

**The Effects of Rural Infrastructure Development on Agricultural
Production Technical Efficiency: Evidence from the Data of Second
National Agricultural Census of China**

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ABSTRACT

This paper studies the effects of rural infrastructure development on agricultural production technical efficiency, using data from the second agricultural census of China. Employing Data Envelopment Analysis, this paper first estimates agricultural production technical efficiency of each administrative area of China. A Tobit model is then applied to study the effects on agricultural production technical efficiency of various types of rural infrastructures. Our empirical results suggest that transportation infrastructure plays the most substantial positive role on technical efficiency, followed by vocational/technical education infrastructure, electricity facilities and water supply systems. In addition, other potential factors influencing agriculture technical efficiency include regional industrial structure, mechanical intensity, the quality of labor and geographical locations.

Keywords: Rural infrastructure, agricultural production, technical efficiency

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1. Introduction

The development of rural infrastructure is highly related to agricultural production. Rural infrastructure not only provides essential agricultural production conditions such as roads, telecommunications, powers and irrigation systems, but also provides education and medical services related to enhancing the quality of rural labors such as cultural and educational facilities, vocational/technical schools, and medical institutes etc. Complete rural infrastructure can boost regional economic development.

Announced by the Chinese State Council on November 9, 2008 as an additional central government investment this year, the 100 billion yuan (\$14.7 billion) stimulus package is expected to be used in social welfare projects, infrastructure construction, environmental protection and industrial restructuring. The National Development and Reform Commission emphasized that one third of the stimulus package around 340 billion yuan (\$5.0 billion) will be invested in rural infrastructure constructions¹. It would be of profound interest to scholars and policy makers to know to what extent rural infrastructure affect the technical efficiency of agricultural production.

Based on a representative sample of 30 administrative areas in 2006, Data Envelopment Analysis (DEA) approach is used to estimate the technical efficiency of each division. Then, based on the regression method, we examine whether the

¹ http://www.chinadaily.com.cn/bizchina/2008-11/24/content_7235212.htm

development of infrastructure is an explanatory factor in the variations in technical efficiency.

This study contributes to the literature in three respects. First, that is the first empirical study of various kinds of rural infrastructure on agricultural production technical efficiency with provincial level data in China. Second, this study makes use of recently published national agricultural census data of China. The Second National Agricultural Census of China was conducted in 2007, which provides an overall investigation on agriculture, rural areas and farmers. Third, the measurement of rural infrastructure development emphasizes the popularity rate of different types of infrastructure such as power, telecommunication, roads, irrigations and schools in towns and villages, which is a new research angle different from the previous studies (Aschauer, 1989, Fan and Chan-Kang, 2005) focusing on the infrastructure stock.

This paper is organized into several sections. A literature review and the research hypotheses of this paper are presented in section 2. Before analyzing the empirical results in section 4, the methodology and the profile of sample data are briefly discussed in Section 3. Finally, the implications and the major findings of this paper are discussed in Section 5.

2. Literature Review and Research Hypotheses

There are many time-invariant factors that affect agricultural production efficiency. In this paper rural infrastructure is identified as being important in explaining the variation in technical efficiency in agriculture. The status and development of rural infrastructure not only influence agricultural production and operation modes directly,

but also improve the living standards for rural people and enhance the quality of rural labor. Deficient rural infrastructure may hinder agricultural production and induce poor technical performance. Rural infrastructure is considered to have an effect on agricultural production efficiency and is regarded as a strategic variable.

Most existing research explores the influence of infrastructure on agricultural production, rural growth and poverty reduction. Chen and Lin (2002) found that rural infrastructures such as irrigations, transportation, storages, primary products market and weather forecasting service can decrease production cost, transportation cost, storage expenses, dealing cost and operation risk, and enhance production efficiency. They concluded that rural infrastructures provide indispensable support for the sustainable development of rural regions. Peng (2002) pointed out that country road construction could reduce the expenditure of agricultural production. Fang et al. (2004) revealed that the potential of agricultural production can be released through rural infrastructure investment. The positive impact of infrastructure on regional economic development is well documented in the literature by Fan and Zhang (2004).

