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# Collaborative Performance Analysis and the Establishment of Main Body of Agricultural Technology Innovation

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**Abstract** Relying on the relevant data from *China Statistical Yearbook* and *Chinese Rural Statistical Yearbook*, the collaborative performance of main body of agricultural technology innovation is evaluated by taking quaternary-parties innovation body as the subjects and by establishing the index system from the perspectives of input and output. The results show serious dislocation of main body and bad collaborative performance. On the basis, the quaternary-parties motivation system concerning agricultural enterprises, agricultural science and technology academy, rural households and governments is established. The system is capable of integrating market, scientific research and diffusion collection into a whole part and solving the separation of agricultural innovation supply and demand.

**Key words** Agricultural technology innovation, Collaborative, Main body, Performance analysis, Factor analysis, China

The separation of supply and demand of agricultural technology innovation has gravely restricted the development of agricultural modernization and the performance of innovation. Agricultural technology innovation is characterized by complexity, high risk, publicity and spillover, which determines the simplicity of main body. Many scholars have studied the main bodies of agricultural innovation. ZHU Guang-qi, thought that the main body of agricultural innovation should be the dualistic structure composed by the government and farmers<sup>[1]</sup>. Biggs *et al.* put forward the dualistic structure of rural households and research institutions<sup>[2]</sup>. Volker Hoffmann *et al.* studied the collaborative structure of rural households and scientists<sup>[3]</sup>. Although the scholars mentioned above have studied the collaborative main body, the producers and users of agricultural technology are no longer the same main body. Besides, the research and promotion of agricultural technology is non-profit undertakings, so the studies on dualistic structure are unstable. However, a favorable collaborative evaluation system can not only display the role of benchmarking and enhance the operation efficiency of the whole innovation system, but also provide valuable decisions for improving the structure of main bodies. GUO Chun-li has conducted the performance evaluation by using DEA method<sup>[4]</sup>, but the DEA can not evaluate according to the non-decision-making units. Besides, there are too much evaluation indices and strong relativity, which may lead to the overlapping of information and affect the effectiveness of evaluation results, thus deprive the persuasion of the evaluation results. However, factor analysis is widely used in performance evaluation by

making use of the relativity of variables. In view of the analysis above, the paper established the quaternary-parties by establishing collaborative performance index system in the first place, and then evaluated the indices by using factor analysis, so as to provide references for the relevant researches.

## 1 Data source, establishment of index system and research method

**1.1 Data source** The data applied in the paper come from *China Statistical Yearbook*, *Chinese Rural Statistical Yearbook* and the time series data from 1992 to 2002.

### 1.2 The establishment of index system

**1.2.1 Principles for the establishment.** The establishment of index system should not only follow the general principles of scientific, systematic and consistent, but also has the features of substitutability, feasibility and the characteristics of agricultural technology innovation. Feasibility refers to that the data of index should be easy to be collected and quantified. The statistics issued currently can be fully used. Feasibility also means reasonable equation for calculating and simple evaluation process, which are easy to be mastered and practiced<sup>[5]</sup>.

**1.2.2 The establishment of index system.** The index system is established from the perspective of input and output by following the above basic principles and taking the quaternary main bodies as subject. The steps of establishing index system are as follows. In the first place, choosing input index. The input index is mainly reflected on personnel and capital. The personnel index refers to the quantity and quality of innovation main body and promotion main body of agricultural science and technology personnel. The indices include the quantity of agricultural science and technology personnel  $x_1$ , the quality of agricultural science and technology personnel  $x_2$ , the quantity of

