FACTORS INFLUENCING PRODUCTION EFFICIENCY IN THE NORTH OF CHINA

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ABSTRACT

Production efficiency for five major crops (winter wheat, summer corn, spring cotton, and summer and spring soybean) grown in the north of China were estimated using a survey of 249 households. The survey of rural households was conducted in Dengzhuang township, Hengshui Prefecture, Hebei Province, in 1993. Education and age of the major labourer had a positive effect on production efficiency. Efficiency was higher when females were the major labourer for all crops but spring cotton. Off-farm income had a positive effect, except for summer crops with high labour requirements. The presence of a tractor reduced efficiency, as did the area of fruit trees. Total household land area had a slightly positive effect on efficiency for all crops except soybean. Extension efforts to increase efficiency need to consider education and the gender of the major labourer. An understanding of the structure of the household and farm can assist preparation of appropriate extension programs.

INTRODUCTION

The introduction of the household responsibility system and market reforms in China required farm households to adjust to the new economic environment. The information needs from extension services has also changed. The reforms resulted in increased output, but production efficiency is still low for many households. Increasing efficiency requires an understanding of the current situation and the factors that affect efficiency.

The Heilonggang area of North China lies along the eastern edge of Hebei province, centered about 250 km south of Beijing. Annual precipitation is about 500 mm per year, with 70-80% falling during the June through August rainy season. Precipitation for winter crops, primarily winter wheat, is low and requires irrigation for adequate production. The availability of irrigation water is a major concern in the area since the main food crop, winter wheat, requires irrigation for adequate production. Most of the irrigation water in this region is pumped from wells 100-150 m deep, and the water table is declining 1 m per year.

The population in the area is 19 million, of which 90% are rural. Land area is 2 mu (0.133 hectare) per capita. The area can grow two crops per year. Winter wheat is grown during the winter season, almost exclusively on irrigated land, and the main summer crops are summer corn and summer soybean. Land that is not irrigated is generally planted to spring cotton or spring soybean. There are many other minor crops including sesame, peanut, millet, sweet potato, and vegetables. Household incomes are low, with limited off-farm employment opportunities.

The objective of this study was to determine the factors that impact on the production efficiency of the five major crops in the area. The information provided by these impacts can be used to increase the effectiveness of efforts to develop the rural areas through agriculture.

MODEL

The estimation of production efficiency involves estimating a production frontier. A production frontier is the potential production, given the resources and inputs used. Figure 1 illustrates the concept of the frontier. The dots represent observations of yield for different input levels. The line "A" represents a fitted line (least squares) through the observed points. The frontier is represented by line "B", at the upper edge of all the observed points.

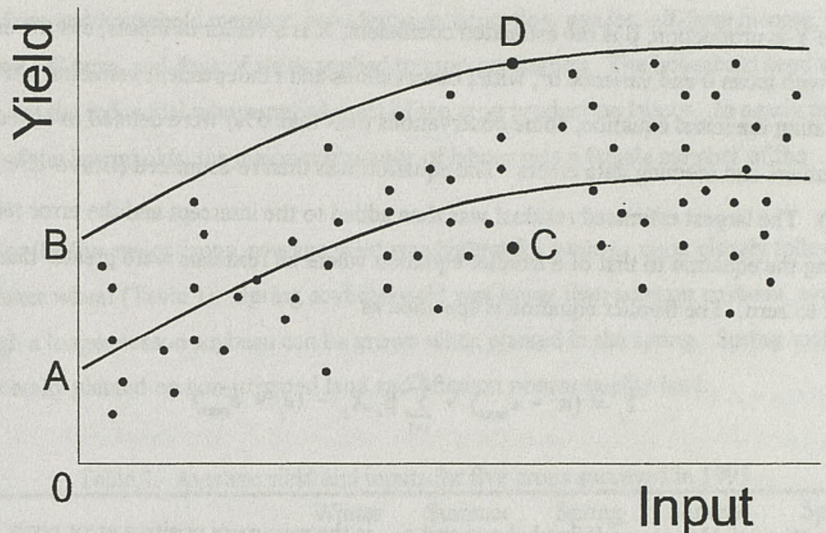

Figure 1. A Production Frontier

Production frontiers have been estimated using four different approaches (Bravo-Ureta and Rieger 1990). The first is to use linear programming methods, minimizing the positive residuals of the estimated equation. The residual is defined as the frontier minus the actual production. The second approach is to statistically estimate a production function and adjust the intercept of the equation based on the largest error term. In Figure 1, the statistical production function is represented as line "A" and the intercept is shifted by the largest positive residual to determine the statistical production frontier represented by line "B". The third approach is to estimate the frontier using a gamma-distributed efficiency term. The forth approach is to estimate a stochastic production frontier where the error term is composed of a one-sided component that measures inefficiency and of a random noise component.