Little research has been done to understand the relationship between rural infrastructure and agricultural production technical efficiency. The objectives of this paper are to empirically ascertain the impact of infrastructure development on agricultural production technical efficiency and to answer a number of other questions that are relevant to the above theme. For instance, among various infrastructures, which induce the most substantial impact on agricultural production technical efficiency?

The development of infrastructure is an important indicator of a region's economic and social status. World Bank (1994) evaluated adequate supply of infrastructure as an essential ingredient of productivity and growth. Most infrastructure literature focus on one specific infrastructure sector, such as telecommunications (Roller and Waverman, 2001), roads(Fernald,1999), irrigation systems etc. This study will give an overall research on five different types of rural infrastructures including transportation, telecommunications, water lines, electricity and schools, and their impact on agriculture technical efficiency. Therefore, it is hypothesized that:

H1: There is a positive relationship between the popularity rate of rural infrastructure and agricultural technical efficiency.

To isolate the relationship between rural infrastructure popularity rate and agricultural production technical efficiency, it is essential to introduce into the model other independent variables that are likely to affect efficiency. Among the existing literature, factors influencing agricultural productivity includes mechanization, specialization, educational level (Chen, Huffman and Rozelle, 2006), scale operation (Wang et al., 1996), access to credit (Chavas et al. 2005, Dong and Putterman, 1997), and location characteristics (Coelli, Rao, and Battese 1998).

Four representative province-attribute factors are chosen to be control variables: industrial structure, mechanical intensity, labor quality, and location. Industrial structure is measured as the share of GDP. Mechanical intensity is computed as the ratio of total power of agricultural machinery to the total number of rural people

engaged. Labor quality is the proportion of labor with senior secondary school education or above. China is a large country and there is obvious gap between different regions. Geographic location may affect the efficiency of agricultural production. In this study, administrative areas are classified into 3 regions², and two dummy variables are defined to represent regional variations.

3 Methodology and Data

3.1 Data Envelopment Analysis

The non-parametric DEA approach is used to compute the technical efficiency of each province and municipality in China. DEA builds an equi-efficiency frontier and an efficiency envelope for each DMU. A number of studies, such as Färe et al. (1989), and Chaves & Cox (1990), have suggested that for the estimate of technical efficiency at provincial level, a non-parametric approach appears to outperform a parametric approach such as the stochastic frontier approach. DEA does not involve any prior specification of production function or of the production relationship between inputs and outputs. DEA analyzes each DMU separately and reveals those which exhibit best practice. If a DMU's input-output combination lies on the best practice frontier, it is regarded as being efficient. By contrast, if it lies below the frontier, it is considered to be inefficient. In a DEA analysis, it is generally assumed that there are n DMUs using amounts of k different inputs to produce m outputs.

² Eastern region includes Beijing, Tianjin, Liaoning, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan. Central region covers Heilongjiang, Shanxi, Anhui, Jiangxi, Henan, Hubei, Hunan. Western region includes Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, Jilin.

X : $k \times n$ vector of observations on DMUs' inputs

x_i : the i^{th} column of X is the i^{th} DMU's k different inputs

Y : $m \times n$ vector of observations on DMUs' outputs

y_i : the i^{th} column of Y is the i^{th} DMU's m different outputs

λ : $n \times 1$ vector of constants specifying the optimal non-negative weights of inputs/outputs

Under the assumption of all DMUs operating at an optimal scale, the output-oriented constant returns to scale (CRS) DEA model is as following:

$$\begin{aligned} & \max_{\phi, \lambda} \phi, \\ \text{st} \quad & -\phi y_i + Y\lambda \geq 0, \\ & x_i - X\lambda \geq 0, \\ & \lambda_i \geq 0, \end{aligned}$$

Where $1 \leq \phi \leq \infty$, and $\phi - 1$ is the proportional increase in outputs that could be achieved by the i -th DMU, with input quantities held constant. The inverse of ϕ defines a TE score with varies between zero and one. The efficiency measure obtained in CRS DEA model is referred to CRS technical efficiency, and marked as TE_{CRS} .

