Estimating and Forecasting the Contribution Rate of Agriculture Scientific and Technological Progress Based on Solow Residual Method

Zhu Jinhe[1], Cui Dengfeng[1, 2]
1.College of Economy & Management, Shihezi University, Shihezi, 832002,China;
2.College of Economy & Management, China Agricultural University, Beijing 100083,China
(E-mail: zhujinhe@shzu.edu.cn,cuidengfeng@ shzu.edu.cn)

Abstract: The agricultural economy growth in Xinjiang Production and Construction Corps of China (XPXG) is closely related to the progress of agricultural science and technology. This paper set a model based on the Cobb-Douglas production function. It selected related statistical data about XPXG during 1956 to 2009, used the three kinds of material capital stock and a kind of human capital stock and made use of the least square method to estimate the output elasticity coefficient of the capital assert investment coefficient, the output elasticity coefficient of cultivated land, the output elasticity coefficient of agricultural machinery and employees, and used Solow Residual Method to estimate the contribution rate of all factors in the agricultural economy growth in XPXG. It thinks that contribution rate of agriculture scientific and technological progress shows the increasing trend. Since year 2000, the agriculture economic growth in XPXG is mainly pulled by the progress of science and technology. By forecasting the contribution rate of agriculture scientific and technological progress and technology progress, we find that the contribution rate of agriculture scientific and technological progress will be stably increasing during 2010 to 2020. The contribution rate of agriculture scientific and technological progress in XPXG will respectively reach to 59.42% and 61.9% in the period of the 12th Five Year Plan and the 13th Five Year Plan.
Key words: Xinjiang Production and Construction Corps of China (XPXG); Agriculture; Contribution rate; Scientific and Technological Progress

1 Introduction

Contribution of scientific and technological progress to economic growth has been subjected to widespread national attention. Since the 1920s and 1930s, some well-known Western economists studied the issues of contribution rate of scientific and technological progress, and formed the school of classical and neo-classical and so on. Because of the different national situation and the complex factors affecting economic growth, it still did not form a set of perfected and generally acknowledged scientific method of calculation. At present scholars mainly adopt the method of production function, which is widely used in theoretical circles at home and abroad as a method, such as the simulation method of production function, Solow residual method, CES method of production function, the equation of growth rate, growth analytic method of Danny's increasing factors. This paper considers that contribution rate of scientific and technological progress means technological progress on the share of contribution to economic growth, which is the comprehensive index measuring both regional competitive strength of science and technology and practical productive forces translated by technology, which is also currently the first considerable index to measure implementation performance of the strategy of contribution rate of agriculture scientific and technological progress means the technological impact on the agricultural economy growth, which including capital scale of agricultural production, the scale of the agricultural labor force, cultivated area, total power of agricultural machinery, Among the various factors affects agricultural economy growth, to leave influencing factors of increased funding, increased labor force, increased total power of agricultural machinery out from consideration, the remaining part is the factor of technological progress.

2 Calculation Method of the Agricultural Technology Progress Contribution Rate

2.1 C-D production function

The basic concept of the technological progress comes from the study of the production function by the economist. Since the U.S. mathematician Cobb and economist Douglas described C-D production function in 1928,the method of describing the relationship between capital and labor input and output has become the basic method of calculation the contribution rate of technological progress, here is the basic form of C-D production function corresponding to agricultural economy:

$$Y = A K^{\alpha} L^{\beta} M^{m} N^{n} \mu \quad (1)$$

In formula:Y indicates total agricultural output K indicates capital input, L indicates labor input, M indicate the arable land area, N indicates the total power of farm machinery, α, β and m indicate output elasticity coefficient of capital , labor and arable land area, A for the efficiency coefficient, is a reflection of the level of general technological progress, μ for the random error, representing the estimated error level.