The approach used in this analysis was to estimate a statistical frontier (Bravo-Ureat 1986). The equation can be specified as

$$Y_j = \alpha + \sum_{i=1}^{m} \beta_i X_{ij} - e_j$$

where Y is production, β is the estimated coefficient, X is a vector of inputs, e is the error term with mean 0 and variance σ^2, with j observations and i independent variables. After estimating the initial equation, some observations (less than 5%) were deleted to account for outliers and seeming data errors. The equation was then re-estimated (Bravo-Ureta 1986). The largest estimated residual was then added to the intercept and the error term, shifting the equation to that of a frontier equation where all residuals were greater than or equal to zero. The frontier equation is specified as

$$Y_j = (\alpha + e_{max}) + \sum_{i=1}^{m} \beta_i X_{ij} - (e_j + e_{max})$$

where the variables are as defined above and e_{max} is the maximum positive error term (equal to AB in Figure 1).

Production efficiency is determined by dividing actual production by the frontier production. By definition, all values for production efficiency will be between 0.0 and 1.0. Production efficiency is then

$$PE_j = Y_j / \hat{Y}_j$$

where PE is production efficiency, Y is the actual yield, $\hat{Y}$ is the estimated production frontier yield, and j is the observation.

An attempt was made to explain the estimated production efficiencies by characteristics of the household and farm. Age, education, gender, off-farm income, the use of a tractor, the area of tree fruits, the total land area, and the land area in soybean production for soybean were used to explain production efficiency for the five crops.

DATA

A survey of 249 households in eight villages was completed for the 1993 production year in Dengzhuang township (He, Zuo and Tan, 1995). Dengzhuang township is in Hengshui Prefecture, which is in the central part of the Heilonggang area. Data were collected for each farm and household member, including age, education, gender, off-farm income, days worked off-farm, and days of work applied to crop production. The household head was often not the individual who supplied most of the crop production labour. In nearly one-third of the households, the major contributor of labour was a female member of the family.

For the five major crops, average yield was highest for summer corn, closely followed by winter wheat (Table 1). Spring soybean yield was lower than summer soybean, even though a longer season soybean can be grown when planted in the spring. Spring soybean is generally planted on non-irrigated land and often on poorer quality land.

Table 1. Average yield and inputs for five crops surveyed in 1993

Item	Winter Wheat	Summer Corn	Spring Cotton	Summer Soybean	Spring Soybean
Number of Farms	237	225	28	152	117
Percent of Surveyed	96	91.1	11.3	61.5	47.4
Yield (jin/mu)[1]	537.37	564.39	123.39	240.33	158.28
CV for Yield (%)	20.8	40.3	73.4	34.5	55.4
Inputs					
Irrigation (¥/mu)	40.3	9.0			
Nitrogen (¥/mu)	37.0	10.2	13.2	3.3	3.1
Other Fertilizer (¥/mu)	18.7	0.9	12.2	2.4	4.3
Field Activities (¥/mu)	21.8	11.4	4.8	10.0	8.8
Seed Cost (¥/mu)	13.8	11.1	5.3	11.3	10.7
Crop Protection (¥/mu)	4.1	3.1	33.1	2.6	2.3
Total Inputs (¥/mu)	135.7	45.7	68.6	29.6	29.2
Non-Harvest Labour (days/mu)	5.5	7.5	11.6	10.2	7.2
Household					
Age (yr)	40.6	40.5	40.3	40.6	39.3
Education (yr)	5.5	5.6	5.1	5.7	5.6
Off-farm Income (¥)	1040.8	1184.2	765.4	1524.1	882.8

[1]Mu is a land area measurement, 15 mu=1 hectare. Jin is a measure of weight, 1 Jin = 0.5kg.

