Asian Agricultural Research 2014, 6(6): 61 -65

The Estimation Methods for Agricultural Surplus Labor Based on Stochastic Frontier Production Function

Chaozhou LU, Yanfen LUO *

Department of Business and Trade, Rongchang Campus, Southwest University, Chongqing 402460, China

Abstract The existing calculation methods for the number of agricultural surplus labor have a common flaw, that is, they can not reflect the impact of technical efficiency changes in agricultural production on the surplus labor. Based on the basic principle of stochastic frontier production function, this paper calculates the agricultural production technical efficiency of various provinces, and selects the province with the highest technical efficiency to assume that its agricultural labor is fully utilized, and there is no agricultural surplus labor. With the ratio of agricultural labor number to agricultural output value in this province as a reference, this paper calculates the number of agricultural surplus labor in other provinces. This calculation method makes up for the shortcomings of the existing calculation methods; it reflects the relationship between the number of agricultural surplus labor and production technical efficiency.

Key words Agricultural surplus labor, Stochastic frontier production function, Technical efficiency

1 Introduction

A lot of literature believes that there is agricultural surplus labor in China, but for its number, different scholars use different calculation methods and the results vary widely. The common calculation methods for the number of agricultural surplus labor mainly include three types. The first is to use labor - land ratio for estimation. The second is to use agricultural production function for estimation, and describe the production of agricultural sector according to the Cobb - Douglas production function or variable elasticity of substitution (VES), thereby calculating the number of agricultural surplus labor. The third is to calculate based on the optimization model of production resource allocation.

For the first method, the number of agricultural surplus labor is only assumed to be related to land and the number of agricultural labor, but not to be related to the number of effective labor; for the second and third methods, the calculation results are closely related to the setting of the form of the production function, the selection of different production functions will cause different estimation results, and both of them fail to reflect the impact of technical efficiency changes on the surplus labor in agricultural production. When the agricultural production technical efficiency is very low, the output will be very low in the case of the same amount of factor inputs, or at the same level of output, the amount of factor inputs is excessive.

Conspicuously, the excess amount of factors is closely linked with the production technical efficiency. The excess amount of factors will increase along with the improvement of technical efficiency. In other words, if the output is maintained unchanged, the amount of factors needed will be less along with the improvement of technical efficiency. In terms of the agricultural labor, with the improvement of agricultural production technical efficiency, if the agricultural labor needed is less, there will be more surplus labor.

Using the stochastic frontier production function, this paper first measures the annual agricultural production efficiency in various provinces during the period 1995 - 2004, and then it selects the province with the highest technical efficiency as the representative, and believes that various factors have been fully utilized in this province during the agricultural production, there is no agricultural surplus labor, and the amount of labor needed per unit of output in the province is the amount of effective labor. Finally, according to the ratio of actual amount of labor per unit of output to the amount of effective labor per unit of output in other provinces, it measures the number of agricultural surplus labor in various provinces. This estimation method can reflect the relationship between the number of agricultural surplus labor and production technical efficiency.

2 The basic principles of stochastic frontier production function

2.1 Technical efficiency In the case of established technical conditions and total amount of resources, if resources are fully utilized, then the output should be in the production possibility frontier, and if the observed output point falls within the production possibility frontier, it indicates that the resources have not been fully utilized, as shown in Fig. 1.

Point I in Fig. 1 means that the resources are fully utilized, so the production is in the state of perfect technical efficiency; Point H means that the resources are not fully utilized, so the production is in the state of non-perfect technical efficiency.

According to the distance relationship between production inefficiency point and the production possibility frontier under the same input, the technical efficiency of a production unit can be

Received: May 1, 2014 Accepted: June 9, 2014

Supported by the Fundamental Research Funds for Central Universities (SWU1409313); Fund Project for the Enterprise Management Cultivation Disciplines, Rongchang Campus, Southwest University (RCQG207001).

