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TECHNOLOGICAL CHANGES AND AGRICULTURAL DEVELOPMENT OF TAIWAN 1946-1965

By
You-tsao Wang
Rural Economics Division

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Technological changes and Agricultural Development of Taiwan, 1946-1965.*

I. Introduction

Economic growth generally is defined in terms of a rising level of real production per person or per unit of resources. Technological advancement is one of the important forces which alters the production structure of a growing economy, including agricultural sector. The significance of technological changes for developing countries is that it permits the continuous changes in the physical and value productivity of resources by the constant flow of innovations and skills for resources utilization. This statement unquestionably applies to the agricultural sector of a country. Technological changes may call for readjustments of resources within the farm and/or changes in the total amount of resources employed in agricultural sector relative to other sectors of the economy.

In the process of economic progress, development planning is concerned almost exclusively with how to achieve a sufficiently high growth rate in output. Efforts were laid to the increase of resources utilized in the past. Since World War II, however, technological change has played an important role, relative to changes in conventional inputs in accounting for agricultural growth in Taiwan and in a number of other countries. The term "technological change," as used here, means broadly in any change relevant to productivity growth. It includes changes in the methods by which farmers sow, cultivate, and harvest crops and care for livestock. It includes changes in the seeds, the fertilizers, the pesticides, the medicines and the feeds used, the tools, the implements and the sources of power. It includes enterprise combinations by which farmers seek to make the best use of their labor and land.[1)]

The purpose of this study is to examine Taiwan's agricultural development with the emphasis of technological progress after World War II, 1946-1965 period. It includes a study of the growth of agricultural output as well as changes in input combinations and in factor productivity. Increase due to the accumulation of conventional inputs, i.e., land, labor and capital as well as the residual attributable to technological change or other factors are also estimated statistically. Although this study deals mainly with the agricultural development after World War II, a brief review will be also sketched for the agricultural development of Taiwan before the war.

1) A. T. Mosher, *Getting Agriculture Moving.* The Agriculture Development Council, New York, 1966, p. 75.

* This study was originally prepared and presented at the Conference on Economic Development of Taiwan, June 19-28, 1967, Taipei, Taiwan, the Republic of China.

II. A Review of the Agricultural Development of Taiwan Before World War II

Many studies have been devoted to investigation of the long-term agricultural development in Taiwan.[2] No repetition in details will be made here for the prewar development. However, some of the features and past trends which had been explored by other competent researchers will be reviewed and summarized to provide a background for the discussion of the postwar development of Taiwan's agriculture. Two independent studies — Hsieh-Lee's paper and Ho's book — are the main sources of information used here.

Against its limited land resource and high population pressure, Taiwan's agriculture is characterized by the vitality and strength of small family farms with an average size of 1.1 hectares and 7 persons. Over a period of about 50 years, Taiwan's economy has emerged from a rather backward state to achieve a highly productive agriculture and rapidly expanding industrial capacity. The development of agriculture in Taiwan can be generally classified into five periods:[3] (1) the initial stage under the Japanese colonial rule, 1910-1920; (2) the continued development under the Japanese colonial rule, 1920-1939; (3) the development during World War II, 1939-1945; (4) the recovery and rehabilitation stage after World War II, 1945-1952; and (5) the further development after the rehabilitation, 1952-1960. The first two periods, covering 1910-1939, may be referred to as the prewar period and the last two periods, from 1946 to 1960, the postwar period. From 1910 through 1920, both capital and technology were imported from Japan in order to expand the cultivated land area and thus to achieve the expansion of agricultural output. Although the investment of capital and the application of production techniques were continued to boost the agricultural production, more emphasis was focussed on how to increase the unit crop yields in the years of 1920-1939. During those 40 years, Taiwan's agriculture was closely linked with the economy of Japan as a colony to provide food and raw materials for Japan and to import fertilizer

