanization. During the period 1952-1997, the arable land area declined by 12 percent, from 108 million hectares to 95 million hectares, while population more than doubled, from less than 0.6 billion to more than 1.2 billion. The ratio of non-agricultural GDP to agricultural GDP, an indicator of industrialization, increased four fold and the share of urban population rose from 14 percent to about 26 percent. It appears that industrialization and urbanization are among the most important factors explaining the decline of China's agricultural land use.

Second, despite hunger and malnutrition in the pre-reform period and the subsequent decline in the arable land area, China has still been quite successful in turning

its food situation around; the ratio of net grain imports to total grain production has fluctuated within a narrow range, from 4.2 percent to -2.5 percent (SSB, 1998). Figure 1 shows that the sown area increased by about 9 percent from 1952 to 1997. Grain yields rose by 177 percent during the same period (SSB, 1998). The multiple-cropping index (calculated by the authors using the sown and arable areas) increased from 1.3 in 1952 to 1.6 in 1997, indicating that land is being more intensively cultivated. Clearly, the increase in grain production stems largely from the rise in multiple-cropping practices as well as higher yields.

Third, it seems that the cycles in the grain trade balance are related to fluctuations in the sown area. Tang (1984) observed that Chinese agriculture had been marked by persistent cycles in response to the central government's policies. However, it is not clear how various factors play out by just looking at figure 1. To gain a better understanding of the observed trends, it is necessary to review the history of China's development and agricultural policies.

LAND REFORMS (1949-1955)

Following the establishment of the People's Republic of China in 1949, the state confiscated land from landlords and distributed it equally to peasants in order to improve both equity and efficiency. At that time, China faced a hostile international environment with political isolation and economic embargos. The political leaders adopted two important development strategies—the prioritization of heavy industrial development to catch up with developed western countries and a grain self-sufficiency policy to lessen its reliance on international markets (Lin, Cai, and Li, 1996). However, these two policies were not complementary over time.

GREAT LEAP FORWARD AND THE GREAT FAMINE (1956-1961)

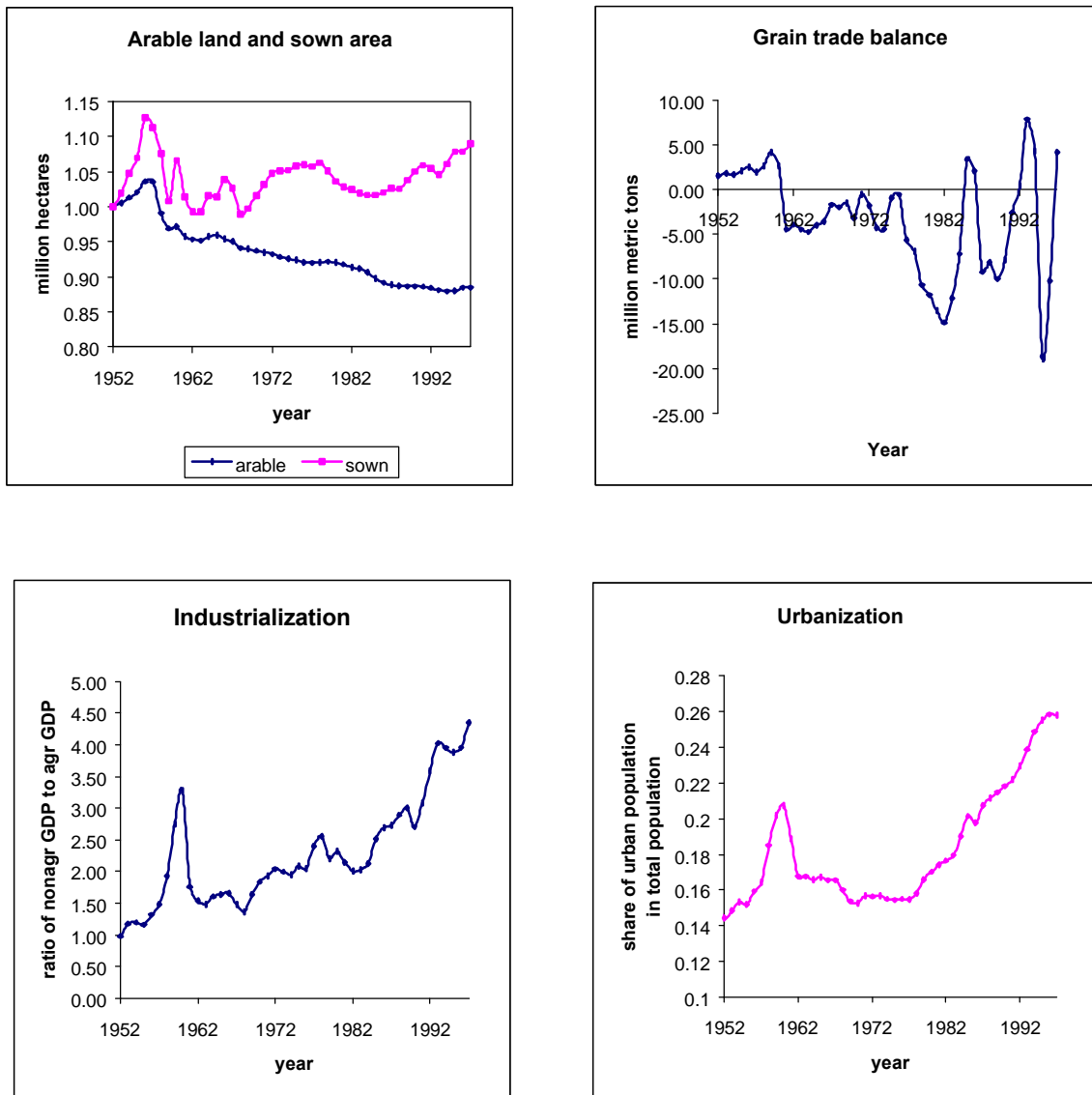
With net grain exports continuing to rise during this period, the focus of national policy shifted from agricultural to industrial development. Chairman Mao thought it would be impossible to catch up with advanced western economies without an industrial revolution. Therefore, the “Great Leap Forward” was called to boost steel and other heavy industrial output at the expense of agricultural production. The ratio of industrial GDP to agricultural GDP rose three-fold in four years, from 0.63 in 1956 to 1.9 in 1960. There was an accompanying sharp decline in arable land and sown area as land and labor were diverted away from agricultural production. The sharp decline in the agricultural land base together with the collectivization movement resulted in a serious food shortage, triggering the greatest famine in human history (Lin, 1990). During the early sixties, China had to import as much as four million metric tons of grain, although it hesitated to do so initially.