2.2 Jain.Tinbergen improved production function

In 1942, Jain •Tinbergen ,the economist of Dutch , who was the first Nobel Economist Prize-winner, improved the typical C-D production function ,considering the selected samples were generally a time series, so introducing the time variables. Improved the formula (1),the corresponding production fuction is:

$$Y = A_0 K^{\alpha} L^{\beta} M^{m} N^{n} e^{\omega t} \mu \quad (2)$$

In formula: A_0 is the initial level of technology;ω is parameters of technological progress,t indicates time, $e^{\omega t}$ called the integrated technological progress factors, is to consider the effect of broad technological progress on output after the introduction of time factors .Tinbergen exchanged the constant A in the C-D production function into the quantity A_0 which is changing over time, skillfully introducing technological progress in production function,solving the problem of quantitative of technological progress. Taking the natural logarithm on both sides of the formula (2),we can get:

$$LnY = lnA + \alpha lnK + {}^{\beta}lnL + mlnM + nlnN + \omega t + \mu \quad (3)$$

2.3 The Solow residual method estimates the contribution rate of scientific and technological progress

In 1957, U.S. economist Robert Solow (R • M • Solow) in the extensive research found that the U.S. economy affect economic growth in the fundamental motivation is technological progress rather than capital accumulation. He considered per capita output as an independent variable to measure technological progress, and came up with "Solow residual method", which was believed by economists that it was classic economics of Scientific and technological progress, and it was widely used in the long-term economic growth study in countries around the world.

2.4 The determination of elasticity α,β,m,n

Measure technological progress in agriculture contribution to economic growth rates, first of all , Should determine the capital and labor output elasticityα,β,m,n. Currently, there are three main methods to determine the elasticity of output: First, the empirical estimation method. But because different countries and different regions have different levels of economic development, the form of production scale reward is uncertain.

Therefore empirical estimation method is less accurate; Second, the ratio method. Use the relevant data of different inputs elements and count corresponding ratio of the output elasticity. Since the data of the method involved is difficult collected, thus, this method is not easy to use. Third, regression method. The use of binding（A+β+m+n =1）or unconstrained（A+β+m+n =1≠1） the production function model, Into the corresponding data, using regression methods to estimate the various elasticity, which uses C-D production function Tinbergen improved model formula (3) to estimate the output elasticity α, β, m, n. This calculation uses the third method（The regression method）to estimate.

3 Carious Elements of the Indicator Data Sources and Processing Methods

3.1 The data sources and range of estimates

The data of the paper primarily from the annual "Statistical Yearbook on XPXG of China” and "Fifty years of New China: XPXG volumes". Draw experiences from developed countries, the contribution rate of scientific and technological progress should be measured by long-term based, at least in the five-year period, in order to achieve better results. Counted once a year scientific and technological progress contribution rate is unscientific, the data obtained is not accurate. Therefore this article selected sample interval from 1956 to 2009.

3.2 Relevant data processing

3.2.1 Taking 1990 as base year constant price estimates.

Scientific and technological progresses in the calculation of the role of agricultural growth, the need for indicators of outputs and inputs to make uniform provisions, eliminate the impact of price changes to ensure consistency and caliber statistics comparability of results. The output and input data of this paper are converted into a 1990 base year constant price index data.

3.2.2 The value of output (Y) determined.

This paper estimates the contribution rate of scientific and technological progress in agriculture, so the output value (Y) is the total agricultural output selection (million). 1990 data from the "Statistical Yearbook on XPXG of China", prior to 1990 data from the "New China five years: the volume on XPXG of China", similar to the following indicators of data.

3.2.3 Choice of the amount of labor input (L)

The amount of labor input (L) refers to the process of agricultural production, elements of the total actual investment of labor, and labor income can be used two ways to measure the labor force. Under current conditions, using income to measure labor input is clearly affected by many factors, and the authenticity of the data is poor, but with the number of measured data is more complete, systematic, standardized, there was no price adjustment, therefore, choose Agriculture (the first industry) 、the number of employees (million) as labor input index.

3.2.4 Explanation of the capital investment (K)

The corresponding amount of capital investment (K) should be represented by the fixed assets stock agricultural input production + current assets, but because of the Statistical Yearbook of China's fixed assets is not reflected in the stock and liquid assets of the statistical data, so some scholars in China and statisticians measure technological progress in the contribution rate work, with the year on fixed assets investment to replace the amount of capital investment, we think this is unreasonable, it does not fully reflect the agricultural production process in the amount of capital invested. Therefore, we usually measured scientific and technological progress contribution rate according to the international 'method which used the capital stock of fixed assets to replace investment in the amount of practice, using the perpetual inventory method to measure the fixed capital stock (million) values from 1956 to 2009 in XPXG of China, to measure the contribution rate of scientific and technological progress. The following introduces mainly the amount of capital investment (K) of measuring methods.

