CHAPTER 5

IMPACTS OF TECHNOLOGICAL CHANGE, INSTITUTIONAL REFORM, AND INPUT USE ON CROP PRODUCTION

In this study, for the purpose of comparison, both Cobb-Douglas and Restricted Translog production functional forms were applied in the estimation processes. The full translog production function requires considerable data, and a number of variables incorporated in the function are highly correlated, which causes severe multicollinearity problem. However, the restricted form of translog production function is the alternative to overcome the statistical problem of multicollinearity (Fan, 1991).

Based upon the specified models (9) and (10), estimation functions for this empirical study specifically, are:

1) Cobb-Douglas form for both average and frontier production function estimation:

$$Ln(Y) = a_0 + a_1 LnLb + a_2 LnLd + a_3 LnCFert + a_4 LnMfert + a_5 LnIrr + a_t t \quad (13)$$

2) Restricted Translog production function:

$$Ln(Y) = a_0 + a_1 LnLb + a_2 LnLd + a_3 LnCfert + a_4 LnMfert + a_5 LnIrr$$

$$+ a_t t + a_6 tLnLb + a_7 tLnLd + a_8 tLnCfert + a_9 tLnMfert$$

$$+ a_{10} tLnIrr + a_{tt} t^2 \quad (14)$$

Variables specified in the econometric analysis are defined as follows:

1) Total value of crop production (Y): this is the total crop production in monetary term, which was calculated by using output of each crop to multiply its price. The summation of values of all crops is the total value of crop production. Crops include rice, corn, wheat, potato, soybean, groundnut, oilseed, tobacco, sugarcane. The total values of crop production in different years are converted into the comparable values on 1980's constant price basis.

2) Labor input (Lb): the persons employed in crop production at the end of each year.

3) Land input (Ld): the total sown area of crop production.

4) Chemical fertilizer (Cfert): the total amount of chemical fertilizer used in crop production each year, which is measured in physical term rather than in terms of pure nutrient.

5) Manure fertilizer (Mfert): manure fertilizer used each year includes animal, human, and crop wastes. In this study, manure fertilizer is estimated from the agricultural population (i.e.,

human waste), and number of domestic animals[7].

6) Irrigation area (Irr): the total irrigated areas at end of each year.

7) Time trend (t): the proxy of technological change. The year of 1952 is defined as 1 and therefore, t = 1 for 1952, t = 8 for 1959,...t = 39 for 1990.

8) Interaction of labor with time trend (Lbt): the product of multiplication of labor used with time t.

9) Interaction of land input with time trend (Ldt): the multiplied value of crop sown area with t.

10) Cross-term of chemical fertilizer with time (Cfertt): the amount of chemical fertilizer applied times time trend.

11) Cross-term of manure fertilizer with time trend (Mfertt): amount of manure fertilizer times time trend t.

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[7] The FAO stated that one animal (house unit) produces about 4 tons of manure per year and a person produces 0.25 ton per year. Manure contains 2.2% pure nutrient, and manure availability is about 75% of total use. Therefor, manure resources are estimated as follows:

Annual manure resources (tons) = ((0.25 * rural population + 4 * numbers of livestock) * 2.2%) * 75%.

12) Cross-term of irrigation with time (Irrt): total irrigated area multiplies time trend t.

According to results of socioeconomic survey, machinery plays only a minor role in agriculture of Guizhou province, especially after 1978, the economic reform, by which the land was highly fragmented, production scale of individual household is pretty small which can not fit machinery farming practically and economically, though some involvements of machinery in transportation were visible. In crop production, the major aspects in which machinery is used are irrigation and spraying of pesticide and insecticide, the latter purpose of machinery use can only occur when pest or insect damage to the crops has reached to a certain degree. The machinery application for irrigation in crop production is the more important one, but, however, its contribution to the crop production can be represented partly by the irrigation variable in production function.

As did in Fan's study (1991), draft animal is also omitted in the econometric analysis of this study. Since draft animal is highly correlated with manure fertilizer and land input, the inclusion of draft animal creates serious multicollinearity problem. Besides, some impacts of draft animal on crop production are reflected by manure fertilizer.