However, in the real market environment, due to imperfect competition and constraints on finance, most DMUs can not operate at an optimal scale. Banker et al (1984) pointed out that the use of the CRS specification when not all DMUs are operating at the optimal scale will result in measures of TE which confounded by scale efficiencies, and extended the CRS DEA model to account for variable returns to scale (VRS). Mathematically, if the condition of $\sum \lambda_i = 1$ is added, then VRS are imposed and will permit the calculation of TE devoid of these SE effects.

$$\begin{aligned} & \max_{\phi, \lambda} \phi, \\ \text{st} \quad & -\phi y_i + Y\lambda \geq 0, \\ & x_i - X\lambda \geq 0, \\ & \sum \lambda_i = 1 \\ & \lambda_i \geq 0, \end{aligned}$$

The efficiency measure obtained in VRS DEA model is referred to pure technical efficiency, and marked as TE_{VRS} . TE_{VRS} is always greater than or equal to TE_{CRS} since

VRS model forms a convex hull of intersecting planes which envelope the data points more tightly than the CRS conical hull. TE_{CRS} can be decomposed into two components, one due to scale inefficiency and one due to pure technical inefficiency.

$$TE_{CRS} = TE_{VRS} \times SE$$

When solving the above output-oriented VRS model, $\phi - 1$ is the proportional increase in outputs that could be achieved by the i -th DMU, with input quantities held constant. In this paper VRS DEA model is used to capture the agricultural production technical efficiency.

3.2 Tobit Model

To determine whether and to what extent the technical efficiency of each province can be explained by rural infrastructure development, we regressed the technical efficiency on the strategic variables together with the five control variables. As the technical efficiency ranges between zero and one, the distribution of efficiency is truncated above from unity. If the OLS method is applied, then the parameter estimates would be biased. The usual way to overcome this problem is to use a limited dependent variable model. In this context, we employed the Tobit model (Tobit, 1958). The underlying assumption of the OLS model is that, in terms of the population, technical efficiency follows a normal distribution, whereas the distribution of efficiency estimates of our sample firms obtained by DEA is a mixture of continuous and discrete distribution. By contrast, the distribution of technical efficiency in the stochastic frontier approach is often assumed to be skewed, for example, half-normal and truncated normal. If we want to obtain the original normal distribution of

technical efficiency, it is more appropriate to employ the Tobit model when accounting for truncated efficiency scores ranging between zero and one. With this assumption, the probability of a DMU being fully efficient is basically the same as if it were extremely inefficient. The specification of the equation is as follows:

$$TE = \alpha_0 + \alpha_1 Road + \alpha_2 Electricity + \alpha_3 Telecommunications + \alpha_4 Water_Supply + \alpha_5 Schools + \alpha_6 Industrial_Structure + \alpha_7 Mechanical_Intensity + \alpha_8 Educational_level + \alpha_9 Eastern + \alpha_{10} Middle + \varepsilon \quad (1)$$

Before proceeding to discuss the empirical results, the data profile of this research is briefly described.

3.3 Data

This paper bases on the 2006 data on the 30 divisions of administrative areas in China. There are 22 provinces, 5 autonomous regions and 4 municipalities in China. Due to the missing observations on Tibet Autonomous Region, a sample of 30 administrative regions remained.

All the data are published by National Bureau of Statistics of China and local Bureau of Statistics, and cited from the China Rural Statistical Yearbook³, Communiqué on Major Data of the Second National Agricultural Census of China, and local Communiqué⁴.

The variables used in the DEA models are defined as follows: the output variable: Q_i is the added value of farming, forestry, animal husbandry, and fishery of each administrative area. In the agricultural production, the main inputs are land, labor, chemical fertilizer, and agricultural machinery. Four variables are chosen as input

³ China Rural Statistical Yearbook 2007, China Statistics Press, Beijing, 2007.