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agricultural research personnel in colleges and universities  $x_3$ , rural population  $x_4$ , quantity of agricultural promotion personnel  $x_5$ . The capital indices reflect the sources of agricultural scientific research funds, the input intensity and costs of capital. The indices include the agricultural scientific research funds allocated by the government  $x_6$ , agricultural technical promotion funds granted by the government  $x_7$ , intensity of agricultural technological investment  $x_8$ , the intensity of fiscal investment for promoting agricultural technology  $x_9$ , government investment strength of agricultural science and technology  $x_{10}$ , the quantity of machine invested by rural households  $x_{11}$ , the ratio of fiscal investment for agricultural technology promotion to fiscal support for agriculture  $x_{12}$ , the ratio of agricultural expenditure to financial expenditure  $x_{13}$ , the ratio of agricultural infrastructure construction to the total investment  $x_{14}$  and capital cost rate  $x_{15}$ . In the second place, choosing output indices. The output indices are reflected on direct interests and indirect interests, which include the quantity of agricultural scientific achievements  $x_{16}$ , land productivity rate  $x_{17}$  and per capita annual

net income of rural households  $x_{18}$ . In the third place, eliminating the overlapping indices, seriously cross-arranged indices and insignificant indices, for example, agricultural science and technology personnel includes researchers in colleges and universities, so the latter should be eliminated.  $x_6$  overlaps with  $x_{10}$ , so the relative number  $x_{10}$  is retained, which is true to  $x_7$  and  $x_9$ . In the fourth step, the substitutability and feasibility of indices should be considered.  $x_1$  can be substituted by the agricultural personnel of the technologists in state-owned enterprises and public institutions. The promotion personnel of agricultural technologies is mainly rural households, so  $x_5$  is substituted by agricultural personnel.  $x_{14}$  is substituted by the total motivation of agricultural machine.  $x_{15}$  represents the cost of agricultural capital and it is substituted by the one-year bank deposit rate.  $x_{16}$  is substituted by the total papers from SCI, EI and ISTP. In the end, the qualitative index  $x_2$  is eliminated, and then the index system with 14 indices of input layer and output layer is established.

**Table 1** Index system

Dimensions	Factor	Indices
Input	Personnel	The quantity of agricultural personnel
		Rural population
		Agricultural personnel
	Capital	Investment intensity of agricultural science and technology
		Fiscal investment intensity of agricultural technology promotion
		Total motivation of agricultural machine
		Opportunity cost
		Fiscal investment on agricultural science and technology
		The ratio of agricultural infrastructure construction to total investment
		The ratio of fiscal investment on agricultural technology promotion to financial support on farmers
		The ratio of agricultural expenditure to total financial expenditure
Output	Direct interests	Quality of agricultural scientific research achievements
	Indirect interests	Land productivity rate
		Per capital annual net income of rural households

**1.3 Research method** Factor analysis, the method of reduction of dimensions, is widely applied in the statistical analysis of multiple inputs and multiple outputs. Under the premise of strong relativity of variables maintaining the original information as far as possible, the factor analysis uses the least dimensions to represent the former data structure and it can eliminate the insignificant index, reduce the dimensions of the input variables and enhance the iterative speed and generalization ability of the model.

## 2 Results and analysis

**2.1 Data processing** In the first step, the quality of data should be recognized and the invalid variables and samples should be eliminated. In order to eliminate the dimensions of each index and increase the comparability of each variable, the original data should be standardized. In the formula,  $x_{ij}^* = (x_{ij} - \bar{x}_j) / \delta_j$ , among which,  $\bar{x}_j$  is average value and  $\delta_j$  is standard deviation. In the end, the processed data is analyzed and the variables with the relevant value less than 0.3 are eliminated ( $x_4$ ,

$x_{12}$ ,  $x_{13}$ ,  $x_{15}$ ), as well as the "insignificant" data of investment intensity of agricultural science and technology and the quantity of agricultural scientific research achievements. The matrix  $[x]_{8 \times 11}$  is obtained and the sample scale agrees with the small sample. The order of the indices is rearranged, which can be seen on Table 2.

**2.2 The fix of public factors** Through analyzing the Tables, it can be seen that the obvious flex point is 2, the latter 6 factors have formed to a platform with the eigen value less than 1. It can be seen from Table 3 that the accumulative contribution rate the former 2 factors accounts for 96.179% of the total variance. Then the two public factors are selected, which are set as  $F_1$  and  $F_2$ .  $F_1$  has large loads on  $x_1$ ,  $x_2$ ,  $x_5$ ,  $x_7$  and  $x_8$ , among which  $x_1$ ,  $x_2$  and  $x_5$  reflect the input of agricultural scientific research personnel, rural households and input of capital, and  $x_7$ ,  $x_8$  reflect indirect interests, so the input-output interest factor is temporarily defined as the public factor.  $F_2$  has large loads on  $x_3$ ,  $x_4$ ,  $x_6$ . It is mainly reflected on agricultural promotion, governmental investment and infrastructure, so environmental protection factor is determined as the public factor.