* Corresponding author. Email: lyfswu01@126.com

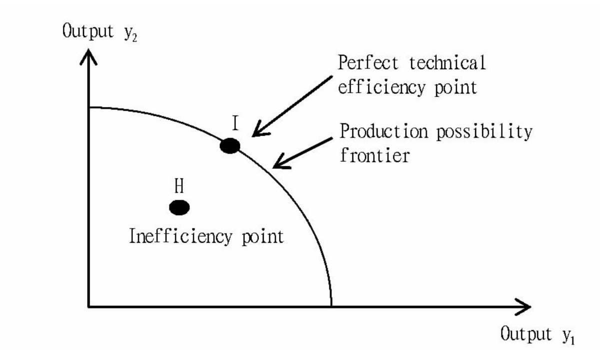

Fig. 1 The production possibility frontier

measured. Taking the single factor input for example, the estimation of technical efficiency is shown in Fig. 2.

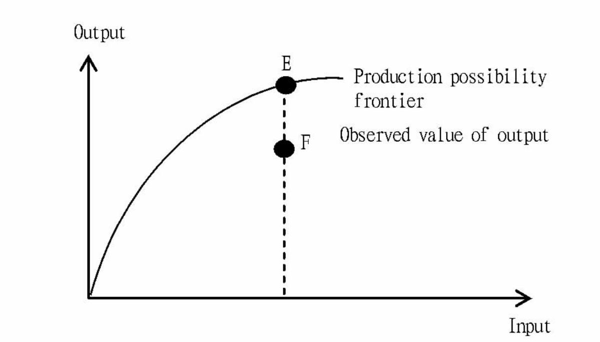

Fig. 2 The production technical efficiency

In Fig. 2, assuming the input is at point G, if the resources are fully utilized, and the technique is brought into full play, the output should be at point E, namely at the production possibility frontier line; if the observed output is at point F, namely below the production possibility frontier, it indicates that the production does not meet the perfect technical efficiency.

The technical efficiency (*TE*) of point E, F is calculated as follows:

Point E: $TE_E = GE/GE = 1$; Point F: $TE_F = GF/GE$.

2.2 Stochastic frontier production function The production process in the state of perfect technical efficiency exists only in theory, that is, the production possibility frontier in the real production can not be observed. In reality, we can only observe the actual amount of inputs and outputs, and based on actual observed values, we can only calculate the actual production function, but fail to calculate the production possibility frontier.

If we build the external output envelopment frontier based on the actual observed values of input and output so that all the observed values of output are below the frontier and close to it as far as possible, then this frontier is called frontier production function, and it can replace the production possibility frontier, as shown in Fig. 3.

Further, the formation of production possibility frontier can be viewed as the result of joint action of the determining factors and random factors, and the production possibility frontier built according to this method is called stochastic frontier production

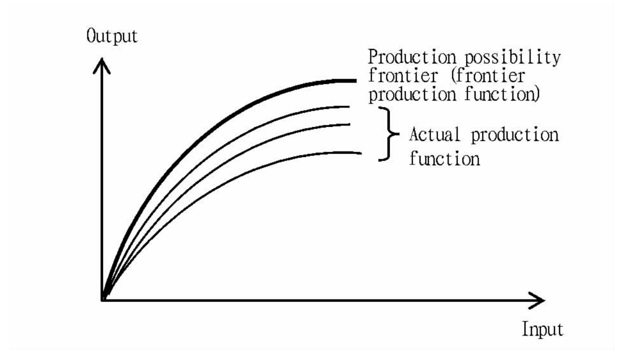

Fig. 3 The frontier production function

function.

The determining factor is the actually observed value of inputs and outputs. The random factors include the following two types:

(i) The first type is the random factors beyond the control of the production units, such as weather and luck, which will lead to fluctuations in the observed value of output of the same production unit with the same input in different time periods, and will also lead to differences in the observed value of output between different production units with the same inputs even in the case of the same technical efficiency.

The error v between the observed value of output with the same input and the maximum possible output, caused by the uncontrollable random factors, is a bilateral error which can be positive or negative.

(ii) The second random factor is caused by the mismanagement of production units, and since the level of management of the same production units in different time periods or since the level of management of different production units is inconsistent, the observed value of output is not the same in the case of the same input and the same "natural" conditions.

The error u between the actual output and the maximum possible output, caused by the level of management, is a unilateral error less than zero.