⁴ National and local Communiqué on Major Data of the Second National Agricultural Census could be downloaded from the websites from national or local Bureau of Statistics of China.

variables. A_i is the total sown area, L_i is the number of rural persons engaged at year-end, F_i is the consumption of chemical fertilizer, and M_i is the total power of agricultural machinery. The definitions of independent variables used in tobit model are explained in Table 1, and the descriptions of all variables are listed in Table 2.

Table 1 Definitions of Variables

Variable	Description of the variables
Q = added value	added value of farming, forestry, animal husbandry, and fishery (in billion <i>yuan</i>)
A = land	total sown area (in 10,000 hectares)
L = labor	Total number of rural persons engaged at year-end (in 10,000 people)
F=chemical fertilizer	Consumptions of chemical fertilizer (in 10,000 ton)
M=agricultural machinery	Total power of agricultural machinery (in 10,000 kw)
<i>Road</i>	The proportion of towns and townships with highways above second class in local areas
<i>Electricity</i>	The proportion of towns and townships finished grid modification
<i>Telecommunication</i>	The proportion of villages having accessed to telephone
<i>Water_Supply</i>	The proportion of towns conducting concentrated water supply
<i>Schools</i>	The proportion of towns and townships constructed vocational/technical schools
<i>Industrial_Structure</i>	The agricultural share of GDP.
<i>Mechanical_Intensity</i>	The ratio of total power of agricultural machinery to the total number of rural people engaged.
<i>Educational_level</i>	The proportion of agricultural laborers with educational level of senior secondary school or above.
<i>Eastern</i>	Dummy variable with a value of one if the province/municipality locates in Eastern region of China.
<i>Middle</i>	Dummy variable with a value of one if the province/municipality locates in Middle region of China.

Table 2 Descriptive Statistics of Variables

Variable	Mean	Standard deviation	Minimum	Maximum
<i>Q</i>	82.299	58.933	6.960	213.890
<i>A</i>	4998.260	3592.820	329.600	14185.600
<i>L</i>	1675.957	1250.278	178.500	4752.400
<i>F</i>	158.680	127.621	7.000	518.100
<i>M</i>	2272.237	2314.854	96.500	9199.300
<i>Road</i>	0.534	0.200	0.186	0.926
<i>Electricity</i>	0.870	0.153	0.459	1.000
<i>Telecommunication</i>	0.975	0.041	0.793	1.000
<i>Water_Supply</i>	0.723	0.144	0.438	1.000
<i>Schools</i>	0.125	0.084	0.007	0.500
<i>Industrial_Structure</i>	0.128	0.065	0.009	0.327
<i>Mechanical_Intensity</i>	1.527	0.851	0.396	3.428
<i>Educational_level</i>	0.148	0.064	0.064	0.360
<i>Eastern</i>	0.367	0.490	0.000	1.000
<i>Middle</i>	0.267	0.450	0.000	1.000

4 Results and Discussions

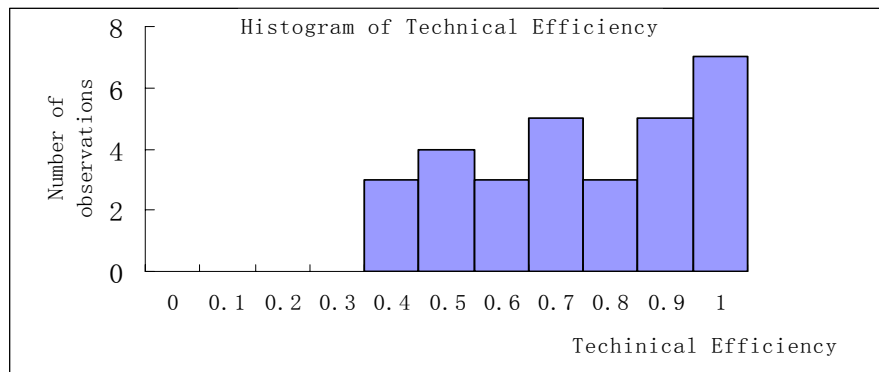
4.1 Results from the DEA model

The Data Envelopment Analysis Program (DEAP 2.1⁵) was used to calculate technical efficiencies in production for our output-oriented VRS DEA model. DEAP estimates technical efficiencies varying between zero and one in a non-parametric mathematical programming approach, and with the VRS specification, the measures of TE are devoid of scale efficiencies. The average score of the sample regions was 71.06%.