2) E. Stuart Kirby: *Rural Progress in Taiwan.* JCRR, Taipei, Taiwan, December 1960.
S. C. Hsieh and T. H. Lee: *An Analytical Review of Agricultural Development in Taiwan – An Input-Output and Productivity Approach,* Economic Digest No. 12, JCRR, Taipei, Taiwan, July 1958.
S. C. Hsieh and T. H. Lee: *Agricultural Development and Its Contributions to Economic Growth in Taiwan,* Economic Digest No. 17, JCRR, Taipei, Taiwan, April 1966.
T. H. Shen: *Agricultural Development on Taiwan since World War II,* Cornell University Press, Ithaca, New York, 1964.
Yhi-min Ho: *Agricultural Development of Taiwan. 1903-60* Vanderbilt University. 1966.
Wei-ming Ho: "Planning & Programming for Agricultural Development in Taiwan," Taipei, Taiwan.

3) S. C. Hsieh and T. H. Lee (1958), *Op. cit.*

and other industrial products from Japan. Generally speaking, during the prewar period of the Japanese occupation, the main crops in Taiwan were rice, sugarcane and sweet potato. Then attention was gradually shifted to tea, pineapple, and banana production. There were considerable improvements on irrigation facilities, fertilizer application, varieties and cultural practice during the prewar period to enhance agricultural development.

From 1939 to 1945, the whole economy of Taiwan suffered very badly from World War II, and its agriculture experienced a downward trend of both output and resource endowment. Agricultural production tumbled down to the 1910 level at the end of World War II. After the restoration of Taiwan to the Republic of China in 1945, Taiwan's agriculture enjoyed a postwar recovery and rehabilitation and then progressed to a planned development stage.

Growth of productivity is commonly measured by the changes in agricultural output related to the changes in resources. It is first measured here in terms of change in agricultural output that took place in Taiwan. According to Hsieh-Lee's work, an index of output constructed on a 1935-37 base indicated the average annual growth rate in each development period as shown in Table 1 and Figure 1. During the prewar period of 1910-39, there was an average annual agricultural output growth rate of 3.3 percent, with a 2.0 percent annual rate of population growth. The annual growth rate of output in the war period dropped down sharply to -12.3 percent due to war and typhoon damages. Output expanded rapidly at a high rate in the period of recovery and rehabilitation and then slowed down to an annual rate of 4.0 percent during 1952-60. The average annual growth rate was 8.1 percent in 1946-60, with a 4.2 percent annual rate of population growth.

There are two general factors affecting the expansion of farm output: (1) increase inputs of resources and (2) advancement of technology, including changes in agricultural organization which increased the efficiency in the use of agricultural resources.

The increase of agricultural output during the prewar period, between the years of 1911-15 and 1936-40, was about 129.4 percent, while the increase of aggregate input including land, labor and capital was only 50.5 percent in the same period. Judging from Table 2, it is clear that land was the limited resource which increased by merely 24 percent during the prewar period and only slightly expanded after World War II. However, the expansion of crop area through multiple cropping and diversification has been an important means for