Table 1: Basic information: land, urbanization, industrialization, and grain net export

Period	Arable land (million ha.)	Sown area (million ha.)	Urbanization (urban / total population)	Industrialization (nonagr. GDP / agr. GDP)	Net grain export (million metric tons)
1952	107.9	141.3	0.14	0.98	1.53
1960	104.9	150.6	0.21	3.27	3.16
1961	103.3	143.2	0.19	1.76	0.78
1965	103.6	143.3	0.17	1.64	-4.40
1966	103.0	146.8	0.17	1.66	-4.10
1967	102.6	144.9	0.17	1.48	-3.08
1968	101.6	139.8	0.16	1.37	-2.42
1969	101.5	140.9	0.15	1.63	-1.75
1970	101.1	143.5	0.15	1.84	-2.26
1971	100.9	145.7	0.16	1.93	-1.78
1972	100.6	147.9	0.16	2.04	-1.88
1973	100.2	148.5	0.16	1.99	-2.21
1974	99.9	148.6	0.15	1.95	-3.51
1975	99.7	149.5	0.15	2.09	-3.21
1976	99.4	149.7	0.15	2.05	-2.00
1977	99.2	149.3	0.15	2.40	-2.41
1978	99.4	150.1	0.16	2.56	-4.42
1979	99.5	148.5	0.17	2.21	-7.78
1980	99.3	146.4	0.17	2.32	-9.82
1981	99.0	145.2	0.17	2.14	-12.02
1982	98.6	144.8	0.18	2.00	-13.41
1983	98.4	144.0	0.18	2.03	-13.51
1984	97.9	143.6	0.19	2.13	-11.40
1985	96.8	143.6	0.20	2.52	-5.32
1986	96.2	144.2	0.20	2.69	-0.59
1987	95.9	145.0	0.21	2.73	-1.25
1988	95.7	144.9	0.21	2.89	-5.08
1989	95.7	146.6	0.21	3.00	-9.12
1990	95.7	148.4	0.22	2.70	-8.68
1991	95.7	149.6	0.22	3.08	-6.83
1992	95.4	149.0	0.23	3.59	-3.36
1993	95.1	147.7	0.24	4.03	1.88
1994	94.9	149.9	0.25	3.95	4.16
1995	95.0	152.4	0.26	3.88	-2.19
1996	95.0	154.0	0.26	3.95	-8.22
1997	95.0	154.0	0.26	4.35	-8.25
Annual growth rate					
1952-65	-0.31	0.11	1.14	4.03	-23.90
1966-78	-0.29	0.18	-0.38	3.67	-0.65
1979-97	-0.26	0.20	2.48	3.84	5.09
1952-97	-0.31	0.21	1.43	3.70	-11.47

Sources: Various SSB publications.

Figure 1: Land use, grain trade, industrialization, and urbanization



Source: Table 1.

PRE-REFORM (1962-1978)

In reaction to the great famine and the increasing reliance on international grain markets, the central government was forced to reconsider its industrialization policy. Grain self-sufficiency emerged as a priority theme of governmental policy. The slogan, “Yi Liang Wei Gang, Gang Ju Mu Zhang” (Food must be taken as a core; once it is grasped, everything falls into place) reflected the spirit of this policy. One way to reconcile the conflict between the two policies was to reduce the urban population and increase the rural population. In the years between 1961 and 1964, 20 million state workers and 17 million urban high school students were sent to the countryside for “re-education” by participating in agricultural production (Selden, 1992). Furthermore, the “household register system”, in conjunction with elaborate rationing mechanisms, made migration from rural to urban areas virtually impossible (Chan, 1995). Hence, the share of the urban population kept dwindling until the late 1970s, which kept the demand for land for non-agricultural purposes under control.

By the early 1970s, the potential for boosting sown area through reductions of the urban population was almost exhausted. Therefore, from the early 1970s, all collectives were mobilized to learn from Da Zhai (a model village in Shanxi province) how to claim more land from marginal areas such as hillsides and lakes (Selden, 1992). During the sixties and seventies, grain self-sufficiency was barely achieved, primarily through keeping a large base of rural population and by cultivating more marginal land. The share of grain imports relative to total grain production was controlled at a level of less than 4 percent during this pre-reform period.