As existing statistics on XPXG of China do not exist in the total amount of real capital stock and structure of data, this paper, widely used in most OECD countries the perpetual inventory method (Perpetual Inventory Method, PIM) as the basic method of estimating capital stock to measure from1956 to 2009 in XPXG of China. The formula as flows:

$$K_t = (1-\delta) K_{t-1} + I_t \tag{4}$$

In formula: K_t and I_t respectively indicate period t capital stock and fixed asset investment, δ is the geometric depreciation rate. When using the perpetual inventory method, estimation and selection of the geometric depreciation rate and base year capital stock are particularly important. According to China's situation, the general overall depreciation rate δ =5%, base year capital stock calculated in accordance with the following international common:

$$K_0 = I_0 / (g + \delta) \tag{5}$$

g is the average annual growth rate of real investment in the sample period, K_0 is the base year capital stock

3.2.5 Explanation of the arable land scale(M)

The corresponding size of arable land (M) should refer to effective crop planting area of the agricultural production process, considering XPXG of China belongs to arid areas, annual changes in the quality of arable land is quite large, so use crop sown area (thousand hectares) to measure one of the indicators.

3.2.6 Explanation of the inputs of agricultural machinery (N)

The corresponding inputs of agricultural machinery (N) shall mean agricultural machinery total power of agricultural production process inputs, this paper is the use of this indicator, agricultural production at each year in XPXG of China for the machinery power (million ten million hours).

4 Calculation of Contribution Rate of Agriculture Scientific and Technological Progress in XPXG of China

4.1 Production function to determine the parameters

By compiling these indices, using the least square method can get (3), the regression results are as follows:

$$Ln\,Y = 5.5017 + 0.1689\,ln\,K + 0.0901\,ln\,L + 0.5141\,ln\,M + 0.2073\,ln\,N + 0.0195\,t + 0.7519\,AR(-1) \tag{6}$$

(9.86)*** (7.42)*** (2.87)*** (2.89)*** (2.41)** (8.08)*** (7.37)***

Note :"***" means 1% significant level ;"**" indicates 5% significance level; "*" indicates 10% significance level.

4.2 The statistics results of the test

(1) R test. Because R = 0.9915, close to 1, pass the test also shows that the regression equation (6) of the goodness of fit is better.

(2) F test. Because of F value significant at 1% significant level, indicating that the regression equation (6) established a significant, indicating that it can through the linear equation (6) to describe the variables t, LnK, LnL, LnM, LnN relationship between the number and LnY .

(3) T test. Through the T-test value of the relevant parameters, we can see, almost all parameters in the 1% significance level are significant, so the regression equation (6) also passed the significant test variables.

(4) Other tests. By DW = 2.008, very close to 2, so the regression equation (6) exists no first-order serial correlation. In addition, through the White test showed that the regression equation (6) exists no heteroscedasticity problems.

Therefore, the regression equation (6) both through the statistical tests and econometric tests, equations established.

4.3 Contribution rate of scientific and technological progress measured results

It could be deduced agricultural production function model on XPXG of China From the sixth formula:

$$Y = 245.1\, K^{0.1689} L^{0.0901} M^{0.5141} N^{0.2073} e^{0.0195\, t} \tag{7}$$

According to Solow residual method estimates the economic growth in the agricultural elements in the contribution rate, in Table 1.

Table 1 The Contribution Rate of Various Production Factors at Different Times unit:%

period	*Contribution rate of capital*	*Contribution rate of labor*	*Contribution rate of land*	*Contribution rate of agricultural machinery*	*Contribution rate of scientific and technological progress*
1956-1970	*8.02*	*8.91*	*48.19*	*24.39*	*10.49*
1971-1990	*15.84*	*0.15*	*26.89*	*24.63*	*32.49*
1991-2000	*41.88*	*-2.45*	*9.49*	*9.75*	*41.33*
2001-2009	*17.07*	*1.03*	*10.21*	*14.98*	*56.71*
1956-2009	*17.45*	*3.26*	*23.89*	*20.38*	*35.02*

period	*Averageannual growth rate oftotal output*	*Average annual growth rate of capital*	*Average annual growth rate of labor*	*Average annual growth rate of arable land*	*Average annual growth rate of agricultural machinery*
1956-1970	13.45	6.39	13.29	12.61	15.83
1971-1990	6.63	6.21	0.11	3.47	7.87
1991-2000	8.28	20.54	-2.25	1.53	3.89
2001-2009	10.15	10.26	1.16	2.01	7.34
1956-2009	9.33	9.64	3.37	4.33	9.17