The variability of yields across farms was lowest for winter wheat. Winter wheat is the major food grain produced for the household and is managed similarly across all farms. The high variability for spring cotton production reflected the unfavourable weather conditions for cotton in 1993, distorted prices in previous years, and a major problem with the boll weevil.

Total input use was highest for winter wheat, about twice that of cotton and three times that of summer corn. A major cost in winter wheat production was irrigation. Fertilizer costs for winter wheat were also several times higher than for other crops. It is not known whether winter wheat utilizes all of these nutrients, or whether they carry over to the summer crop. Field activities (land preparation, seeding, harvesting, etc.) costs were highest for winter wheat. Crop protection costs were highest for spring cotton, consisting primarily of insecticides to control the boll weevil. Non-harvest labour inputs were highest for spring cotton and summer soybean.

RESULTS

The average production efficiency was highest for winter wheat production and lowest for spring soybean (Table 2). Summer corn, spring cotton and summer soybean had average production efficiencies of 54-61%.

The variation in production efficiency was lowest for winter wheat production, with no farms less than 43%, and 77% of farms were in the 60 to 90% range. The variability in production efficiency for the spring and summer crops was high, with a 52% coefficient of variation for spring soybean. Despite what might appear to be a similarity in production across households in the Heilonggang area, there is considerable variation in the efficiency of their production.

The variation in production efficiency across households was explained, in part, by the structure of the household. The age, education and gender of the family member who supplied the majority of crop production labour explained some of the variation in efficiency (Table 3).

Table 2. Distribution of production efficiency (PE) of crop production among households

PE Intervals	Winter Wheat		Summer Corn		Spring Cotton		Summer Soybean		Spring Soybean	
(%)	farms	%	farms	%	farms	%	farms	%	farms	%
0-10									10	9.2
10-20			1	0.5					7	6.4
20-30			6	2.8			3	2.1	20	18.3
30-40			21	9.9	4	17.4	8	5.6	7	6.4
40-50	5	2.2	52	24.4	6	26.1	33	22.9	15	13.8
50-60	26	11.5	64	30.0	3	13.0	37	25.7	16	14.7
60-70	68	30.1	40	18.8	2	8.7	31	21.5	19	17.4
70-80	58	25.7	18	8.4	4	17.4	22	15.3	8	7.3
80-90	47	20.8	8	3.8	2	8.7	7	4.8	3	2.8
90-100	22	9.7	3	1.4	2	8.7	3	2.1	4	3.7
Total	226	100	213	100	23	100	144	100	109	100
Efficiencies										
Mean PE (%)	73.16		54.86		60.59		58.22		45.46	
Max PE (%)	100		100		100		100		100	
Min PE (%)	42.76		17.08		35.45		26.45		5.23	
CV of PE (%)	16.67		25.94		32.81		24.66		52.11	

Age had a significant positive effect on efficiency for winter wheat (0.124% per year of age) and spring cotton (0.604% per year of age). These two crops are management intensive and the additional experience of the older farmers had a positive effect on efficiency. Age had a negative effect, but not significant, for summer corn and summer soybean production. Education had a positive impact on efficiency for winter wheat, summer corn and spring cotton, but negative for soybean. None of the estimates were significant, though the sign does indicate a direction of impact. Average years of education in this sample was about 5.5. The relatively low education level probably reflects limited education opportunities more than the ability to learn and apply new techniques and practices, or techniques learned through formal education. The gender of the major labourer had a significant impact on winter wheat efficiency, 4% higher if the main labour input was from a female. Efficiency was higher for female labourers for all crops but spring cotton. Female labour was the main labour supply in households where the male had off-farm work. While off-farm income was taken into account, actual off-farm days of labour were not. The gender variable could be measuring some additional household structure information.