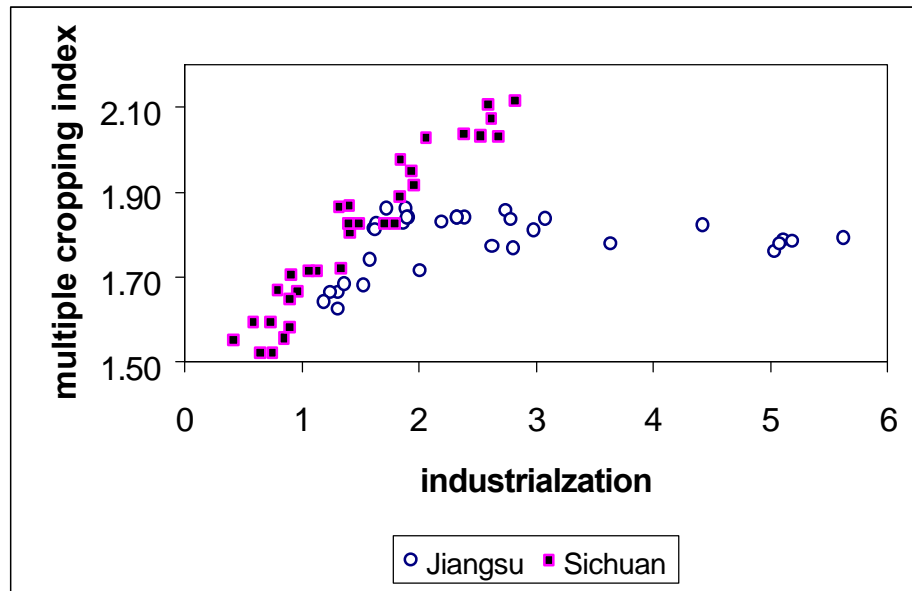
RURAL REFORM (1979-1985)

With the end of the Cultural Revolution, the Chinese economy was on the verge of collapse. The potential for increasing grain production through developing more marginal land and increasing land utilization under the old collective system was nearly exhausted. By the late seventies, China had to import as much as 10 million metric tons of grain from the world market. In response to the agricultural crisis, the government started to give more flexibility in decision making to individual household producers by officially promoting the household responsibility system nationwide. This idea originated from farmers in Anhui Province and by the end of 1983, 98 percent of villages had adopted the household responsibility system (Lin, 1992). Alongside the reform, the role of state interventions on acreage plans was greatly reduced. Alternatively, to control agricultural land use and boost food production, the government fostered market-oriented strategies, such as increasing procurement prices for grain and other crops. These reforms greatly enhanced farmers' incentives to allocate their inputs more efficiently and adopt more profitable technologies (Lin, 1991, 1992; Fan and Pardey, 1997). Thanks to the success of rural reform, agricultural output and grain production (measured at constant prices) grew 7.4 percent and 4.8 percent annually from 1978 to 1984, respectively (SSB, 1998). Because of the rapid agricultural growth, the share of agricultural GDP in total GDP increased from 0.28 to 0.32 during this period. Although there was little change in sown area during this period, a spectacular growth in agricultural output was generated.

POST-RURAL REFORM (1986-1997)

The rural reforms released a large amount of labor and provided a base for industrial development. Since the mid-eighties, the town and village enterprises (TVEs) in rural areas have experienced a phenomenal growth, making it possible to absorb much of the surplus labor in rural areas. Developing rural industry became a major objective for many local governments (Rozelle and Boisvert, 1995).

However, the development of the TVEs has not been distributed evenly. The TVEs developed much more rapidly in coastal provinces than in inland provinces largely because coastal areas had better access to capital and new technologies. Meanwhile, localized migration from rural areas to nearby towns was much easier although many institutional barriers still existed for cross-regional migration (Kanbur and Zhang, 1999). As a result, the industrialization level in coastal provinces was of a different magnitude from that in inland provinces. In many of the industrialized coastal provinces, farmers faced more opportunities for higher pay from non-farm work. Thus, farmers had less incentive to continue intensive cropping. Accordingly, the multiple-cropping index for many coastal provinces, such as Jiangsu Province, began to decrease from their historical highs of the late 1980s (see Figure 2).

Figure 2: Land use intensity and industrialization

However, for inland provinces, the dual economy, characterized by lower levels of industrial development and large surpluses of rural labor, was still dominant. Most farmers had to stick to their land because of limited local non-farm opportunities and the potential cost on migration across regions. Thanks to cheaper fertilizer and other land saving technologies resulting from industrialization throughout China, farmers were able to intensify cropping on their land. As a result, many inland provinces, such as Sichuan Province, experienced an increase in the multiple-cropping index over this period (see Figure 2).

In 1991, a much more open reform policy was advocated in an effort to stimulate the sluggish Chinese economy. The experience of special economic zones in Shenzhen and other coastal cities was regarded as a successful development pathway for others to follow. Many local governmental officials were sent to the South or the East to gain

experience. Through this learning experience and in an effort to compete for foreign direct investment, special economic zones were established throughout China. Thousands of acres of arable land were converted to special zones and roads, but many of them were left idle due to the lack of foreign investment. From 1991 to the end of 1996, 10.3 million hectares of arable land were converted to non-agricultural use, among which 1.16 million hectares for use of special zones or real estate development were idle (MOA, 1998).

To gain status and receive promotion, local leaders often had to compete with or copy peer officials in neighboring districts (Rozelle and Boisvert, 1994). Even realizing that converting arable land to industrial zones might not bring net benefits to their local economies, many officials still chose to do so in large part due to the pressures from peer neighboring governments. They were afraid that they would be regarded as slow reformers with closed minds by the central government if they did not imitate the behavior of other local governments by having a special zone within their boundary (MOA, 1998). This primarily explains why arable land and sown areas declined and grain imports rose during the early nineties.