4.4 Comparative analysis

Throughout the fifty years' history of agriculture economic development in XPXG of China, according to the calculation results of the indicators and data in Table 1, it is easy to see that there are so few features as flows:

4.4.1 Contribution rate of agriculture scientific and technological progress in XPXG of China showed a clear increasing trend.

Such as from 1956 to 1970 the average annual contribution rate of agriculture scientific and technological progress in XPXG of China is 10.49% ,from 1971 to1990 the average annual contribution rate of technological progress increased to 32.49% ,from 1991 to 2000 the average annual contribution rate of scientific and technological progress further increased to 41.33%, after entering "The Tenth Five-year Plan Period" the 2001 to 2009 the average annual contribution to the scientific and technological progress has exceeded 50% rate, reaching to 56.71%. Overall, from 1956 to 2009 average annual contribution rate of agriculture scientific and technological progress in XPXG of China was 35.02%.

4.4.2 Contribution rate of agriculture capital in XPXG of China shows the trend of first increased and then decreased.

Such as from 1956 to 1970 average annual contribution rate of agriculture capital in XPXG of China was only 8.02%, from 1971 to 1990 the average annual capital contribution rate rose to 15.84% from 1991 to 2000 the average annual contribution rate of capital further rose to 41.88%, after entering " The Tenth Five-year Plan Period", capital contribution rate on a declining, from 2001-2009 average annual capital contribution rate decreased to 17.07%. Overall, average annual contribution rate of agricultural capital from 1956 to 2009 in XPXG of China was 17.45%.

4.4.3 Contribution rate of agricultural labor in XPXG of China has been low, and during the period of "Eighth Five-year Plan" and "Ninth Five-year Plan" the annual contribution rate of labor appeared negative phenomenon.

Such as from 1956 to 1970 average annual contribution rate of agricultural labor is the highest period was 8.91%, from1971 to 1990 the contribution of labor dropped to 0.15%, from 1991 to 2000 further dropped to -2.45%, after entering The "Tenth Five-year Plan", the labor contribution rate has gone up, from 2001 to 2009 average annual labor contribution rate was 1.03%. Overall, average annual contribution rate of agricultural labor from 1956 to 2009 in XPXG of China was only 3.26%.

4.4.4 Contribution rate of agricultural land in XPXG of China showed upward trend after the first drop.

Such as the average annual contribution rate of agricultural land from 1956 to1970 years in XPXG of China was 48.19%,from 1971 to 1990 the average annual contribution rate of cultivated land dropped to 26.89% ,from 1991 to 2000 the average annual contribution rate of cultivated land dropped further to 9.49%, after entering "The Tenth Five-year Plan Period", the contribution of arable land has gone up, from 2001 to 2009 average annual capital contribution rate rose to 10.21%. Overall, from 1956 to 2009 annual contribution rate of agricultural land average in XPXG of China was 23.89%.

4.4.5 Contribution rate of agricultural machinery Power in XPXG of China also basically showed upward trend after the first drop.

Such as the average annual contribution rate of agricultural machinery power from 1956 to1970 years in XPXG of China was 24.39%, from 1971 to 1990 the average annual contribution rate of agricultural machinery Power was 24.63%, essentially unchanged compared with the previous; from 1991 to 2000 years the average annual contribution rate agricultural machinery power had dropped to 9.75%, after entering " The Tenth Five-year Plan Period", it had gone up, from 2001 to 2009, average annual contribution rate of agriculture mechanical power increased to 14.98%. Overall, from 1956 to 2009 average annual contribution rate of agriculture mechanical power was 20.38%

From the trend of above five factors contributed to the changes in agricultural economy growth, economic growth from 1956 to 1970 in XPXG of China depends mainly on agricultural cultivated area expansion to pull, improvement of agricultural machinery level also played a large role in driving; agricultural economy growth from 1971 to 1990 in XPXG of China depends mainly on the expansion of cultivated land, agricultural mechanization and agriculture scientific and technological progress, three forces pulling together, the largest pulling power is scientific and technological progress; economic growth from1991 to 2000 in XPXG of China depends mainly on agriculture, capital investment and technological progress, the two forces pulling together, including pulling power of capital investment is slightly stronger; agricultural economy growth from 2001 to 2009 in XPXG of China was mainly driven by technological progress, more than half growth of agriculture economic was caused by technological progress.