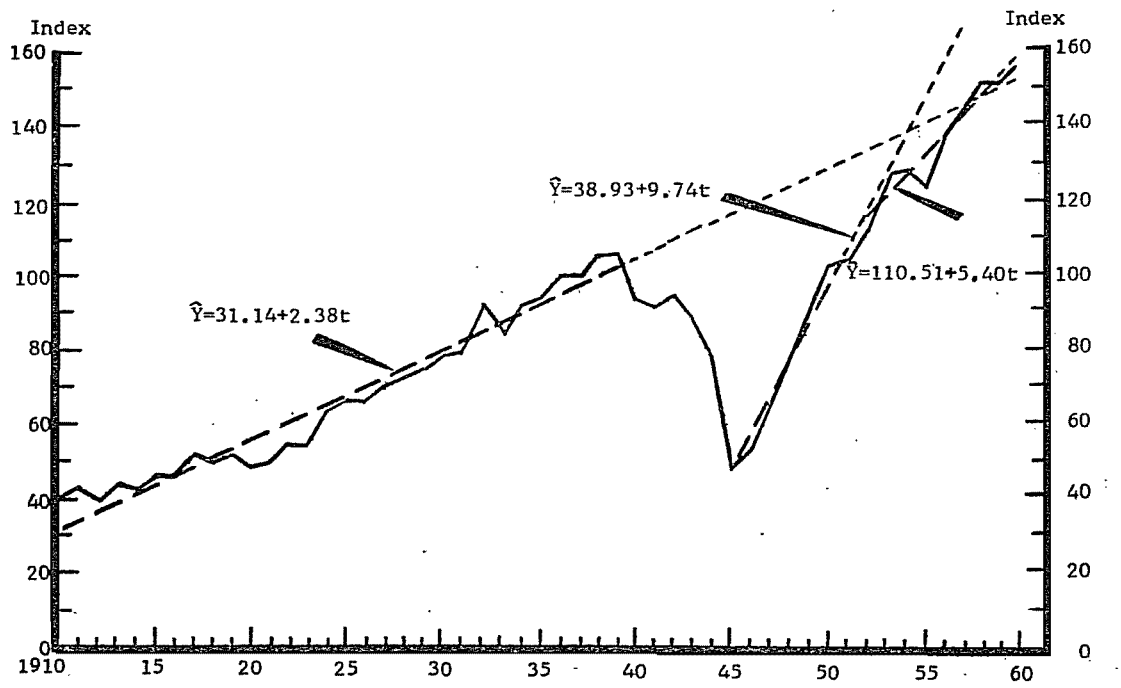
a more intensive use of land for output expansion. The increase of capital input represents a significant factor contributing to the development of agricul-

Table 1. Average Annual Growth Rate of Agricultural Output in Different Stages of Agricultural Development in Taiwan, 1910-60

Stage of Agricultural Development	Period	Average annual growth rate of agricultural output in percent	Average annual growth rate of total population in percent
Initial stage under Japanese colonial rule	1910-20	1.7	1.4
Continued development under Japanese colonial rule	1920-39	4.2	2.4
Development during World War II	1939-45	−12.3	0.5
Recovery and rehabilitation after World War II	1945-52	12.9	4.9
Further development after the rehabilitation	1952-60	4.0	3.6
Prewar period	1910-39	3.3	2.0
Postwar Period	1945-60	8.1	4.2

Source: S. C. Hsieh and T. H. Lee (1966), *op. cit.*, p. 14.

Figure 1. Index of Aggregate Agricultural Output in Taiwan (Base Period: 1935-37)



Source: S. C. Hiseh and T. H. Lee (1966), *op. cit.*, p.12.

ture in Taiwan, particularly after the war. The expansion of agricultural output was mainly accomplished by the substitution of capital for land resource, i. e., to increase the ratio of capital land for higher productivity of land, and since capital and labor are mutually complementary in production under Taiwan's situation, more capital input in agriculture usually calls for more labor input, resulting in more employment opportunity and higher labor productivity.

Productivity is usually expressed by the ratio of output per unit of input. Taking 1935-37 as a base, during the prewar period, the index of average productivity of aggregate resources including land, labor and capital increased from

Table 2. Indices of Agricultural Inputs and Aggregate Farm Output

Period	Cultivated Land	Crop area	Agricultural Worker	Labor input	Working Capital	Fixed Capital	Aggregate input	Aggregate output
1911—15	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1916—20	105.6	107.4	97.3	111.6	130.9	109.6	109.5	115.2
1921—25	109.6	114.1	97.5	118.1	160.1	183.5	117.7	134.1
1926—30	115.9	121.8	102.9	125.8	225.9	319.1	132.3	165.6
1931—35	118.5	133.8	111.4	138.9	279.7	339.5	141.1	202.6
1936—40	123.7	141.2	119.0	144.6	324.9	310.0	150.5	229.4
1941—45	120.9	136.2	--	138.5	139.1	281.9	134.8	182.6
1946—50	123.2	159.8	143.6	141.4	163.7	268.3	134.6	178.7
1951 - 55	126.2	186.3	150.8	178.7	331.7	318.1	166.1	269.9
1956—60	126.5	195.4	149.4	198.4	511.7	389.9	184.2	337.1

Source: Hsieh and Lee (1966) *op. cit.*, pp. 19 and 24.