With the decline in agricultural land area and a lack of attention to agricultural issues, China had to import nearly 20 million metric tons of grain from the international market in 1995 (SSB, 1996). This record high level of imports sent a strong alarm to policy makers. In an attempt to reduce food imports and regain grain self-sufficiency, the central government implemented two measures. First, an administrative decree was issued in April 1997 (MOA, 1998) to keep farmland loss under control. Under this decree, all the arable land converted to non-agricultural use during the period 1991-1995 was to be re-examined and the additional conversion of arable land to non-agricultural use was frozen

for one year. Second, since provincial governors were required to be responsible for the “Mi Dai Zi” (rice bag) (Crook, 1997), the national self-sufficiency policy degenerated into a policy of local self-sufficiency. Mandatory targets for acreage plans were assigned to lower levels of governments. Because of these efforts, both arable land and sown area were stabilized and grain imports were reduced.

Our review of the history of China’s agricultural policy reveals that balancing industrial development, urbanization, and food security has been a persistent challenge for the central government. From time to time, the government had to adopt mandatory administrative means to manage the problem. Urbanization and industrialization are important driving forces behind the conversion of farmland. Nevertheless, the relationship between industrialization and land intensification is more complicated. Total grain production depends on total sown area, which in turn, is determined by the availability of arable land area and the extent of land use intensity.

3. CONCEPTUAL FRAMEWORK

Since arable land area and land use intensity are determined by different actors, we need to model them separately. In the first step, we present a model of arable land use for a local government because it has the authority to convert farmland for non-agricultural use. For simplicity, we assume that the total arable land area is fixed, and the land can be used for either agriculture or non-agriculture.³

³ Because most of China has already been heavily populated, there is little room to claim marginal land. Arable land may also be lost due to environmental changes such as soil erosion and salinity (Huang and Rozelle, 1995; Ash and Edmonds, 1998). Because environmental changes are mostly related to population growth, increase in

As discussed in the last section, the demand for agricultural land is likely to be associated with industrialization, urbanization, land use decisions in neighboring regions, and national policy. Therefore, the arable land function can be expressed as follows:

$$A_t = F(ind_{t-1}, urb_{t-1}, A_{mt-1}^b, \dot{e}_{t-1}) , \quad (1)$$

where A_t is the arable land area in time t ; ind_{t-1} refers to the industrialization level at time $t-1$, defined as the ratio of non-agricultural GDP to agricultural GDP; urb_{t-1} is the share of urban population; A_{mt-1}^b is the land used for agriculture in time $t-1$ by the local government which has the highest GDP per capita among all neighboring provinces, and is a proxy for peer pressure from neighboring provinces; and q_{t-1} is the national grain trade deficit, which we use as a proxy for the overall national policy for land use in year $t-1$ ⁴.

Generally, the demand for non-agricultural land use is positively related to industrialization and urbanization. Because the total endowment of land is fixed, if more land is used for industrial and urban development, then less land is left for agricultural use. Therefore, we expect a negative relationship between agricultural land use and industrialization and urbanization. Since the demand for arable land cannot exceed a region's natural limit, it is sensible to model the share of arable land as a logit model so that a prediction based on the model will not exceed its natural endowment. The model can be written explicitly as:

agricultural inputs, and development of rural enterprises, partly captured by the population and industrialization variables in the model, the environmental variables are not explicitly included in this analysis.

⁴ Although rapid change in grain trade positions often has an important impact on the tightness of land use policy, other factors may also affect land policy.

$$\frac{A_t}{\bar{A}} = f(ind_{t-1}, urb_{t-1}, A_{mt-1}^b, q_{t-1}) \quad (2)$$

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Where f is a logit function of the form $\frac{1}{1 + \exp(-bX)}$ and all the independent variables in

$X = \{ ind_{t-1}, urb_{t-1}, A_{mt-1}^b, q_{t-1} \}$ are in log form and β is a vector of corresponding coefficients. The hypothesized signs of the coefficients in β are shown in the parentheses under expression (2). A negative sign for industrialization suggests a conflict between the objectives of the industrialization and grain self-sufficiency policies. Since the total land area \bar{A} and land allocations for non-agricultural uses are generally unknown, we cannot estimate (2) directly. By multiplying through by \bar{A} and taking the logarithm of both sides, the following equation is obtained for estimation:

$$\ln(A_t) = \ln(\bar{A}) - \ln(1 + \exp(-bX)) . \quad (3)$$

Since $\ln(\bar{A})$ is fixed for each province, a dummy variable for each province is an appropriate proxy. The dummy variable also helps eliminate some systematic measurement errors of arable land. Accordingly, (3) can be estimated by a nonlinear regression procedure.