5.1 Estimates of Average Production Function and Frontier Production Function

For the purposes of selecting the best fit model for the crop production of Guizhou province, and considering different specifications of the production models, total six models were specified and estimated. The Cobb-Douglas functional form of (13) was used in models 1 and 2 in which only neutral technological change was identified, while Restricted Translog function (14) was applied for models 3, 4 which are the full production models incorporating biased technological change variables as well as neutral technological change variable. Restricted Translog production function (14) also employed in models 5, 6 in which irrigation variable was dropped based on the unrealistic estimate of irrigation variable in model 3 and 4. The Ordinary Lest Squares (OLS) technique was employed for the average production function estimation and the Maximum Likelihood (ML) technique was used to estimate the frontier production function. Results of production functions estimation are presented in Table 13.

In Table 13, λ and σ^2 are defined as:

$$\sigma^2 = \sigma_u^2 + \sigma_v^2$$

$$\lambda = \sigma_v / \sigma_u$$

Where σ is the standard deviation of error term, σ_u and σ_v are the standard deviation for the truncated normally distributed error term u and the normally distributed stochastic term v.

Table 13. The estimates of production functions

Regression variable	Model 1 Average	Model 2 Frontier	Model 3 Average	Model 4 Frontier	Model 5 Average	Model 6 Frontier
Constant	.285	.824	-4.052	-2.185	-6.806**	-6.64
	(.106)	(.187)	(-.95)	(-.371)	-(1.73)	(-1.19)
Lb	.323***	.310*	.558***	.514*	.511***	.532**
	(2.12)	(1.47)	(2.71)	(1.32)	(2.61)	(1.72)
Ld	.522***	.522***	.480***	.453***	.566***	.532***
	(3.06)	(2.46)	(2.12)	(2.21)	(3.13)	(2.42)
CFert	.251***	.268***	.183***	.187*	.194***	.172**
	(3.11)	(3.23)	(2.12)	(1.42)	(2.20)	(1.63)
MFert	.137*	.145*	.274***	.304*	.301***	.308***
	(1.40)	(1.30)	(2.49)	(1.50)	(2.68)	(1.96)
Irr	-.161*	-.201**	-.150	-.240		
	(-1.46)	(-1.84)	(-.87)	(-1.04)		
t	.0144**	.0146	.00786	.0131	.00823	.0119
	(1.78)	(1.07)	(.76)	(.97)	(.75)	(1.01)
Lbt			-.0254	-.0247	-.00351	-.00326
			(-1.13)	(-.95)	(-.21)	(-.026)
Ldt			.00185	.00167	.00299	.00328
			(.14)	(.10)	(.21)	(.27)
Cfertt			.0142***	.0128	.0115***	.0114***
			(2.31)	(1.12)	(1.98)	(2.11)
Mfertt			-.000778	-.00286	-.00950	-.0102*
			(-.072)	(-.20)	(-1.01)	(-1.34)
Irrt			.0136*	.0160*		
			(1.40)	(1.34)		
t^2			.00000102	-.0000419	-.000123	-.000165
			(.005)	(-.12)	(.59)	(-.65)
λ		1.12		1.843		1.48
		(.75)		(.71)		(.98)
σ^2		.0609***		.0517***		.0537***
		(3.54)		(2.47)		(3.64)
Observations	36	36	36	36	36	36
R^2	.970		.983		.980	

Numbers in the parentheses are t-ratios.
*** significant at 5% level
** significant at 10% level
* significant at 20% level

In the first two models of production functions, only neutral technological change was considered. The coefficient of time trend t--the proxy of technological change is statistically significant at 10% level in the average production estimation. In the frontier production, the estimate of time trend t is close to that of average production, but not significant. Coefficients for labor, land, chemical fertilizer are statistically significant at 5% level, manure fertilizer is significant at 20% level. The sum of coefficients for traditional inputs, i.e., labor, land, manure fertilizer is above 0.9, which implies that traditional inputs are still the most important factors in crop production systems in Guizhou province. Chemical fertilizer plays an important role with a coefficient of 0.251. However, models 1 and 2 show an unrealistic result of negative coefficient for irrigation resulting possibly from the exaggerated data by using irrigable area as the actual irrigated area.