The two random factors jointly affect the error between the actual output and the production possibility frontier. The stochastic frontier production function model developed by Aigner, Lovell and Schmidt (1977), Meeusen and van den Rroeck is as follows:

Let the production function be:

$Y_i = f(X_i; \beta) \times \exp(v_i - u_i)$

Take the logarithm to get the following form:

$y_i = f(x_i; \beta) + (v_i - u_i)$

where observation point $i = 1, 2 \cdots\cdots N$; y_i is the output logarithm value of observation point i; x_i is the input logarithm value of observation point i; v_i is the random bilateral error; u_i is the random unilateral error greater than zero.

According to the frontier production function estimated by the above equation, it is determined by the distribution characteristics of the random error term.

Assuming that v_i and u_i are independently distributed, $v_i - N$

$(0, \sigma_v^2)$, $u_i - N^+(0, \sigma_u^2)$.

Let $\varepsilon = v - u$, $\sigma^2 = \sigma_v^2 + \sigma_u^2$, $\lambda = \sigma_u/\sigma_v$, $f^*(\ )$ is the standard normal distribution density, and $F^*(\ )$ is the standard normal distribution function.

Based on the derivation of M. A. Weinstein (1964), there is:

$$f(\varepsilon) = \frac{2}{\sigma} f^*\left(\frac{\varepsilon}{\sigma}\right) * [1 - F^*(\varepsilon\lambda\sigma^{-1})]$$

For N observation points, the log-likelihood function can be constructed:

$$\ln\psi(y/\beta,\ \lambda,\ \sigma^2) = N\ln\frac{\sqrt{2}}{\sqrt{\pi}} + N\ln\sigma^{-1} + \sum_{i=1}^{N}\ln[1 - F^*(\varepsilon_i\lambda\sigma^{-1})] - \frac{1}{2\sigma^2}\sum_{i=1}^{N}\varepsilon_i^2$$

Seek partial derivative of β, λ, σ^2, respectively, and let it be zero, the equation can be obtained as follows:

$$\frac{\partial\ln\psi}{\partial\beta} = \frac{1}{\sigma^2}\sum(y_i - \beta x_i)x_i + \frac{\lambda}{\sigma}\sum\frac{f_i^*}{(1 - F_i^*)}x_i = 0$$

$$\frac{\partial\ln\psi}{\partial\beta} = \frac{1}{\sigma}\sum\frac{f_i^*}{(1 - F_i^*)}(y_i - \beta x_i) = 0$$

$$\frac{\partial\ln\psi}{\partial\sigma^2} = -\frac{N}{2\sigma^2} + \frac{1}{2\sigma^4}\sum(y_i - \beta x_i)^2 + \frac{\lambda}{2\sigma^3}\sum\frac{f_i^*}{(1 - F_i^*)}(y_i - \beta x_i) = 0$$

u_i By calculating the optimal solution of linear programming of the above equations, we can get the estimated value of β, λ, σ^2, and thus calculate the frontier production function.

2.3 The calculation of the number of agricultural surplus labor In reality, the agricultural labor forces in the agricultural sector all participate in productive labor, but from the whole country, there is an underutilized state for the agricultural labor, or, under given output, the agricultural labor input is excessive. In theory, the technical efficiency of part of the labor can be considered as 1, namely having the perfect technical efficiency while the technical efficiency of another part of the labor can be considered as 0, namely in the perfectly inefficient state, with the marginal product is 0.

2.3.1 The agricultural production technical efficiency of the Chinese provinces and cities. Let the logarithmic form of agricultural production function of the Chinese provinces be:

$$\ln A = \beta_0 + \beta_1\ln K + \beta_2\ln H + \beta_3\ln T + \beta_4\ln N + \beta_5\ln B$$

where A is the actual output value of agriculture; K is the total machinery power; H is the application rate of chemical fertilizer; T is the effective irrigation area; N is the number of agricultural labor; B is the number of large livestock.

The error between annual frontier production function and actual production function is: $(v - u)$, v_i and u_i are independently distributed, $v_i - N(0, \sigma_v^2)$, $u_i - N^+(0, \sigma_u^2)$.

The data are collected from the agricultural input and output data of 30 provinces and cities except Chongqing in the period 1995 – 2004.

According to the basic solving methods for the stochastic frontier production function, using FRONTIER (Version 4.1) software, we calculate the technical efficiency of various provinces in different years based on the panel data of agricultural input of 30 provinces and cities in the period 1995 – 2004, and the real agricultural output calculated with the prices in 1978 as the base year prices, as shown in Table 1.