5 Prediction of Contribution Rate of Agriculture Scientific and Technological Progress in XPXG of China

The above had given the contribution rate of agriculture scientific and technological progress from 1956 to 2009 in XPXG of China for a more systematic measurement and found that the contribution rate of agriculture scientific and technological progress in XPXG of China showed a clear growth trend. The following will further use measurement methods to estimate long-term growth trend curves of the contribution rate of the agriculture scientific and technological progress in XPXG of China, and to achieve a more accurate forecast the contribution rate of agriculture scientific and technological progress from 2010 to 2020 in XPXG of China.

5.1 Estimation of long-term trend curve of contribution rate of agriculture scientific and

technological progress

According to the theory of economic cycles, methods of looking for long-term growth trend curve are generally linear equations, exponential equation method, and the logarithmic equation method and so on. In this paper, according to the comparison of different regression equations found long-term growth trend of contribution rate of the agriculture scientific and technological progress in XPXG of China. basically fit in with log-log model, estimated results are as follows:

$$Ln\ Y = -2.483 + 0.485\ ln\ T + 0.857\ AR(-1) - 0.285\ AR(-2) \quad (8)$$

(-13.9)*** (8.82)*** (11.62)*** (-4.57)***

R2 = 0.7828, $\overline{R^2}$ =0.7683,F=54.07***, DW=2.005

And similar to the regression equation (6), showing that the regression equation (8) through all the statistical tests and econometric tests, equations established.

5.2 Forecast of contribution rate of agriculture scientific and technological progress in XPXG of China

By the regression equation (8), contribution rate of agriculture scientific and technological progress can be estimated. The predicted value of contribution rate of agriculture scientific and technological progress from 2010-2020 in XPXG of China was showed in Table 2.Table 2 shows that by 2010 the contribution rate of agriculture scientific and technological progress in XPXG of China will reach to 57.89%; expected to “The Twelfth Five-year Plan Period”, annual contribution rate of agriculture scientific and technological progress in XPXG of China will reach to 59.42%, The" Thirteenth Five-year Plan” Period, average annual contribution rate of agriculture scientific and technological progress in XPXG of China will reach to 61.9%.

Table 2 Predicted Value of Contribution Rate of Agriculture Scientific and Technological Progress from 2010 -2020 in XPXG of China

year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Contribution rate of agriculture scientific and technological progress	57.89	58.41	58.92	59.43	59.93	60.43	60.92	61.42	61.90	62.38	62.86

6 Conclusions

(1) By Solow residual method estimates the different stages of production factors in the contribution rate of agriculture economic growth in XPXG of China and found the following characteristics: First, the contribution rate of agriculture scientific and technological progress in XPXG of China showed a clear increasing trend. Overall, from 1956 to 2009 average annual contribution rate of agriculture scientific and technological progress was 35.02%. Second, contribution rate of agriculture capital in XPXG of China shows the trend of first increased and then decreased. Third, contribution rate of agricultural labor in XPXG of China has been low, and during the period of "Eighth Five-year Plan" and "Ninth Five-year Plan" the annual contribution rate of labor appeared negative phenomenon. Fourth, the contribution rate of agriculture land and agricultural machinery power in XPXG of China showed upward trend after the first drop.