The distribution of technical efficiency is as following:

⁵ DEAP 2.1 was written by Professor Tim Coelli which could be downloadable from <http://www.uq.edu.au/economics/cepa/software.htm>.

Figure 1 Frequency Distribution of Estimated Technical Efficiencies



4.2 Results from the Tobit Model

After computing the technical efficiencies, we proceeded to test the hypotheses on whether infrastructure development enhance agricultural production technical efficiency, by estimating equation (1) using the TOBIT method. The results of the estimation of the equations with technical efficiency as the depended variable are given in Table 3. The parameters of the Tobit model were obtained by using maximum likelihood estimators.

Table 3 Estimation results of the effects of strategic and control variables on technical efficiency of provincial data of China, 2006

Dependent Variable = technical efficiency Tobit Model			
Constant	0.181 (0.735)		
<i>Road</i>	2.859** (0.932)	<i>Industrial_Structure</i>	-0.967* (0.517)
<i>Electricity</i>	1.725** (0.811)	<i>Mechanical_Intensity</i>	0.068* (0.041)
<i>Telecommunication</i>	-0.122 (0.832)	<i>Educational_level</i>	0.146** (0.070)
<i>Water_Supply</i>	0.844** (0.233)	<i>Eastern</i>	0.244** (0.120)
<i>Schools</i>	2.643** (0.990)	<i>Middle</i>	0.046 (0.091)
<i>Number of observations</i>		30	
<i>Log likelihood</i>		11.103	

Notes: (1) The figures in parentheses are the estimated standard errors.

(2) * denotes the significance at the 10% level; ** denotes the significance at the 5% level.

The parameter estimates for the tobit model listed in Table 3 suggest the impact of different types of infrastructure on agricultural technical effects. The results indicate that except telecommunication, the popularity rates of road, the proportion of towns and townships finished grid modification, the proportion of towns conducting concentrated water supply and the proportion of towns and townships constructed vocational/technical schools all have significant effects in determining levels of technical efficiency.

The coefficient estimate of road is 2.859, significant at the 0.05 level, and also exhibits the expected positive sign, indicating that provinces in China with higher proportions of towns and townships with highways above second class in local areas attain higher levels of agricultural production technical efficiencies. The road variable is an indicator of the development of transportation infrastructure. The more towns and townships have higher class roads, the less the circulation costs of materials and primary products are. If the proportion of towns and townships with highways above second class in local areas increases by one unit, the agricultural production technical efficiency would increase by 2.859 units. The relatively large coefficient estimate indicates that this factor is the most substantial determinant of level of efficiency.

Electricity facilities also play a significant and positive role on technical efficiency. The status of electricity facilities is represented by the proportion of towns and townships finished grid modification. In the past, there isn't sufficient investment on the constructions of rural grid, so the poor quality, expensive price and low efficiency of rural grid cumbered the economic development of rural areas. Since

1998, central and local government started to modify rural grid. At the end of 2006, the proportion of towns and townships finished grid modification occupied 81.9 percent throughout China ⁶. However, among different provinces, the grid modification progressing rate varied greatly from 45.9% to 100%.

Telecommunication is the proportion of villages having access to telephone. The sign of the coefficient on telecommunication variable is negative, and telecommunication popularity rate is unlikely to have a significant effect on TE. This result is out of our expectance and may be ascribed to the concentrated distribution of telecommunication. In the rural area of China, the proportion of most villages having access to phone reaches to 97% or above. The mean of telecommunication is 0.975 and its standard deviation is 0.041, with a range from 0.793 to 1. If the variation of an independent variable is not obvious, this independent variable would not exhibit significant explanation effect on the variation of the dependent variable.