Table 3. Changes of Agricultural Resource Productivity
1935-37 = 100

Year	Aggregate resource productivity	Land Productivity (per unit cultivated land area)	Labor productivity (per worker)	Capital Productivity
1911	67.9	54.9	53.5	162.8
1916	66.7	57.5	57.0	135.8
1921	67.8	57.5	61.1	121.3
1926	78.2	71.9	76.6	99.2
1931	88.9	84.6	86.3	98.6
1936	99.9	101.0	101.2	97.7
1941	94.4	90.6	87.3	111.1
1946	72.3	56.4	47.3	156.0
1951	100.8	101.2	80.4	117.1
1956	116.5	132.0	105.3	102.6
1960	125.4	150.3	116.7	102.8

Source: Hsieh and Lee (1966), *op. cit.*, p. 38.

68 to 94 or by 39 percent while during the postwar period, it increased from 72 to 125 or by 73 percent. Table 3 shows that the notable features in Taiwan's agriculture were the sharp rise of average land productivity accompanied by sharp decline in average productivity of capital. During the prewar period, land and labor productivities advanced by 65 and 63 percent, respectively, while the productivity of capital declined by about 32 percent.

It should be noted that the agricultural output index constructed by Hsieh and Lee consists of a total of 76 different agricultural products with 1935-37 as the base period. Another study made by Y. M. Ho[4] used a similar method to build an output index composed of 74 agricultural products but used 1952-56 as the base period. Although two different bases were used by these two studies, both methods are basically the same. However, the output index constructed by Hsieh and Lee was an index of *gross* agricultural production which included those agricultural products such as seeds and feeds used on farms as intermediate inputs; while the output index constructed by Ho was the *net* agricultural production deducting the part of agricultural products used on farms as intermediate products. Although these two indices are different, they move very closely together.

Ho's study shows that the average annual growth rate for the prewar and war years, 1901-1944, was 2.6 percent, and 8.6 percent for the years 1945-1960. Ho also indicated in his study that the increased agricultural output was brought about in part by the increased farm input and in part by technological changes. After the discussion of the trends of inputs, Ho constructed an aggregate input index which comprised land area, labor, working capital and fixed capital. As for the particular method used and assumptions made, Ho used the aggregate input index as the changes in the expected output in the absence of technical change. The annual growth rate of observed output was 3.14 percent for the whole study period while the aggregate input increased by an average rate of 2.0 percent per year for the same period. The difference of 1.14 percent between the observed and the expected growth rate of agricultural output was credited by Ho to the average rate of technical progress. The rate of technical change averaged about 1.14 percent per year for the whole period, a high rate of 3.2 percent of technical change was attained in the period of 1946-60 and 2.9 percent in 1921-30. Ho also estimated that of the 2.0 percent expected annual growth in agricultural output, 0.34 percent was due to the increment in physical land area, 0.27 percent to labor, 1.27 percent to working capital, and

4) Yhi-min Ho, (1966), *op. cit.*

0.11 percent to fixed capital input.

A considerable portion of the increment in agricultural output was mainly attributed to two factors: increases in the degree of utilization of limited land and in the yields per crop area. Varietal improvement in seeds and greater application of fertilizers, among other things, were the important factors affecting the gains in yields. The introduction of better seed varieties characterized by a shorter growing period, changed cultural practices, an improved cropping system, and the provision of irrigation served to raise the intensity of land use. By Ho's estimates, 15 to 24 percent of the computed *unexplained* output can be attributed to the changes in the degree of land utilization during the prewar period and 20 to 33 percent during the period of 1951 to 1960.