(2) Seeing from changes trend in the contribution of various elements to the agricultural economy growth, economic growth from1956 to 1970 in XPXG of China depends mainly on agricultural cultivated area expansion to pull, improvement of agricultural machinery level also played a large role in driving; agriculture economy growth from 1971 to 1990 in XPXG of China mainly depends on the expansion of cultivated land, agricultural mechanization and agriculture scientific and technological progress, three forces pulling together, the largest pulling power is scientific and technological progress; agriculture economy growth from 1991 to 2000 in XPXG of China depends mainly on, capital investment and technological progress, the two forces pulling together, including pulling power of capital investment is slightly stronger; agricultural economy growth from 2001 to 2009 in XPXG of China was mainly driven by technological progress, , more than half growth of agriculture economic was caused by technological progress.

(3) Due to agricultural economy growth was influenced by many non-quantifiable and many unpredictable factors, such as the climatic factors of agricultural production cycle、the market price of the agricultural products sales cycle, etc. These factors may affect agricultural production, or might

affect the agricultural output value, finally it will inevitably affect contribution of scientific and technological progress to agricultural economy growth, could lead to calculating the contribution rate of agriculture scientific and technological progress specific year imprecisely and unscientifically.

However, the contribution rate of agriculture scientific and technological progress in XPXG of China, despite the above-mentioned factors, the growth curve of the contribution rate of agriculture scientific and technological progress showed fluctuations but tends to increase. The paper by estimating the contribution rate of agriculture scientific and technological progress to predict the long-term trends of agriculture scientific and technological progress in contribution to XPXG's economy growth, table 2 shows that by 2010 the contribution rate of agriculture scientific and technological progress in XPXG of China will reach to 57.89%.The Predicted Value of contribution rate on agriculture scientific and technological progress from 2010 to 2020 in XPXG of China showed a steadily increasing trend. Expected that the "Twelfth Five-year Plan" period, the annual contribution rate of XPXG's agriculture scientific and technological progress will reach to 59.42%.The" Thirteenth Five-year Plan" Period, the average annual contribution rate of agriculture scientific and technological progress will reach to 61.9%.

References

[1] Deng Guohua. The Determination Mistakes and Empirical Analysis on the Contribution Rate of Scientific and Technological Progress [J]. Modern Finance, 2001, (2): 8-11 (In Chinese)

[2] Dong Ximing, Dong Changrui, Wu Shuguang. Analysis on Gansu Economic Growth in the Contribution Rate of Scientific and Technological Progress [J]. Technology Management Research, 2006, (10): 48-50 (In Chinese)

[3] Fan Xiaojun. Guangxi's Economic Growth in the Contribution Rate of Scientific and Technological Progress Measurement and Analysis [J]. Productivity Research 2005, (9): 105-106 (In Chinese)

[4] Hu Zongwei, He Daan. Technological Advances in the Optimal Calculation Method-Comment on "SOLOW Residual Method" [J]. Science of Sci-Tech Management, 2005 ,(5): 39-42 (In Chinese)

[5] Huang Yan, Li Yunhua. Several Issues should be Noted in Determination of Regional Scientific and Technological Progress [J]. Economic Geography, 2002, (2): 253-256 (In Chinese)

[6] Jiang Heping, Su Jicai. 1995-1999 Measurement and Analysis of Contribution Rate to the National Agriculture Scientific and Technological Progress [J]. Agricultural Economy, 2001,(5): 12-17 (In Chinese)

[7] Jiang Yu. Heilongjiang Province's Economic Growth in the Contribution Rate of Scientific and [1] Technological Progress Analysis [J]. Scientific and Technological Progress and Policy, 2008, (5): 108-111 (In Chinese)

[8] Wei He Qing. Technological Progress Contribution Rate Calculated in the Measurement Problem of Capital [J]. Modern Finance, 2004, (8): 122-123 (In Chinese)

[9] Zhang Yinglu, Xing Li, Yuan Kaizhi, Fan Shengen. Content and Determination of Agriculture Scientific and Technological Progress [J]. China Agriculture Scientific and Technological Progress, 2009, (2) :53-56 (In Chinese)

[10] Zhou Zhaode, Zhang Linghong.Hainan Province, Calculation of Contribution rate of Agriculture Scientific and Technological progress in the" Eighth Five-Year" [J]. Scientific and Technological Progress and Policy, 2000, (11): 139-140 (In Chinese)

[11] Zhu Tuanqin, Hubei Province Scientific and Technological Progress to Economic Growth in the Contribution Rate Calculation [J]. Statistics and Decision 2005, (10): 83-84 (In Chinese)