By inserting the cross-term of each input and time trend which captures the relative changes of each input in total input over time into the production function, biased technological changes are incorporated into models 3 and 4. The negative signs for cross-terms of labor and manure fertilizer with time as well as time itself indicate that, the elasticities of those variables are decreasing with time, in other words, the importance of labor and manure fertilizer have been declining in the past decades. This is just because the increased labor force in the rural area had no better employment opportunities but stayed on the farm for crop production. This, to a certain extent, is one of the results from the over-emphasis of policy on crop production in 1950s and 1960s, which led to less development in other sectors and in turn, fewer employment opportunities available to farmers. Fewer opportunities against fast population growth created large surplus labor, which results in decreasing labor share, the averaged amount of contribution to the total value of crop production by labor is declining.

The minus sign for manure fertilizer, perhaps, from the reason that, the emphasis of fertilizer used in production has been diverted to chemical fertilizer since the introduction of chemical fertilizer in early 1960s from manure fertilizer which is characterized by the relative complicate processes of manure fertilizer preparation and scarcer manure fertilizer resource.

The negative and very small non-significant coefficient for quadratic form of time trend reveals, theoretically, that little change in productivity of neutral technology has occurred in the past decades, it also can be interpreted as that the technology used at present is not more efficient than that in the past.

As expected, land, chemical fertilizer, and irrigation contribute to the total value of crop production at growing rates. Chemical fertilizer, as mentioned above, has been applying at a growing rate in crop production. Chemical fertilizer was introduced in the 1960s which was the earlier period of this study, during this period, not only has been changing the quality of chemical fertilizer, but also increasing the farmers′ use efficiency. Both changes can be the important factors of increasing elasticity for chemical fertilizer.

The positive effect of cross-term for land and time trend on production, obviously, is resulted from the increasing scarcity of land resource. The commonly held solution to the problem of growing land scarcity with a rapid growing population is enhancing the land productivity, increasing the unit-land-output. The 5%-level significant coefficient for land-time cross term clearly reflects this fact existing in Guizhou province.

The significant coefficient at 20% level for cross-term of irrigation with time can be explained by the improved effectiveness of irrigation through an increase in irrigation power (Fan,1991).

In models 3 and 4, the production elasticity of irrigation is still negative insignificantly. Therefore, it was omitted in the models 5 and 6. This omission of irrigation is justifiable, because the irrigation in China, again, mainly occurs through increasing irrigation power rather than an expansion in the size of irrigated area . Therefore, this omission does not greatly change the estimates (Fan, 1991). Furthermore, the omission can help avoid collinearity among variables. Estimates of models 5 and 6 show little change compared with those of models 3 and 4.

5.2 Production Elasticities of Inputs

Production elasticity of input X_i in the production functional form is derived as:

$$\partial LnY/\partial Lnx_i=a_i+a_{it}t. \qquad (15)$$

Thus, if $a_{it} > 0$, production elasticity of input i is increasing; on the contrary, if production elasticity a_{it} < 0, it means the production elasticity of input i is declining. Based on the above-mentioned calculation approach (15) for production elasticity, production elasticities for inputs from 1952 to 1990 are estimated and presented in Table 14.

Table 14. Production elasticities of inputs, 1952-1990

Year	Input			
	Labor	Land	Chemical Fert.	Manure Fert.
1952	0.529	0.535	0.172	0.308
1953	0.525	0.538	0.183	0.298
1954	0.522	0.542	0.195	0.288
1955	0.519	0.545	0.206	0.277
1959	0.516	0.548	0.218	0.267
1960	0.512	0.552	0.229	0.257
1961	0.509	0.555	0.240	0.247
1962	0.506	0.558	0.252	0.237
1963	0.503	0.562	0.263	0.226
1964	0.499	0.565	0.275	0.216
1965	0.496	0.568	0.286	0.206
1966	0.493	0.571	0.297	0.196
1967	0.489	0.574	0.309	0.185
1968	0.486	0.578	0.320	0.175
1969	0.483	0.582	0.332	0.165
1970	0.480	0.584	0.343	0.155
1971	0.476	0.588	0.354	0.145
1972	0.473	0.591	0.366	0.135
1973	0.470	0.594	0.377	0.124
1974	0.467	0.597	0.388	0.114
1975	0.463	0.601	0.400	0.104
1976	0.460	0.604	0.411	0.094
1977	0.457	0.607	0.423	0.084
1978	0.454	0.611	0.434	0.073
1979	0.451	0.614	0.446	0.063
1980	0.447	0.617	0.457	0.053
1981	0.444	0.621	0.468	0.043
1982	0.441	0.624	0.480	0.033
1983	0.437	0.627	0.491	0.022
1984	0.434	0.630	0.503	0.012
1985	0.431	0.634	0.514	0.002