Table 3. Estimated coefficients for variables that impact on production efficiency for five crops

Variables	Winter Wheat	Summer Corn	Spring Cotton	Summer Soybean	Spring Soybean
Age	0.124*	-0.064	0.604*	-0.068	0.152
Education	0.208	0.314	1.320	-0.136	-0.0466
Gender (F=1)	4.02***	0.620	-14.15	3.757	2.708
Off-Farm Income	0.00019	0.00032	-0.0008	-0.0008	0.00247
Tractor	-1.699	-2.498	-5.498	3.557	-2.711
Tree Fruit Area	-0.228	-0.360	-4.382	0.363	-0.686
Soybean Area				-1.53**	-4.73***
Land Area	0.074	0.218	0.919	-0.095	0.108

Significance level: *=10%; **=5%; ***=1%

Off-farm income had a small positive effect on efficiency for winter wheat, summer corn and spring soybean. Off-farm income should result in fewer financial constraints when purchasing inputs, and therefore a more efficient allocation of resources. However, off-farm employment also reduces the labour available for farm activities and possibly reduces the quality of management as well. Spring cotton and summer soybean had the highest non-labour requirements (Table 1) and the impact of off-farm income for these crops was negative. This could be an indication of a labour constraint in the production of these crops when there is also off-farm employment.

The presence of a tractor reduced production efficiency by 1.7 to 5.5 percent, except for summer soybean in which it was increased by 3.5%. While these estimates were not statistically significant, they do indicate that mechanization will not necessarily result in higher production efficiency under the current production circumstances. The increased efficiency that will result from better timing and reduced physical labour requirements, is being off-set by negative factors. Most farms with a tractor also use the tractor to transport materials, including grains, fertilizer, construction materials, and coal. The presence of a tractor could indicate that the transport activities are taking higher priority than field crop activities and this negatively affects production efficiency.

The total area of different crops grown can impact on the resource availability of the household. Fruit tree production, which is highly profitable and requires a higher level of management, had a negative impact on the efficiency of production for the five crops in this analysis. The total land area operated by the household had a small positive effect on efficiency. Larger production units had higher production efficiency. The average household had 11 mu, which was nearly the mid point of the range of sizes. The land area planted to soybean had a significant negative impact on the efficiency of soybean production, -1.5% per mu for summer soybean and -4.7% per mu for spring soybean. Expanded soybean plantings could result in less efficient soybean production, unless the cause of this negative yield impact can be determined and corrected.

CONCLUSIONS

The estimates obtained in this study for the impact of age, education and land area agree with estimates from other studies and regions (Coelli and Battese 1996, Hussain and Byerlee 1995). The set of variables used to explain production efficiency differs from studies, so an exact comparison is not possible. This study included the impact of the gender of the main labour contributor, which has not been addressed in other efficiency studies. The household is complex and an increased study of the household might help to explain more of the variation in efficiency across farms.

Estimating the efficiency of production for winter wheat, summer corn, spring cotton, summer soybean and spring soybean indicated there are considerable opportunities to increase the production of crops through increasing efficiency. Winter wheat, the major food crop, had the highest efficiency and the variation in efficiency was lowest of all crops in the survey. Considerable management effort is applied successfully to this crop. The spring and summer crops had a lower average efficiency, and some households had extremely low efficiency. There seems to be plenty of opportunity to increase production efficiency and hence crop production.

Determining why production efficiency varies across households can be used to direct extension, or other activities, to increase efficiency. However, explaining the variation in efficiency was difficult and the results were not always clear (especially in a developing region where production records are seldom kept and the respondents are recalling the survey data for the past year from memory). The structure of the labour in the household had a major impact on efficiency. Experience, measured by age, and education contributed to increased efficient production. The gender of the major labour provider can also contribute to efficiency. The reasons for the gender impact are not well understood, but should be studied further. The household member who contributed the majority of labour also tended to have more of an impact on production efficiency. The labour structure needs to be considered by extension personnel so that the correct individuals are targeted and that programs are appropriate.

The effects of off-farm income opportunities and income obviously affected production efficiency. There appeared to be two conflicting effects of off-farm income. First, the income generation contributed to more efficient resource allocation because constraints on input purchases were reduced or eliminated. Second, the off-farm employment reduced labour availability and possibly management effort, leading to reduced efficiency. With a strategy of developing the rural economy through both agriculture and industry, the impacts of off-farm employment on agriculture need additional understanding.

Total land area worked by the household seemed to have a small positive impact on production efficiency. However, it may have a negative impact on production efficiency for some crops, primarily through labour allocation to the more profitable crops or those that have high labour requirements.

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