The next step is to model land use intensity. In China, each household is assigned a fixed amount of land by government, so the physical land area is not a decision variable for a farmer. But farmers can influence total output through their decisions on land use

patterns and intensity⁵. For simplicity, but without loss of generality, we assume each farmer has one unit of land. Let us further assume that there are only two production seasons with technologies F_1 and F_2 , respectively, and the price of output is equal to P in both seasons. Moreover, we assume constant returns to scale in agricultural production. If farmers do not have a non-farm working opportunity, they would optimize their land use intensity to maximize the total profit from agricultural production as follows:

$$\begin{aligned} \text{Max } p &= PF_1(l_1 | \Phi) + PaF_2(l_2 | \Phi) - w(l_1 + \alpha l_2) - gc(\alpha) \\ &\{l_1, l_2, \alpha\} \end{aligned} \quad (4)$$

where l_1 and l_2 are the amount of labor used in the first (major) season and second season production, respectively; Φ is a vector of public investments such as irrigation and agricultural research (R&D); α represents the proportion of the land used for cropping in the second season ($1+\alpha$ can therefore be regarded as a multiple-cropping index); $c(\alpha)$ is the non-labor cost incurred in second season production (it is assumed to be convex in α); w stands for the agricultural wage; and g is the annual rate of reduction in non-labor input costs due to cost-reducing technological change in the industrial sector (an indirect benefit of industrialization).⁶ Since we assume that farmers use all their land for production in the main season, the non-labor cost is fixed for the main season and therefore it does not appear in (4). The first order conditions for (4) are:

⁵ For one rationale to separate the area allocations and yield in estimating an agricultural supply function, see McGuirk and Mundlak (1991).

⁶ Under the assumption of constant returns to scale for production, the cost neutrality technology in (4) is equivalent to a profit neutral or Hicks neutral technical change (Chambers, 1988).

$$PF_1'(l_1 | \Phi) = w \quad (5)$$

$$PF_2'(l_2 | \Phi) = w \quad (6)$$

$$PF_2(l_2 | \Phi) = l_2 w + g c'(a) \quad (7)$$

A reduced form solution for the multiple-cropping equation can be expressed as

$$\hat{a} = \hat{a}(P, w, \Phi, g). \quad (8)$$

From (7), we can conduct a standard comparative static analysis for \hat{a} with respect to w , Φ , and g :

$$\frac{d\hat{a}}{dw} = -\frac{l}{gc''(\hat{a})} < 0 \quad (9)$$

$$\frac{d\hat{a}}{d\Phi} = -\frac{P(\partial F_2(l_2 | \Phi)/\partial \Phi)}{gc''(\hat{a})} > 0 \quad (10)$$

$$\frac{d\hat{a}}{dg} = -\frac{c'(\hat{a})}{gc''(\hat{a})} < 0. \quad (11)$$

Since c is convex, the denominators in (9) and (11) are positive. Therefore, an increase in the wage lowers the multiple-cropping index, while technical progress in the industrial sector, represented as a decrease in g , promotes multiple cropping. Since an increase in public investment generally has a positive impact on production, the numerator in (10) is positive, implying that public investment fosters land use intensity.

Unfortunately, we do not have usable data on the technology, wage, and price variables for empirical analysis. Hence, we develop an argument as to why the rate of industrialization and urbanization may serve as proxies for wage, price, and the technical progress coefficient in the empirical specification of the model (10).

In a dual economy, with limited non-farm opportunities and abundant surplus labor, the agricultural wage is fixed at a subsistence level (Lewis, 1954). With the expansion of the industrial sector and reductions of surplus labor in the rural sector, the agricultural wage will eventually be bid up to a higher level. Writing it more formally, we have:

$$\frac{\partial w}{\partial ind} = \begin{cases} 0 & \text{if } ind \leq ind^* \\ > 0 & \text{if } ind > ind^* \end{cases} \quad (12)$$

where ind^* is the turning point for an economy which becomes industrialized from a traditional dual economy.

Another consequence of industrialization is that the unit costs of non-labor inputs generally move downward thanks to technological innovations. This is exactly what happened to China where the real prices of fertilizer and pesticides have declined but the quality has increased over the last several decades (SSB, 1998). So, we make the following legitimate assumption:

$$\frac{\partial g}{\partial ind} < 0. \quad (13)$$

With the above conditions, we can derive the relationship between multiple cropping and industrialization,

$$\frac{d\hat{a}}{dind} = \frac{\partial \hat{a}}{\partial w} \frac{\partial w}{\partial ind} + \frac{\partial \hat{a}}{\partial g} \frac{\partial g}{\partial ind} \quad (14)$$

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The signs of the changes in the arguments on the corresponding variables are shown in the parentheses. The third and forth parentheses in (14) reveal that industrialization increases land use intensity by lowering non-labor input costs. When industrialization is low, represented by surplus labor, the impact of industrialization on the agricultural wage is zero or negligible. So, the first part of (14) is close to zero. Under this circumstance, the net effect of industrialization on land use intensity is positive. However, when industrialization develops to a certain stage, the tighter labor market will put upward pressure on the agricultural wage rate. When the first part of (14) becomes negative and dominant, the multiple-cropping index would begin to decline. Overall, the model suggests an inverse-U shape relationship between land intensity and industrialization. This is an important hypothesis that can be tested empirically.

4. RESULTS

To test the hypotheses in (2) and (14) empirically, we use a panel data set for the period 1965 to 1997 for 24 provinces that includes land use, industrialization, and urbanization. 1965 is the earliest year for which systematic sown area data for each province are available. After taking a one-year lag for all the independent variables, we

have 768 observations in total. A detailed description of the data is provided in the Appendix.

Table 2 reports the estimated logit model for the arable land area (3). Provincial dummies are used as a proxy for total land \bar{A} for all the regressions. The first regression (R1) includes regime dummies and is estimated for the whole period 1965-97. The negative and statistically significant coefficient on the urbanization variable is consistent with the predictions of equation (2). This suggests that urbanization has contributed to the loss of arable land. The regime dummies are significant at the 5% level, indicating that institutional change may have significant impacts on total arable land area. However, the coefficients for other variables are insignificant.