Table 14 shows that the production elasticities of labor and manure were decreasing during 1952-1990 time period, at the same time, the production elasticities for land and chemical fertilizer were increasing. The changes in production elasticities of inputs indicate the changes in importance of inputs in crop production.

5.3 Production Efficiency Estimation

By using equation (4) and the estimates of frontier production function from (model 6), production efficiency for the whole province in different years and time periods was estimated and tabulated in Table 15.

Table 15. Production (Technical) efficiency of crop production in Guizhou province in selected years.

Year	Efficiency	Year	Efficiency	Year	Efficiency
1952	0.751	1975	0.676	1983	0.783
1953	0.765	1976	0.699	1984	0.800
1954	0.770	1977	0.704	1985	0.753
1955	0.772	1978	0.713	1986	0.775
1959	0.629	1979	0.714	1987	0.731
1960	0.707	1980	0.723	1988	0.750
1965	0.744	1981	0.730	1989	0.781
1970	0.662	1982	0.752	1990	0.759

The average production efficiencies of five years interval and based on the periods of different economic institution are calculated and shown in Table 16.

Table 16. Production efficiency (PE) of crop production during different institutional periods

Time period	Average PE	Institutional period	Average PE
1955-1960	0.732	1952-1965	0.713
1961-1965	0.691		
1966-1970	0.694		
1971-1975	0.677	1966-1977	0.688
1976-1980	0.711		
1981-1985	0.764		
1986-1990	0.759	1978-1990	0.751

The average production efficiency in 1950s was more than 70%, then it was decreasing to the average of 69.1% from 1961 to 1965 and 69.4% in 1966-1970. From 1970s onwards, production efficiency was growing from the five-year average of 67.7% in 1971-1975 to 71.1% in the period of 1976-1980. The trend continued with the five-year average efficiency reached 76.4% in 1981-1985 interval. The production efficiency however, declined from 1985 on, the five-year average dropped to 75.9% in 1986-1990.

Production efficiency varies with institutional reform. During 1952 to 1965 period in which the first economic reform was carried out, production efficiency was relatively high, the average for the whole period was 71.3%. In the so called " Great Cultural Revolution" period, crop production was affected, production efficiency decreased by 3.5 percentage points to 68.8% on average. The second economic reform brought the average production efficiency up to 75.1% from 68.8% in the previous period, increased by 9.5%.

5.4 Accounting for Crop Production Change in Different Periods

The purpose of accounting for crop production growth in different time periods or different institutional reform periods is using the developed empirical approach to separate the effects of institutional factor, technological change, and input use. Since in the past four decades, institutions were reformed several times, drastic changes occurred from one reform to another. With the quite different institutional factors, inputs used and technology adopted also varied from time to time, and their effects on crop production are assumed different. Separation of effects of those three factors in terms of whole study covered period therefore, is less meaningful to reveal the true facts.