**2.3 The scores of factors** Taking the ratio of variance contributes of each factor to the total variance contributes as the weight; the comprehensive score of factor in each year can be obtained.  $F=0.66F_1+0.34F_2$ . Supposing  $f(x)$  is the collaborative performance of innovation main body of agricultural technology, the output variable;  $x_1-x_8$  affect the variables of the same performance, the input performance. Taking the relevant coefficient of factors as parameters, the following performance evaluation function can be obtained.

$$f(x)=0.13x_1+0.12x_2+0.12x_3+0.05x_4+0.13x_5+0.14x_6+0.08x_7+0.11x_8$$

From the relevant coefficient of factors, it can be seen that the collaborative performance is greatly affected by  $x_1, x_2, x_3, x_5$  and  $x_6$ , and the above variables are the behaviors of agricultural scientific research institutions, rural households and government. Thus, the determinant and main body that affect the collaboration of main body can be found out and the further understanding on innovative collaboration can be achieved.

**2.4 Result analysis** It can be seen from Table 4 that, except the year of 1995, the two common factors of each varies greatly, which indicates that the two factors have not formed

the collaborative effect. In 1996 and 1997, the negative force of environmental protection factor surpassed the positive force of input-output interest factor, but as a result of the small weight of the environmental protection factor, the output interests have not decreased greatly. The value of the two factors in other years varies greatly, and the negative and positive value takes nearly equal part, which indicates the obvious fluctuation of parameters. The fluctuation of order parameter means the uncertain demand. The tiny fluctuation will be amplified quickly through system collaboration effect, and the whole system will fluctuate and the leap-forward jump and orderly increase will be achieved, and then the new order state will be formed. But in 1995, the input-output effects of technology innovation and environmental protection factor were negative with equal strength, the functions of the increased items and decreased items are amplified at the same time, which triggered negative collaboration effects. Therefore, the collaborative performance of Chinese agricultural innovation of the whole 11 years was bad, which was basically in agreement with the conclusions drawn by DEA analysis<sup>[4]</sup>.

Table 2 Standardized data

Year	$x_1$	$x_2$	$x_3$	$x_4$	$x_5$	$x_6$	$x_7$	$x_8$
1992	-1.768	-1.165	0.035	1.415	-1.303	-0.210	-1.975	-2.055
1993		-0.943	-0.354	0.402	-1.147	-0.901	-1.627	
1994	-1.163	-0.704	-1.002	0.113	-0.943	-1.090	-0.798	-1.255
1995	-0.940	-0.520	-1.262	-0.611	-0.704	-0.854	0.045	-0.603
1996	-0.328	-0.190	-1.002	-1.817	-0.454	-0.461	0.507	0.036
1997	0.126	-0.706	-0.743	-0.852	-0.097	-0.037	0.561	0.336
1998	0.471	-0.166	-0.094	-0.273	0.232	0.498	0.633	0.468
1999	0.727	0.151	0.554	0.691	0.622	1.299	0.572	0.556
2000	0.952	0.899	0.814	0.933	0.991	1.755	0.502	0.634
2001	1.016	1.597	1.333		1.259		0.701	0.841
2002	0.908	1.745	1.722		1.543		0.879	1.043

Table 3 Analysis of factor loading and comprehensive factor

Variables	Factor loading coefficient		Factor score coefficient		Summary of factor name
	$F_1$	$F_2$	$F_1$	$F_2$	
$x_8$	0.992	-0.047	0.218	-0.109	Input-output interest factor
$x_1$	0.968	0.216	0.189	0.004	
$x_7$	0.950	-0.294	0.231	-0.209	
$x_5$	0.928	0.364	0.167	0.070	
$x_2$	0.842	0.344	0.151	0.069	Environmental protection factor
$x_4$	-0.275	0.941	-0.144	0.421	
$x_3$	0.377	0.912	-0.001	0.350	
$x_6$	0.690	0.709	0.085	0.237	
Eigen value	5.087	2.608			
Contribution rate//%	63.584	96.179			