Table 2: Estimated logit results for arable area

	R1	R2	R3	R4
	Whole period	Pre-Reform	Reform	Post-reform
Industrialization	-0.009 (0.100)	-0.023** (0.082)	0.014 (0.063)	-0.025** (0.006)
Urbanization	-2.167** (0.197)	-1.604** (0.246)	-2.297** (1.007)	-0.955** (0.148)
Peer pressure	-0.024 (0.018)	0.006 (0.020)	0.003 (0.088)	0.052** (0.018)
Grain trade deficit	0.377 (0.344)	1.614** (0.714)	0.542 (2.131)	-0.086 (0.161)
Pre-reform (65-78)	-0.076** (0.018)			
Reform (79-85)	-0.057** (0.018)			
No. of obs.	768	312	168	288
Adj. R ²	0.983	0.996	0.985	0.999
Log likelihood	882.12	600.04	215.54	690.59

Note:

1. This is the logit equation (3). The dependent variable is the logarithm of arable land. All the independent variables have a one-year lag. One and two asterisks indicate that estimates are at the 10% and 5% significance levels, respectively.
2. The industrialization variable is defined as the ratio of non-agricultural GDP to agricultural GDP; the urbanization variable is represented as the share of urban population in total population; the peer pressure variable refers to the logarithm of the total arable land area in a neighboring province, which has the highest GDP per capita.
3. Figures in parentheses are standard errors.

To further explore the impact of different regimes associated with institutional change, we divided the total sample period into three periods: pre-reform (1965-1978), reform (1979-1985), and post-reform (1986-1997). The model was estimated separately for each of the three regimes and the results are presented as R2, R3, and R4 in Table 2. In spite of some difference in their magnitudes, the coefficients for all three regimes are consistent with each other. Except for the industrialization variable in the reform period (R3), the coefficients for industrialization and urbanization have significantly negative signs. The results show that industrialization and urbanization are indeed driving forces behind the conversion of farmland to non-farm uses. The relatively large value of the coefficients for the urbanization variable in the pre-reform and reform periods may illustrate the economic rationale behind the government's policy of preventing the rural population from moving to cities and sending thousands of urban youths and cadres to the countryside. However, with the successful rural reform, agricultural labor productivity greatly improved, reducing the reliance on a large rural population to cultivate farmland.

The peer pressure is significant at the 5% level only in post-reform period when local governments became more decentralized. The grain trade deficit only has a positive and significant impact on arable land area during the pre-reform period when the national food situation was very tight. Thanks to the rural reform, agricultural production became more efficient and total grain supply increased. Furthermore, the rapid growth of non-farm exports provided a large amount of foreign reserves, increasing China's capability to buffer year-to-year domestic production fluctuations in grain production.

Next, we model land use intensity and test the curvature of the land use intensity with respect to industrialization. Specifically, we want to show that the second derivative

is negative. Thus, the model needs to include both a linear and quadratic term for industrialization.⁷ In order to proxy for the agricultural wage rate, price, and technical progress variables described in equation (14), we use urbanization and its quadratic term, and the interaction of industrialization and urbanization variable in our model. In addition, we add a learning variable to capture the adoption of technologies in agricultural production (Foster and Rosenzweig, 1995). The learning variable is defined as the MCI in the neighboring province with the highest GDP per capita. To write it more explicitly, the multiple-cropping index can be estimated as a function of the following variables:

$$\hat{\alpha} = \hat{\alpha}(ind, ind^2, urb, urb^2, ind * urb, learning, irrigation, R \& D). \quad (15)$$

Where *ind* measures industrialization, expressed as the ratio of non-agricultural GDP to agricultural GDP; *urb* is the share of urban in total population; *irrigation* is the share of irrigated area relative to total arable area; and *R&D* is the logarithm of total expenditure on agricultural research. All the variables have a one-year lag.

Table 3 presents the estimated results for seven different specifications. The first four regressions are for China as a whole and for three regions (North, Central, and South). Two regime dummies for the pre-reform and reform periods are included in these regressions. Three more regressions are conducted separately for all China under the three regimes.

⁷ Other functional forms, such as inverse function, were also tried and the results are similar.

Table 3: Estimated results for land use intensity

	China	North	Central	South	Pre-reform	Reform	Post-reform
Intercept	-0.394*	1.058	0.186**	0.377	0.174	1.922	-0.530*
	(0.202)	(0.839)	(0.213)	(0.265)	(0.250)	(0.556)	(0.271)
IND	0.148**	0.031	0.049*	0.219**	0.153*	0.042	0.119**
	(0.031)	(0.088)	(0.038)	(0.051)	(0.081)	(0.106)	(0.045)
IND ²	-0.021**	-0.016	-0.029**	-0.062**	-0.014	-0.002	-0.018**
	(0.005)	(0.013)	(0.007)	(0.009)	(0.016)	(0.012)	(0.006)
URB	-0.321	-2.821	4.451**	-2.614*	-7.163**	-1.013	-2.835**
	(0.543)	(3.176)	(0.914)	(1.568)	(1.688)	(1.611)	(1.089)
URB ²	0.217	6.210	-20.630**	-3.988	19.322**	6.808**	-4.069**
	(1.273)	(5.292)	(4.697)	(6.074)	(4.225)	(3.201)	(1.899)
IND*URB	-0.087	0.243	0.840**	1.008**	0.624*	-0.109	0.012
	(0.118)	(0.321)	(0.295)	(0.365)	(0.373)	(0.345)	(0.123)
Learning	0.093**	0.171*	-0.035*	0.105**	0.080**	-0.041	0.107**
	(0.021)	(0.084)	(0.013)	(0.025)	(0.032)	(0.044)	(0.031)
Irrigation	0.176**	0.296	0.010	0.342**	-0.010	0.452**	0.217
	(0.085)	(0.276)	(0.069)	(0.104)	(0.134)	(0.186)	(0.191)
R&D	0.109**	-0.047	0.034**	0.082**	0.149**	-0.139**	0.051**
	(0.021)	(0.063)	(0.017)	(0.024)	(0.037)	(0.057)	(0.025)
Pre-reform	0.074**	0.209**	0.033*	0.011			
(65-78)	(0.026)	(0.076)	(0.019)	(0.033)			
Reform	-0.005	0.120**	-0.005	-0.046**			
(79-85)	(0.009)	(0.025)	(0.007)	(0.012)			
Adj. R ²	0.927	0.372	0.954	0.895	0.936	0.972	0.976