Basically, the model employed in accounting for the crop production growth is derived from equation (10), which can be expressed specifically, as:

$$LnY(t)=a_0+a_1LnLb(t)+a_2LnLd(t)+a_3LnCfert(t)+a_4LnMfert(t)$$

$$+a_{1t}LnLb(t)t+a_{2t}LnLd(t)t+a_{3t}LnCfert(t)t+a_{4t}LnMfert(t)t$$

$$+a_tt+a_{tt}t^2+Ln(e^{u(t)})+v(t) \qquad (16)$$

By taking the partial derivative of function (16) with respect to time t, then the total growth rate of crop production is going to be accounted for as:

$$\partial LnY(t)/\partial t=\partial[a_0+a_t t+a_{tt}t^2+v(t)]/\partial t+a_1\partial LnLb(t)/\partial t$$
$$+a_2\partial LnLd(t)/\partial t+a_3\partial LnCfert(t)/\partial t+a_4\partial LnMfert(t)/\partial t$$
$$+LnLb(t)\partial a_1(t)/\partial t+LnLd(t)\partial a_2(t)/\partial t+LnCfert(t)\partial a_3(t)/\partial t$$
$$+LnMfert(t)\partial a_4(t)/\partial t+\partial Ln[e^{u(t)}]/\partial t \qquad (17)$$

Where

$a_i(t)=a_{it}*t$

The accounting for the sources of total crop production growth is presented in Table 17. Effect of neutral technological change is treated as the residual. Effect of biased technological change on crop production is singled out.

During the period of 1952-1965, 90.5% of crop production growth was from the increase in input use. Among the inputs used in production, labor, land, and chemical fertilizer contributed to the crop production growth more or less equally. Manure fertilizer played an important role, it contributed 20% of the total crop production increase. Total productivity increase shared only 9.5% of the growth of crop production. The first economic institutional reform made a contribution of 7.57% to the crop production, technological change had little effect, it accounted for 1.93% of total increase in crop production. Of the 1.93% contribution by technological change, 1.66 percentage points from neutral technological change, sharing about 86% of the total

Table 17. Accounting for growth of crop production in terms of annual growth rates (%) in different time periods

Source	Time Periods			
	1952-1965	1966-1977	1978-1990	1952-1990
Total Production Growth	3.37 (100)	2.81 (100)	3.37 (100)	3.18 (100)
Total Input Growth	3.05 (90.5)	2.52 (89.7)	2.43 (72.1)	2.34 (73.5)
Labor	0.811 (24.06)	1.114 (39.6)	0.668 (19.82)	0.931 (29.28)
Land	0.724 (21.48)	0.612 (21.78)	0.975 (28.91)	0.721 (22.67)
Chemical fert.	0.812 (24.09)	1.092 (38.86)	0.732 (21.71)	0.556 (17.50)
Manure fert.	0.705 (20.91)	-0.291 (-10.36)	0.055 (1.62)	0.130 (4.08)
Total Productivity Growth	0.32 (9.5)	0.29 (10.3)	0.94 (27.9)	0.84 (26.42)
Institutional reform	0.255 (7.57)	-0.0974 (-3.47)	0.637 (18.9)	0.276 (8.68)
Technological change	0.065 (1.93)	0.387 (13.77)	0.303 (9.00)	0.564 (17.77)
Neutral technology	0.056 (1.66)	0.372 (13.24)	0.282 (8.37)	0.555 (17.45)
Biased technology	0.009 (0.27)	0.015 (0.53)	0.021 (0.62)	0.009 (0.283)
Labor biased technology	-0.057 (-1.69)	-0.057 (-2.03)	-0.058 (-1.71)	-0.057 (-1.79)
Land biased technology	0.051 (1.51)	0.052 (1.85)	0.052 (1.55)	0.051 (1.60)
Chemical fert. biased technology	0.215 (6.38)	0.220 (7.83)	0.225 (6.68)	0.215 (6.76)
Manure fert. biased technology	-0.200 (-5.93)	-0.200 (-7.12)	-0.200 (-5.92)	-0.200 (-6.29)

Note: Growth rates of input and output are in percentage; numbers in parentheses are contributions to crop production growth in percentage.

contribution by technology, the rest 14% from neutral technological change.

Within the category of biased technological change, chemical fertilizer using bias is the most important aspect, contributed 6.38% to the total crop production, followed by land bias technological change, 1.51%. In other words, productivity improvement of chemical fertilizer alone increased the crop production by 6.35%, and increase in land productivity boosted crop production by 1.51%. For labor bias, because of the quick increasing labor force, relative slow development of employment opportunities, labor productivity was decreasing, which contributed to the crop production growth negatively.