One more finding by Ho's study worthy mentioning here is the estimation of returns to research and education. By using Tang's distributed lag scheme,[5] Ho estimated that an investment of NT$1.00 in agricultural research and rural education in the long run could contribute as much as NT$13.93 to farm output (excluding the part of agricultural products used in farms as intermediate inputs). The long-run social returns to education and research in agriculture were estimated to have a marginal efficiency as high as 55 percent, compared with a marginal efficiency of some 35 percent in the long-run social returns to such investment in Japan as estimated by Tang's study.

III. Changes of Agricultural Output and Input

A brief summary has been made on the long-run process of prewar development of Taiwan's agriculture in the previous section. In the remaining bulk of this study, the development and changes in the production structure of agriculture after World War II will be analyzed. The changes of agricultural output and the trend of input will be discussed in this section. Productivity growth of agricultural resources and technological changes and its contributing factors are to be explored in the following sections. It is also to be noted the term "agriculture" used in this study includes farm crops and livestock products only, not forestry and fishery.

A. Growth of Agricultural Output

The agricultural products concerned in this study cover a total of 85 dif-

5) Anthony M. Tang: "Research and Education in Japanese Agricultural Development, 1880-1938," *The Economic Studies Quarterly,* XIV, 2 and 3, Feb. and May, 1963. See also Ho's books, *op. cit.* chapter IX.

ferent products, including 12 food crops, 21 special crops, 25 items of vegetables, 14 items of fruits, and 13 livestock and poultry products. The index so constructed covered more than 95 percent of the total agricultural output in terms of either the total crop area or the total value of products. In the construction of the output index, the constant product prices of 1951 were used as the weights for aggregating the total value of various agricultural products as shown in Table 4. Therefore, in this paper, agricultural output refers to the gross agricultural production including the part of agricultural products used on farms as the intermediate inputs such as seeds and feeds. This is similar to the method used in Hsieh-Lee's study but different from what Ho did in his book.[6)]

Table 4. Gross Agricultural Output of Taiwan 1946-1965
(In 1951 constant prices)

Unit: NT$1,000,000

Year	Total 85 items	Food Crop 12 items	Special Crop 21 items	Fruits 14 items	Vegetables 25 items	Livestock and Poultry 13 items
1946	1,993.7	1,170.4	242.4	91.4	126.6	362.9
1947	2,495.6	1,357.3	299.9	208.0	185.4	435.0
1948	3,041.7	1,488.3	650.1	207.0	181.4	515.0
1949	3,672.6	1,680.0	1,079.8	187.1	192.0	533.7
1950	4,015.5	1,885.0	1,009.7	195.6	218.0	707.2
1951	4,025.6	1,925.6	787.0	197.4	226.1	889.4
1952	4,438.6	2,020.5	983.8	199.7	229.5	1,005.1
1953	5,149.5	2,140.5	1,330.8	195.6	232.0	1,250.6
1594	5,141.7	2,257.9	1,168.7	186.7	238.6	1,289.8
1955	5,166.4	2,175.7	1,197.8	213.0	245.6	1,334.3
1956	5,502.5	2,389.7	1,235.6	211.4	252.4	1,413.4
1957	6,041.0	2,488.9	1,427.7	256.8	270.2	1,597.5
1958	6,530.1	2,616.6	1,504.0	315.8	283.6	1,810.1
1959	6,602.6	2,579.2	1,619.7	321.9	288.8	1,793.2
1960	6,499.4	2,675.2	1,415,8	366.9	309.4	1,730.1
1961	7,070.5	2,831.3	1,622.0	396.9	315.0	1,905.3
1962	7,192.0	2,900.1	1,499.3	443.9	329.5	2,019.2
1963	7,384.3	2,699.6	1,866.0	427.7	352.3	2,038.7
1964	8,113.1	3,070.3	1,795.2	619.1	345.5	2,282.5
1965	8,985.7	3,163.4	2,337.4	769.0	341.0	2,374.9

Source: *Taiwan Agricultural Year Book,* Department of Agriculture and Forestry (PDAF), Provincial Government of Taiwan.

6) Ho used the net agricultural production which the intermediate farm products used on farms being deducted from the gross agricultural output.