Table 1 The technical efficiency of various provinces and cities in the period 1995 – 2004

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Beijing	0.263 28	0.265 11	0.266 93	0.268 76	0.270 59	0.272 43	0.274 26	0.276 11	0.277 95	0.279 79
Tianjin	0.210 82	0.212 52	0.214 23	0.215 95	0.217 66	0.219 39	0.221 11	0.222 84	0.224 58	0.226 32
Hebei	0.625 01	0.626 53	0.628 04	0.629 55	0.631 06	0.632 56	0.634 06	0.635 56	0.637 05	0.638 53
Shanxi	0.217 36	0.219 08	0.220 80	0.222 53	0.224 27	0.226 01	0.227 75	0.229 50	0.231 26	0.233 01
Inner Mongolia	0.333 23	0.335 13	0.337 03	0.338 93	0.340 83	0.34273	0.344 63	0.346 53	0.348 44	0.350 34
Liaoning	0.589 96	0.591 57	0.593 18	0.594 78	0.596 38	0.597 98	0.599 57	0.601 15	0.602 74	0.604 32
Jilin	0.366 34	0.368 24	0.37015	0.372 06	0.373 96	0.375 87	0.377 78	0.379 68	0.381 59	0.383 49
Heilongjiang	0.414 15	0.41604	0.417 93	0.419 82	0.421 71	0.423 60	0.42548	0.427 36	0.429 25	0.431 13
Shanghai	0.359 41	0.361 31	0.363 22	0.365 13	0.367 03	0.368 94	0.37085	0.372 75	0.374 66	0.376 56
Jiangsu	0.969 22	0.969 38	0.969 53	0.969 69	0.969 84	0.97 000	0.97015	0.970 30	0.970 45	0.970 60
Zhejiang	0.845 07	0.845 81	0.846 54	0.847 27	0.847 99	0.848 71	0.84943	0.850 15	0.850 86	0.851 57
Anhui	0.543 20	0.544 92	0.546 63	0.548 34	0.550 04	0.551 75	0.55344	0.555 14	0.556 83	0.558 52
Fujian	0.685 83	0.687 17	0.688 50	0.689 83	0.691 16	0.692 48	0.69379	0.695 10	0.696 41	0.697 72
Jiangxi	0.471 63	0.473 47	0.475 30	0.477 13	0.478 96	0.480 79	0.48261	0.484 43	0.486 25	0.488 07
Shandong	0.826 30	0.827 12	0.827 93	0.828 74	0.829 54	0.830 34	0.83114	0.831 93	0.832 72	0.833 51
Henan	0.663 51	0.664 91	0.666 32	0.667 72	0.669 11	0.670 50	0.67189	0.673 27	0.674 65	0.67602
Hubei	0.557 80	0.559 49	0.561 17	0.562 85	0.564 52	0.566 19	0.567 86	0.569 52	0.571 18	0.57284
Hunan	0.654 59	0.656 02	0.65 745	0.658 88	0.660 30	0.661 72	0.663 13	0.664 54	0.665 95	0.66735
Guangdong	0.863 31	0.863 97	0.864 62	0.865 27	0.865 92	0.866 56	0.867 20	0.867 84	0.868 47	0.869 11
Guangxi	0.454 59	0.456 45	0.458 30	0.460 16	0.462 01	0.463 85	0.465 70	0.467 54	0.469 38	0.471 22
Hainan	0.302 02	0.303 89	0.305 77	0.307 65	0.309 53	0.311 41	0.313 29	0.315 18	0.317 07	0.318 96
Sichuan	0.705 80	0.707 07	0.708 34	0.709 61	0.710 86	0.712 12	0.713 37	0.714 61	0.715 86	0.717 09
Guizhou	0.275 20	0.27705	0.278 89	0.280 74	0.282 59	0.284 44	0.286 30	0.288 15	0.290 01	0.291 87
Yunnan	0.360 77	0.362 68	0.364 58	0.366 49	0.368 40	0.370 30	0.372 21	0.374 12	0.376 02	0.377 93

(To be continued)