Note:

1. One and two asterisks indicate that estimates are at the 10% and 5% significance levels, respectively.
2. The dependent variable is the multiple-cropping index. IND (Industrialization) is represented by the ratio of non-agricultural GDP to agricultural GDP; URB (Urbanization) is measured as the share of urban population in total population; the learning variable denotes the multiple-cropping index by the richest neighboring province.
3. Intercept and province dummies are not reported here. All the independent variables, except the regime and provincial dummies, are lagged by one year.
4. Figures in parentheses are standard errors.

For the regression for China as a whole, all the coefficients except those involving the urbanization variable are significant. The significant negative sign on IND^2 confirms our model's prediction of an inverse-U shape relationship between land use intensity and industrialization. The two public inputs—irrigation and R&D—have significant positive impacts on land use intensity, which is consistent with the theoretical prediction given by (10).

Since the potential for multiple-cropping is constrained by natural and environmental conditions, we divide China into three regions: North, Central, and South to check the robustness of the results. The North region includes: Liaoning, Jilin, Heilongjiang, Inner Mongolia, Xinjiang, and Qinghai. Because of the cold winter, there is only one major production season in these areas, leaving little room for multiple cropping. Not surprisingly, the adjusted R^2 is only 0.37 for the estimation of the north region. Except for the learning and regime dummy variables, all the coefficients are insignificant, implying that industrialization and urbanization do not affect land use intensity in the North.

The Central region includes the provinces of Hebei, Henan, Shandong, Shanxi, Shannxi, and Gansu. It has one to two production seasons. All the other provinces are defined as the South region. The South region has two to three agricultural production seasons. For the Central and South regions, the coefficients on the linear and quadric terms of industrialization are significant and confirm that there is an inverse-U shape relationship between the land use intensity and industrialization. The quadratic term of the urbanization variable is significant for the south region but not for the Central region. The R&D variable has significant and positive coefficients for both regions while the coefficient for the irrigation variable is only significant for the South region.

In these regressions for China and the three regions, most regime dummies are “significant”, confirming the importance of institutional change. To gain a better understanding of the impact of institutional changes, three separate all-China regressions were estimated for the three regimes (Table 3). The inverse-U shape relationship between multiple cropping and industrialization is observed only for the post-reform period. Prior to the 1980s, China was a largely dual economy, characterized by surplus rural labor and a persistent low rural wage rate. Thus, industrialization did not have a significant impact on the rural wage rate, the important factor underlying multiple-cropping. As the economy developed with the success of the rural reforms, labor gradually became scarce in some regions, leading to higher wages and lower multiple cropping.

Interestingly, the relationship between land use intensity and urbanization changes from a U shape in the pre-reform period to an inverse-U shape in the post-reform period. On the one hand, the increase in urban population leads to higher demand for agricultural products, therefore higher agricultural prices. On the other hand, urbanization absorbs rural surplus labor and increases rural wages. The interplay between these two factors may lead to the different curvatures of land use intensity for urbanization at different times.

Three common features are apparent by looking over all the regressions in Table 3. First, the inverse-U shape relationship between land use intensity and industrialization is robust to various model specifications, which lends strong support to our hypothesis. Second, the significance of the regime dummies and the differences in estimated coefficients across regimes suggest that institutional changes do influence land use intensity. Third, farmers generally learn from their more successful neighbors about

cultivation practices, a result that is consistent with previous findings (Foster and Rosenzweig, 1995).

Based on the results in Table 3, we can calculate the turning points of land intensity in terms of industrialization. Using the most recent 1997 data and estimation results for China as a whole in the post-reform period, we find that the multiple-cropping index reaches a maximum when the ratio of agricultural GDP relative to total GDP is 21%. Because of the interaction term between industrialization and urbanization, each province reaches its turning point at a different industrialization level that is consistent with its urbanization level. In 1997, all the coastal provinces, except Guangxi Province, surpassed the turning point, while most inland provinces did not. Clearly, the potential for future growth in grain output exists primarily in the inland provinces. It may take a long time for all provinces to pass the turning point. However, once all provinces become sufficiently industrialized and surpass the turning point for land use intensity, China's total sown area will have to decline because industrialization is also causing a decline in the total arable area. There are at least two ways to deal with this situation. One way is to slow down population growth and reduce the demand for land and food. In this respect, China has been rather successful in controlling its population growth but the slow down may not be enough. A surer way is to boost crop yields by increasing public investment in R&D and irrigation (Fan and Pardey, 1997).

5. CONCLUSIONS AND POLICY IMPLICATIONS

This paper develops a framework to model the determinants of land use based on policy and historical experiences. The models for arable land area and multiple-cropping are specified separately to reflect the different decision processes underlying them. A long period panel data set at the provincial level is constructed from various governmental sources to conduct the empirical analysis and hypothesis tests. In spite of the complexity of modeling land use, the results are quite encouraging, and provide us with a better understanding of the driving forces behind the changes in China's agricultural land use.