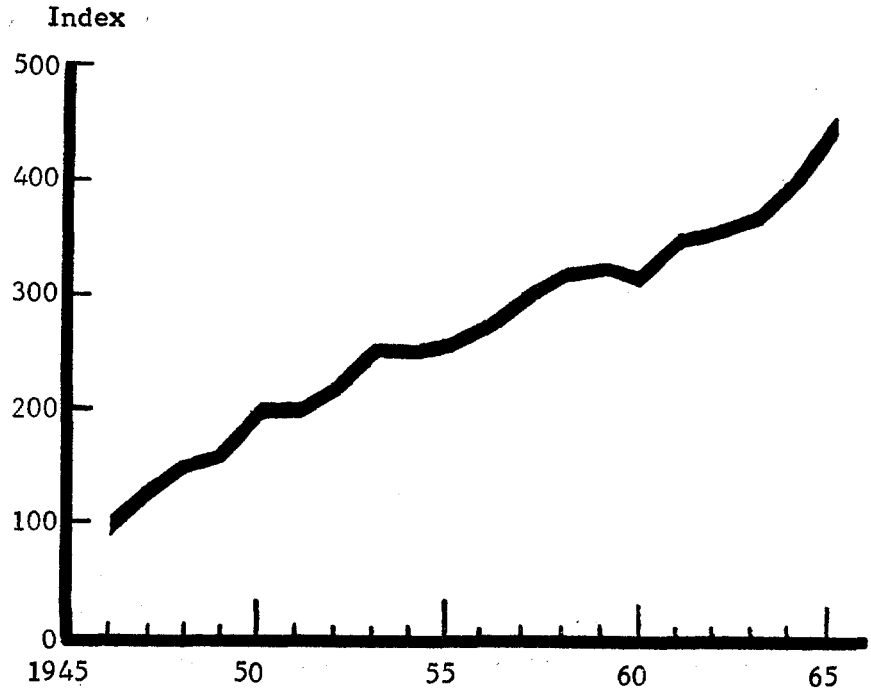
Table 5. Growth rate of Agricultural Output 1946-1965

Year	Output Index	Growth Rate
1946	100.00	—
1947	124.66	24.66
1448	152.56	22.38
1949	184.20	20.74
1950	201.40	9.34
1951	201.90	0.25
1952	222.62	10.26
1953	258.27	16.01
1954	257.88	(−) 0.15
1955	259.12	0.48
1956	275.97	6.51
1957	302.99	9.79
1958	327.52	8.09
1959	331.16	1.11
1960	325.98	(−) 1.67
1961	354.63	8.79
1962	360.71	1.72
1963	370.36	2.68
1964	406.92	9.87
1965	450.68	10.75
Average annual growth rate		
1946-1965		8.25
1946-1952		14.20
1953-1965		4.75

Source: Computed from Table 4.

The output index and the annual rate of change in output are presented in Table 5. During the 20 years of the postwar period, from 1946 to 1965, the gross real agricultural output showed a 4.5 times increase as shown in Figure 2. The average annual growth rate was 8.25 percent and dominated by short-run fluctuation as can be seen in Figure 3. Of the 19 yearly changes only 3 were changes of less than that of 1.0 percent point, while 4 were changes between 1.0 to 5.0 percent, and 12 were more than 5.0 percent. One possible explanation of the wide yearly fluctuation of agricultural output is the uncontrollable natural factors such as weather. This is especially noticeable in the case of Taiwan which is a small island and any change in natural condition, favorable or unfavorable, usually affect the agricultural production of the

Figure 2. Index of Agricultural Output of Taiwan 1946-1965



Source: From Table 5.