3 Conclusions and discussions

**3.1 Conclusions** In view of the separation of supply and demand of agricultural technology innovation, the dislocation of agricultural technology innovation is analyzed by using performance evaluation method and the quaternary-party structure of main body is put forward. The quaternary-party structure solved the disputes of agricultural technology innovation

main body. The results show that the dislocation of main body can not produce collaborative effects. The research can provide reference for making agricultural policies and is conducive to the implementation of collaboration of agricultural technology innovation.

**3.2 Discussions** From the time series above, it can be seen that the main bodies of Chinese agricultural technology innovation are the government, rural households, and agricultural

**Table 3 The score and ordination of factors**

Samples	Score of factors		Score of total factors	Ordination n <sup>1</sup>	Ordination n <sup>2</sup>
	F <sub>1</sub>	F <sub>2</sub>			
1	-1.225 3	0.344 5	-0.880 8	11	Valid
2	-0.557 8	0.009 0	-0.548 8	8	
3	-0.693 7	-0.127 9	-0.821 6	10	Invalid
4	-0.316 1	-0.316 5	-0.632 6	9	Valid
5	0.120 2	-0.468 0	-0.347 9	7	Invalid
6	0.148 2	-0.283 4	-0.135 2	6	Valid
7	0.218 6	-0.070 1	0.148 5	5	Invalid
8	0.348 9	0.227 0	0.575 9	4	Invalid
9	0.495 5	0.357 3	0.852 8	2	Invalid
10	0.652 8	0.145 9	0.798 7	3	Invalid
11	0.741 4	0.182 1	0.923 5	1	Invalid

research institutions. The government and the state-owned agricultural research institutions provide capital, technologies, labors and policies, so they are the suppliers of technology innovation. Rural households, as the demanders of technology innovation, have formed principal and subordinate status. The principal part is the government and the subordinate part is rural households. The differences of the two parties determine that the superior party has the right to decide and the inferior party has to obey the superior. When the policy-makers have different aims, if they all make strategies just for optimizing their own targets, the positive collaborative effects will not be produced. Only when the strategies made by deciders at various levels are interrelated, the collaborative effects can be achieved. For on thing, on account of the overstaffed governmental departments, weak management, absence of effective excitation mechanism, limited ability to communication and study and inflexible structure and procedures, the capability of agricultural technology innovation is weakened. For another thing, due to inadequate knowledge of farmers, they are hard to accept new technologies and the poverty of farmers has deprived of their ability to resist the risks, so they can change their weak position. The dualistic structure of main body can not achieve the collaborative effects, and the root is the dislocation of main body. That is why the collaborative performance from 1992 was bad. In essence, the feature of collaboration is the process of studying. It means the continuous improvement of the ability of people and organization. At the inferior level, rural households should shake off the simple improvement technology provided by the government and scientific institutions, but enter the technology innovation fields of demand, indentifying, adopting. That is to say, rural households participate in the activities of

development, research and experiment to transfer from negative to positive. At superior level, when making policies, the government should take the studying capability of rural households and other institutions into consideration. It should shift their role from leading role to supporting role and devote itself to the public technology innovation. Therefore, the new elements of study capability-agricultural enterprises and agricultural scientific research institutions should be introduced into. In western countries, agricultural enterprises are always the main body of agricultural technology innovation, which can integrate the market, scientific research and expansion into a whole. Besides, after being operated like enterprises, agricultural scientific research intuitions are also the main body of agricultural technology innovation. Agricultural scientific enterprises are the enterprises integrating agricultural science and technology to agricultural economy. The crucial feature of agricultural scientific enterprise is that it integrates research, development, production and selling into a whole, and then creates the quaternary-party structure-agricultural enterprises, agricultural scientific research institutions, rural households and government. The quaternary-party collaboration produces positive collaborative effects, which are conducive to the popularization and expansion of agricultural technology innovation.

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