The irrigation infrastructure is proxied by the proportion of towns conducting concentrated water supply. The coefficient of water supply is 0.844 and significant at 0.05 level. Regions with more concentrated water supply exhibit higher agricultural production efficiency. Concentrated water supply could help reducing the irrigation cost and enhancing irrigation efficiency.

The popularity rate of vocational/technical schools in towns and townships has significant and positive effect on agricultural production efficiency. The coefficient estimate of schools is 2.643, and the magnitude is the second largest among the five

⁶ Communiqué on Major Data of the Second National Agricultural Census of China.

types of infrastructure. Vocational/technical schools play great role on training rural laborers, and are important components of educational infrastructure.

From the above analysis, we could rank the five types of rural infrastructure by its marginal impact on agricultural production technical efficiency, the first is road, and the second is school, and then followed by electricity, water supply and telecommunications.

We now turn to examining the effects of the five control variables of local industrial structure, mechanical intensity, educational level of rural laborers, and locations.

Industrial structure is measured as the ratio of agricultural share of GDP. The coefficient estimate of this ratio is negative and significant at 0.05 level, which means the lower portion of the agricultural share of GDP is, the higher technical efficiency the agricultural production achieves. Agricultural share of GDP was found to be around 12.8% and ranges from 0.9% to 32.7%. In china, the industrial structure differs greatly among provinces and municipalities. In the regions with larger proportion of agricultural industry, the support role of the industry and commercial services sector on agriculture are less prominent than in the areas with more developed industry and services.

The coefficient estimate of mechanical intensity (measured by power of agricultural machinery per rural people engaged) is positive and significant at 0.10 level, and suggests that regions that are highly mechanized are more efficient. The use of agricultural machinery can enhance agricultural production efficiency.

The quality of labor is often used as an explanatory variable for variations in technical efficiency (Parikh and Shah, 1994). Educational level is evaluated by the proportion of rural labors that have completed senior secondary school or above. The positive and significant estimate coefficient suggests that rural labors receiving more education are better at agricultural production.

To control for the disparity of locations, we include two dummy variables. The base group comprises of provinces and municipalities in the western region of China. The estimated coefficient of dummy variable eastern is 0.244 and significant at 0.05 level, which means the average technical efficiency of provinces in the eastern region of china are 0.244 higher than those located in the western. While the insignificant estimate of coefficient on middle area reveals that the difference of agricultural production technical efficiencies between middle region and western region are not obvious.

5 Conclusions

To conclude, this paper has empirically examined the effects of five types of rural infrastructure on the technical efficiency of 30 provinces and municipalities in China, and has also investigated the role of four control variables, industrial structure, mechanical intensity, educational level of rural labor, and geographical locations in generating efficiency. This study involved a two-stage process where agricultural efficiency was estimated using DEA and variation in the resulting efficiency of agricultural production efficiency was explained by using a tobit model.

Using a data set consisting of cross sectional provincial data newly published in the Second National Agricultural Census of China, We have found that all the selected five types of rural infrastructure, except telecommunications, the popularity rates of towns and townships having roads, finishing grid modification, conducting concentrated water supply, constructing vocational/technical schools are positively associated with agricultural production technical efficiency to a certain extent.

The research hypothesis on rural infrastructure development and agricultural technical efficiency is supported by the empirical evidence. We also compare the impact effect of various types of rural infrastructure on agricultural technical efficiency. Transportation infrastructure plays the most substantial positive role on technical efficiency, followed by the vocational/technical education infrastructure, electricity facilities and water supply systems. These results lead us to suppose that increasing rural infrastructure construction can enhance agricultural production technical efficiency, government can boost agriculture development through improving the infrastructure facilities in rural areas.

Furthermore, we also analyzed control factors that may affect agricultural production efficiency. We found, as expected, that industrial structure, mechanical intensity and the quality of rural labor are regional attributes determining agricultural production efficiency. Provinces and municipalities in eastern China exhibit higher agricultural production technical efficiency than those in middle China, while the difference between middle and western region is not significant.

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