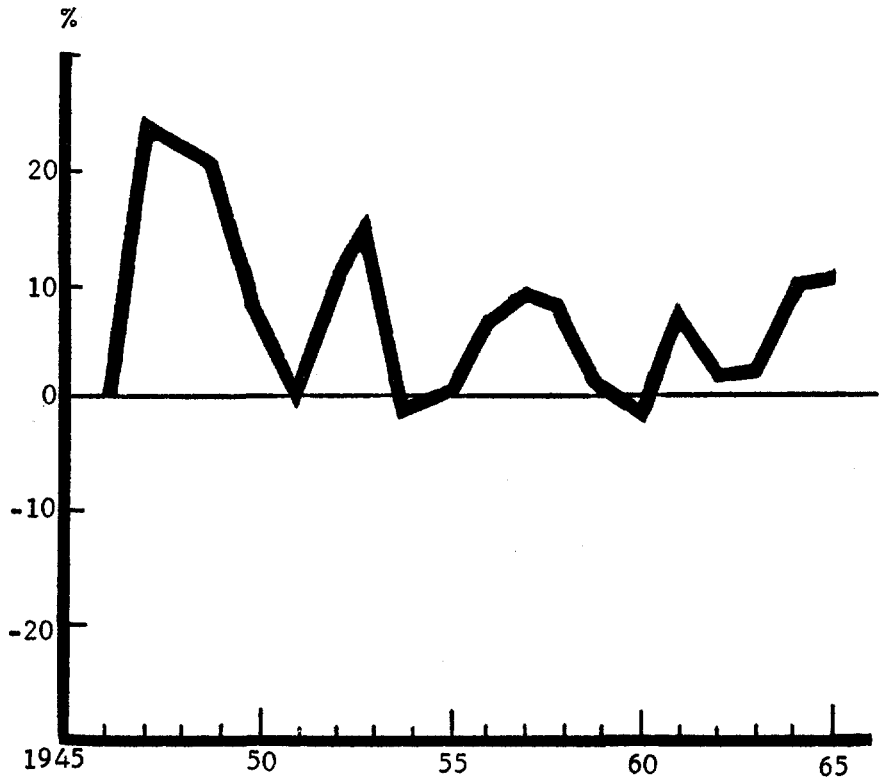
whole island.

In spite of the short-run fluctuation, agricultural output showed a steady growth trend during the period under review. Agricultural output increased rapidly with an annual average rate of 14.27 percent in the period of recovery and rehabilitation, 1946 to 1952. While it grew at an annual rate of 4.75 percent for the period 1953 to 1965. It should be noted that the year of 1939 was the peak year of agricultural production before the war in Taiwan.[7] By the year 1952, agricultural output had recovered to this previous record and went up beyond it steadily. Taking 1952 as the ending year of the postwar recovery and rehabilitation period, the annual average growth rate for the period 1952-1965 was 5.58 percent.

The increase of production shifted the supply functions of individual crops. This shift and the changes in demand conditions for agricultural products together affected the composition of agricultural output during the period as summarized in Table 6. The food crops as a percentage of the total output declined about 40 percent from 58.71 percent in 1946 to 35.21 percent in

7) See Figure 1.

Figure 3. Changes in Growth Rate of Agricultural Output



Source: From Table 5.

1965, vegetables also had a similar trend in its percentage share. Special crops climbed up from 12.16 percent in 1946 to 26.01 percent in 1965, a phenomenal rise of 114 percent increase, and the share of fruits increased by 87 percent from 4.58 percent in 1946 to 8.56 percent in 1965. Livestock and poultry products also showed a 45 percent increase in their share during the same period. It should be noted that rice is the most important product in Taiwan's agriculture, although its percentage share of the total showed a substantial decline, from 45.53 percent in 1946 to 26.53 percent in 1965. The total production of rice was 894,000 metric tons in 1946 and surpassed the prewar peak of 1950, and then reached 2,348,000 metric tons in 1965. The production of sweet potato also increased from 1,331,000 metric tons to 3,131,000 metric tons in 1965. Other crops such as wheat, peanut and soybean also registered gains during the same period. Tea was expanded rapidly from less than 3,000 metric tons in 1946 to 21,000 metric tons in 1965. The annual production of the main crops are shown in Appendix Table A.