(Continued Table 1)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Tibet	0.077 60	0.078 63	0.079 67	0.080 72	0.081 78	0.082 85	0.083 92	0.085 00	0.086 09	0.087 19
Shaanxi	0.281 56	0.283 41	0.285 27	0.287 12	0.288 98	0.290 84	0.292 70	0.294 57	0.296 44	0.298 31
Gansu	0.227 08	0.228 82	0.230 58	0.232 33	0.234 09	0.235 86	0.237 62	0.239 40	0.241 17	0.242 95
Qinghai	0.079 55	0.080 60	0.081 66	0.082 72	0.083 79	0.084 88	0.085 97	0.087 06	0.088 17	0.089 28
Ningxia	0.085 85	0.086 95	0.088 05	0.089 17	0.090 29	0.091 42	0.092 55	0.093 70	0.094 85	0.096 02
Xinjiang	0.306 11	0.307 99	0.309 87	0.311 75	0.313 63	0.315 52	0.317 41	0.319 30	0.321 19	0.323 08
Average	0.453 87	0.455 38	0.456 88	0.458 39	0.459 89	0.461 40	0.462 91	0.464 41	0.465 92	0.467 42

2.3.2 The number of agricultural surplus labor in various Chinese provinces and cities. From the annual technical efficiency of various provinces and cities in Table 1, it can be found that the agricultural production technical efficiency is the highest in Jiangsu Province, and its technical efficiency is at around 0.97, close to 1, that is, it is close to perfect technical efficiency state. We can believe that factor inputs of Jiangsu Province have been fully utilized during the agricultural production, that is, the number of surplus labor in Jiangsu Province from 1995 to 2004 was close to 0.

Meanwhile, the agricultural output of Jiangsu Province accounts for about 8% of the country's total agricultural output, and this proportion is higher than the proportion of agricultural output of other provinces except Shandong and Henan.

The agricultural production technical efficiency of Jiangsu Province is close to 1, and its output accounts for a high proportion of national agricultural output, so the agricultural production of Jiangsu Province can be considered as the representative of the Chinese agricultural production in the case of full utilization of factors. The number of per unit of labor required for agricultural output in Jiangsu Province can be regarded as the number of effective labor per unit of output in China's agricultural production. Based on this, we can calculate the annual number of agricultural surplus labor of various provinces and cities.

The number of effective labor per unit of output = The number of agricultural labor in Jiangsu Province/Total agricultural output value in Jiangsu Province

v is defined as the proportion of effective labor to agricultural labor, then:

$$v = \frac{\textit{The number of agricultural labor in Jiangsu Province/Total agricultural output value in Jiangsu Province}}{\textit{The number of agricultural labor in one province/Total agricultural output value in one province}} \quad (1)$$

u is defined as the proportion of inefficient labor to agricultural labor, then:

$$u = 1 - v \quad (2)$$

According to formula (1), (2), we can calculate the number of surplus labor (SN) in one province:

$$SN = N \times u \quad (3)$$

Using the production data concerning the agricultural sector and the above three formulas, we can calculate the annual number of agricultural surplus labor of various provinces and cities, as shown in Table 2.

Table 1 The number of agricultural surplus labor of various provinces and cities in the period 1995 – 2004 Unit: 10^4 people