The empirical evidence shows that industrialization and urbanization are important contributory factors to the conversion of farmland. Therefore, the “industrialization” and grain self-sufficiency policies, both proposed in fifties, are inherently in conflict with each other. Prior to the economic reform, these two objects were barely achieved, and only then through the household register system that kept a large rural population in place. Since the reform, the two goals have become more balanced largely by increasing land productivity through the practice of multiple cropping.

Moreover, the results suggest an inverse U-shape relationship between land use intensity and industrialization. On the one hand, industrialization brings down non-labor input costs for agricultural production, promoting the practice of multiple cropping. On the other hand, industrialization, especially the rapid development of rural enterprises, offers more non-farm job opportunities, raising wages and making intensive farming unattractive as surplus labor is exhausted. Therefore, in the short run, the total sown area

may still be stable or slightly expanding. In the end, as the country develops further, the total sown area will inevitably shrink, threatening the objective of grain self-sufficiency.

Until recently, the primary way for government to control farmland loss and increase sown area was through administrative orders, but the efficiency loss from doing so may have been high (Rozelle and Huang, 1999). However, there are several better ways to deal with the potential decline in sown area. First, encouraging labor movement across regions will cause the economically advanced provinces to delay reaching their maximum levels of cropping intensity. Second, long-term investment in agricultural research should be guaranteed in order to further increase yields. If the growth rate of yield surpasses the rate of loss in sown area, total grain output will not fall. Third, considering the important effect of the learning variable on land use intensity, it is sensible to strengthen the agricultural extension system to assist farmers in adopting land-saving technologies. Finally, China should increasingly make use of international trade to exploit its comparative advantages by gradually augmenting the import of land-intensive crops, such as grain, and paying for these with additional exports of labor-intensive commodities, such as fruits and vegetables.

APPENDIX: DATA SOURCES

Sown area and arable land area are widely used as indicators of agricultural land use. However, it is generally believed that the official statistics for cultivated land area are significantly biased (Ash and Edmonds, 1998; Ministry of Agriculture, 1998). Sown area statistics are a more policy responsive and consistent indicator.

Land sown areas for each province from the period from 1979 to 1997 were obtained from various issues of *China Agricultural Yearbooks*, *China Rural Statistical Yearbooks* and *China Statistical Yearbooks*. For earlier years, the data for sown area were taken from *National Agricultural Statistical Materials for 30 years, 1949-1979*. Some missing observations were supplemented by data in provincial yearbooks. The arable areas from 1980 to 1997 were taken from various issues of *China Agricultural Yearbooks* and *China Rural Statistical Yearbooks*. For earlier years, the information was taken from the *National Water Resource Statistical Materials for 30 years, 1949-1979*. However, the sown area and arable land data for most provinces only go back to the early 1960s. Therefore, the data set used in our estimation only covers the period from 1965 to 1997. Tibet, Hainan, and Ningxia are excluded due to lack of consistent data. The three direct administrative cities—Beijing, Shanghai, and Tianjin—are also not included considering their relatively small shares of agricultural production. As a result, the data set contains 24 provinces.

The total and rural population data for each province for the period of 1982 to 1997 were taken from various issues of *China Agricultural Statistics Yearbook*. Prior to 1982, the data were taken from *China Provincial Historical Statistical Materials, 1949-1989*. Some missing data were estimated based on provincial yearbooks and the *National*

Water Resource Statistical Materials for 30 years, 1949-1979. The urban population was estimated by subtracting rural population from total population. Urban and rural residencies are determined by the household registration system. Principally speaking, rural and urban residents are supposed to specialize in farm work and non-farm work in their registration areas, respectively. The ratio of the urban-to-total-population is used as a proxy for urbanization. However, with the success of the rural reform, many workers have been freed from agricultural activities and have moved to urban areas, especially big cities, to seek opportunities without any entitlement to subsidies like urban residents. There may be possible biases resulting from using the official registered numbers of rural and urban population.

Nominal GDP and the annual growth rates of real GDP for industrial, agricultural, and service sectors are available from SSB's *The Gross Domestic Product of China*. A ratio of non-agricultural GDP relative to the GDP in the agricultural sector is used to measure the levels of industrialization. The ratio of industrial GDP to total GDP is not used as a measurement because it would give a declining trend of industrialization due to an increasing share of GDP in the service sector. The previous year's growth rates of real GDP are used as a criterion to select the best neighbor province to imitate.

Total grain import and export data from 1950 to 1991 were downloaded from the USDA/ERS database. The information after 1991 was obtained from various issues of *China Statistical Yearbooks*. The Ministry of Foreign Economic Relations and Trade (MOFERT) were responsible for compiling the grain trade statistics prior to 1985. Since 1985, the Customs Department started reporting the trade statistics as well. There are slight differences between the two sources but their trends are similar. As the Customs

statistics are more reliable (Colby, Crook, and Webb, 1992), we use the data from this source after 1985. Annual aggregate grain production is available from the same sources as the grain trade statistics.

The irrigated area data were taken from various issues of *China Statistical Yearbooks*. The agricultural R&D expenditure data for the years following 1986 were taken from various issues of *Statistical Materials on Agricultural Science and Technology* (MOA, 1987-1997). Data for earlier years were obtained from the provincial academies of agricultural sciences. The nominal research expenditure data were deflated to constant 1980 Yuan using the national retail price index taken from *China Statistical Yearbooks*.

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