For manure fertilizer, emphasis shift from manure fertilizer caused by introduction of chemical fertilizer led to improper practice in both preparation and application processes, which has given rise to a decline in effectiveness of manure fertilizer, this decreased effectiveness contributes -5.93% to crop production.

In 1966-1977, value of crop production grew at a declining rate, annual growth rate decreased to 2.81 down from 3.37 in the previous period. During the eleven-year period (1966-1977), increased input use accounted for 89.7% of the crop production, total productivity increase shared 10.3%, technological change contributed 13.77% to the crop production. It should be noted that, during this period crop production was decreased 3.47% by the unsuitable institutions--the "Great Cultural Revolution". Because of the negative contribution from institution, the sharp increase in technology adoption was unable to increase productivity much, compared with the previous period.

Neutral technology was a critical component from 1966 to 1977 of the technological change, though biased technology had an increasing contribution. 95% of the technological change was neutral technological change. In biased technical change, land and fertilizer bias were the major two. Contribution by land biased technological change to crop production growth in this period rose by 22.5%, chemical fertilizer increased by 22.7% over the proceeding period. On the other hand, contributions by both labor and manure fertilizer were declining.

In 1978-1990, the second radical economic reform, annual crop production growth re-bounced back to 3.37%, total input use increased at a growth rate of 2.43% annually, lower than former two periods. Contribution to crop production by input also lower than before, at about 72.1% of crop production growth. Individually, labor accounted for 19%, land, 28.91%, chemical fertilize, 21.7%, manure fertilizer, 1.62%, of crop production increase. Institutional factors contributed 18.9% to the production, and technological change shared about 9% of the production growth. 8.37% of crop production growth was from neutral technological change, and 0.62% from biased technological change.

For the study period (1952-1990) as a whole, the annual growth rate of crop production was 3.18%, total input use was growing at a rate of 2.34% annually. Of the total production growth, 73.5% came from increase in input use, 8.68% from the institutional reform, and 17.77% was from technological advancement.

Among inputs, labor and land have been the two most important contributors to crop production increase in Guizhou province. Labor contributed 28.28%, land contributed 22.67% respectively to the total increase in crop production. Chemical fertilizer made a contribution of 17.5%.

In relation to effect of technology, neutral technological change, again, is the dominant contributor. It accounted for 17.45% of total crop production growth, sharing about 98% of the total contribution made by technology.

In biased technology category, chemical fertilizer using technology topped others with contribution of 6.76% to the crop production growth, land using bias technological change contributed 1.6%. Labor and manure fertilizer decreased production by 1.79% and 6.29% separately.

The productivity of crop production system, with institution improvement and technological invention and diffusion as its sources, has also enjoyed an increase. During the entire study period (1952-1990), average growth rate of crop productivity was 0.84% per annum. In 1966-1977 period, annual productivity increased at a rate of 0.29%, during the second reform (1978-1990), annual productivity growth rate reached 0.94%, increased by 224% over the period of 1966-1977. However, a decreasing growth rate of productivity is also estimated. From the first economic reform (1952-1965) to the "Great Cultural Revolution" period (1966-1977), annual growth rate of productivity declined to 0.29%, reduced by as much as 9%.

Institutional factor is one of the major sources contributing to productivity growth. During the period of 1952-1965, 79.7% of the productivity boost came from institutional change, the rest 20.3% from technology invention and adoption. In 1966-1977, technological change replaced institution. During this historical period, productivity increase was solely from technological change, institutional factor was adversely affected productivity growth; in 1978-1990, institution change, again, became the leading factor, which accounted for 67.8% of total productivity growth, 32.2% of productivity increase was contributed by technological change. Considering the overall study period, institution contributes 32.9% to the total productivity growth, while new technology accounts for 67.1% of total productivity increase.

Neutral technology improvement in the first reform period shared 17.5% of productivity growth, in the "Great Cultural Revolution" years it was the most important source, in the second economic period, it contributed 30% to the productivity increase.

Biased technology exerted only a little effect on productivity increase. 2.8% of productivity improvement in the first reform was from bias technology change, 5.25% in the "Great Cultural Revolution" era, and 2.2% in the 1980s' economic reform period.