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Beijing	−84.6849	−74.7965	−78.8573	−78.5594	−79.8587	−84.8355	−91.0641	−91.0119	−96.0363	−65.0913
Tianjin	−40.8576	−39.1583	−46.1702	−49.9642	−41.4457	−44.0392	−44.8330	−41.6218	−53.6024	−32.6332
Hebei	666.5671	532.9546	407.6358	388.3197	378.6618	442.5953	417.2937	487.8525	426.9380	485.0753
Shanxi	357.3666	339.6005	345.4870	342.4120	404.7312	403.0631	434.1121	421.6927	391.6464	414.1274
Inner Mongolia	161.7311	123.7635	99.1602	69.8121	89.5972	94.2606	105.6513	140.5146	94.4267	124.1721
Liaoning	−103.1969	−143.6804	−152.3404	−170.1845	−157.1350	−114.6691	−127.4256	−103.2318	−98.4077	−23.2778
Jilin	89.4053	34.3951	28.1866	−34.9926	−33.5330	34.3515	24.8489	52.3142	3.3090	55.1049
Heilongjiang	−132.0418	−181.0183	−133.6023	150.4993	203.6896	249.2222	214.5608	223.0031	165.5294	172.5430
Shanghai	−101.1325	−102.5729	−99.7639	−94.9709	−79.0702	−86.7982	−85.8113	−75.7663	−84.1514	−51.6417
Jiangsu	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Zhejiang	331.0975	316.1630	258.7669	271.4397	250.2485	173.4257	162.4985	164.6100	126.8289	201.1751
Anhui	1034.5847	1010.3182	929.9489	997.1600	980.0945	1035.9531	1041.5093	1052.5323	1037.9212	1022.7652
Fujian	77.6319	27.6487	−9.5096	−29.3660	−48.2384	−52.5074	−27.7952	23.6557	10.3999	104.3166
Jiangxi	535.1732	487.9207	426.6528	465.0588	445.6351	381.4874	390.6343	428.4227	440.9135	465.7487
Shandong	804.9224	646.2401	614.0396	686.0878	669.6399	646.2536	612.3457	670.3237	435.4095	558.7271
Henan	1616.2379	1440.5082	1459.8448	1430.4987	1737.4550	1989.8904	1911.0631	1915.3971	1939.0819	1843.6490
Hubei	425.9279	339.5871	216.6876	282.5451	288.5203	267.9875	272.9617	320.9036	264.8924	309.8241
Hunan	1158.0282	1060.6161	958.4884	1041.9000	1113.0591	1104.2072	1106.0520	1131.0051	1082.0019	1077.7348
Guangdong	21.4886	116.2058	104.6186	170.9948	176.6130	271.1942	313.1572	366.8856	340.5142	513.4669
Guangxi	883.5248	825.2981	762.8561	886.9651	911.4309	900.4991	906.9866	939.9857	891.3144	908.4196
Hainan	−20.0694	−22.4527	−28.6789	−30.6375	−56.6905	−69.7243	−61.5085	−60.7971	−52.1806	−15.1400
Sichuan	2590.6581	2448.8612	1682.2537	1657.3120	1607.2920	1512.2218	1493.6012	1425.7298	1289.3866	1309.6972

(To be continued)

(Continued Table 2)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Guizhou	1047.7923	1042.5998	1030.2234	1055.2168	1093.9476	1045.1371	1057.4824	1063.4690	1027.9800	1042.2357
Yunnan	1198.7608	1166.1510	1137.2375	1152.8736	1128.6333	1135.2466	1167.0948	1199.5937	1186.4715	1240.6038
Tibet	53.9963	56.2796	56.0280	54.2673	52.3198	49.5661	49.6543	51.1665	47.4696	55.7666
Shaanxi	700.5662	661.4844	654.5618	650.3628	638.2608	634.1490	630.4205	652.1591	651.8365	651.4056
Gansu	403.0873	396.7605	405.8502	405.6918	427.1990	441.7881	440.8939	496.2415	508.2110	539.0929
Qinghai	81.4522	89.9909	88.4123	89.3323	95.6736	97.1744	94.5751	92.4035	86.3367	91.2471
Ningxia	85.7273	81.0776	83.9606	84.1457	88.9108	91.5075	88.4002	88.2263	80.6361	85.0862
Xinjiang	-95.7810	-73.0057	-99.2052	-77.5873	-70.7653	-71.2054	-47.8264	-27.4452	-102.8750	-13.0030
Total	13747.96	12607.74	11102.77	11766.63	12214.88	12477.40	12449.53	13008.21	12042.20	13071.20

Note: The negative value in the table means that the agricultural labor is relatively insufficient.

3 Conclusions

When the agricultural production technical efficiency is very low, the output with the same amount of factor input is very low, or at the same level of output, the amount of factor input is excessive. Conspicuously, the excess amount of factors is closely related to the production technical efficiency. The excess amount of factors will increase along with the increased technical efficiency.

In other words, if output remains unchanged, with the increasing technical efficiency, the number of factors required will be smaller. In terms of the agricultural labor force, with the increasing agricultural production technical efficiency, the agricultural labor needed will be less and the surplus labor will be more. The existing calculation methods for the number of agricultural surplus labor all fail to reflect the impact of technical efficiency changes in the agricultural production on the surplus labor.

In this paper, we use the basic principle of stochastic frontier production function to calculate the agricultural production technical efficiency of various provinces and cities. And we select the province (Jiangsu Province) with the highest technical efficiency to assume that its agricultural labor is fully utilized, and there is no agricultural surplus labor.

With the ratio of agricultural labor number to agricultural output value in this province as a reference, we calculate the number of agricultural surplus labor in other provinces. It turns out that the national agricultural surplus labor is about 126 million in recent years. This calculation method makes up for the shortcomings of the existing calculation methods, and it reflects the relationship between the number of agricultural surplus labor and production technical efficiency.

References

[1] XIONG ZY, YU D. A shortcut to measure unemployment in China[J]. Statistical Research, 2004(7): 56-58. (in Chinese).

[2] National Bureau of Statistics. The quantitative research on surplus rural labor force

[J]. The World of Survey and Research, 2002(3): 18-21. (in Chinese).

[3] YANG DQ, HAN L. Measuring application efficiency of factors based on VES production function[J]. Science & Technology Progress and Policy, 2005, 22(1): 170-172. (in Chinese).

[4] WANG HL. A method to estimate the number of surplus labor force in our rural areas[J]. Statistical Research, 1998, 15(1): 48-50. (in Chinese).

[5] ZENG XY, WU YH, ZHENG DY. Random DEA model and its application [J]. Systems Engineering—Theory & Practice, 2000, 20(6): 19-24, 64. (in Chinese).

[6] Aigner, D. J., C. A. K. Lovell, P. Schmidt. "Formulation and estimation of stochastic frontier production function models" [J]. Journal of Econometrics, 1977: 6.

[7] Battese, G. E., T. J, Coelli. "Prediction of firm-level technical efficiencies with a generaliazed frontier production function and panel data" [J]. Journal of Econometrics, 1987: 38.

[8] XIAO D, HU HH. Data envelopment analysis and maximum likelihood estimation[J]. Systems Engineering Theory · Methodology · Applications, 1996, 5(1): 46-50. (in Chinese).

[9] LIU YS. Economic dualism[M]. Beijing: Economic Science, 1989. (in Chinese).

[10] John C. H. Fei. The development of labour surplus economy[M]. Beijing: Economic Science Press, 1992. (in Chinese).

[11] Yair Mundlak. Agriculture and economic growth :Theory and measurement [M]. Beijing: Economic Science Press, 2004. (in Chinese).

(From page 60)

[8] XU SB. Analytic hierarchy process[M]. Tianjin: Tianjin University Press, 1988: 8-13. (in Chinese).

[9] ChencHui Chou, Gin-shuh Liang, Hung-Chung Chang. A fuzzy AHP approach based on the concept of possibility extent[J]. Quality & Quantity, 2013, 1(47): 1-14.

[10] Ou Tong, Shuai Shao, *et al*. An AHP-based water-conservation and waste-reduction indicator system for cleaner production of textile-printing industry in China and technique integration[J]. Clean Technologies and Environmental Policy, 2012, 5(14): 857-868.

[11] ZHU CQ, XING YH. Construction, measurement, and improvement of China's material civilization index system[J]. Research on Financial and Economic Issues, 2009(7): 22-30. (in Chinese).

[12] NIU WP, CHEN YX. Evaluation on regional competitiveness of Guangdong Province based on the AHP method[J]. Journal of South China Agricultural University(Social Science Edition), 2007, 6(2): 40-46. (in Chinese).

[13] SUN ZL, LV XF. A ponderation on adjustment of rural industrial structure of the Wuling Mountain Area[J]. Social Science Journal of Shenyang Agricultural University, 2007, 9(6): 844-847. (in Chinese).

[14] SUN Q, CUI W, ZHOU PD, *et al*. SWOT analysis on rural poverty alleviation of Bijie experimental zone in the new period[J]. Guizhou Agricultural Sciences, 2011, 39(12): 262-267. (in Chinese).

[15] GAO GL, DENG ZM, XIONG KN. The ecological environment construction and sustainable development of Guizhou Karst: Karst's call and hope [M]. Guiyang: Guizhou Scientific and Technology Publishing House, 2003, 4: 87-89. (in Chinese).

[16] CHEN NY, ZHOU XD. Discussion on vicious circle of getting rid of poverty[J]. Inquiry Into Economic Issues, 2000(3): 34-37. (in Chinese).

[17] REN XD, GAO XC. The division of Karst environment and poverty type [J]. Rural Economy, 2010(2): 55-58. (in Chinese).