Table 6. Composition of Agricultural Output of Taiwan 1946-1965

Year	Total 85 items	Food Crop 12 items	Special Crop 21 items	Fruits 14 items	Vegetables 25 items	Livestock and Poultry 13 items
1946	100.00	58.71	12.16	4.58	6.35	18.20
1947	100.00	54.60	12.07	8.37	7.46	17.50
1948	100.00	48.93	21.37	6.81	5.96	16.93
1949	100.00	45.75	29.40	5.09	5.23	14.53
1950	100.00	46.94	25.15	4.87	5.43	17.61
1951	100.00	47.83	19.55	4.90	5.62	22.10
1952	100.00	45.53	22.16	4.50	5.17	22.64
1953	100.00	41.55	25.84	3.80	4.51	24.30
1954	100.00	43.91	22.73	3.63	4.64	25.09
1955	100.00	42.12	23.18	4.12	4.75	25.83
1956	100.00	43.42	22.46	3.84	4.59	25.69
1957	100.00	41.21	23.63	4.25	4.47	26.44
1958	100.00	40.07	23.03	4.84	4.34	27.72
1959	100.00	39.06	24.53	4.88	4.37	27.16
1960	100.00	41.16	21.78	5.68	4.76	26.62
1961	100.00	40.04	22.94	5.61	4.46	26.95
1962	100.00	40.32	20.85	6.17	4.58	28.08
1963	100.00	36.56	25.27	5.79	4.77	27.61
1964	100.00	37.85	22.13	7.63	4.26	28.13
1965	100.00	35.21	26.01	8.56	3.79	26.43

Source: Computed from Table 4.

B. The Trend of Agricultural Inputs

The increase of agricultural output is either a result of changes in agricultural resource inputs or advancement in technology, or both. The part of output increment attributable to the corresponding increase in inputs can be defined as the "explained output"; while the residual part not so attributed is the "unexplained output," i.e., not explained by the conventional inputs such as land, labor and capital goods.

Inputs can be usually classified into three broad conventional categories such as land, labor and capital. Expansion in total agricultural output in Taiwan has been achieved with a small increase in total cultivated land area and a moderate increase in labor input, but it has required a large amount of increase in capital input. This section examines changes in inputs during the period of 1946-65.

1. Land Resource

The total land area of Taiwan is 3,596,121 hectares, (13,884 square miles) of which about 25 percent is arable under present technical conditions. During the past 20 years, the cultivated land area had been expanded about 60,000 hectares, from 830,000 hectares in 1946 to 890,000 hectares in 1965 as shown in Table 7. It remains almost unchanged in the last ten years. Of the total cultivated land, about 60 percent are paddy field and the remaining 40 percent dryland. It is apparent that the expansion in the physical dimension of land area is practically limited. This does not mean, however, that land is no longer a contributing factor to the growth of output in Taiwan. Through the improvement in the quality of land and the increase in the intensive degree of land utilization, land input can still play an important role as the contributing factor to raise output.

Table 7. Land Resource, 1946-1965

Unit: Hectare

Year	Total Cultivated land	Paddy Land	Dryland	Index
1946	831,851	507,636	324,315	100.00
1947	833,952	516,378	317,574	100.24
1948	863,157	516,384	336,773	103.75
1949	864,864	528,097	336,767	103.96
1950	870,633	530,235	340,398	104.65
1951	873,871	533,804	340,067	105.04
1952	876,100	533,643	342,457	105.31
1953	872,738	533,316	339,422	104.90
1954	874,097	532,565	341,532	105.07
1955	873,002	532,688	340,314	104.93
1956	875,791	533,113	342,678	105.27
1957	873,263	533,144	340,119	104.97
1958	883,466	533,674	349,792	106.19
1959	877,740	528,762	348,978	105.50
1960	869,223	525,580	343,643	104.48
1961	871,759	528,149	343,610	104.78
1962	871,858	530,354	341,504	104.80
1963	872,208	528,709	343,499	104.84
1964	882,239	531,790	350,449	106.04
1965	889,563	536,772	352,791	106.92

Source: *Taiwan Agricultural Year Book*, PDAF, Taiwan Provincial Government. 1952, 1958, and 1966 editions.

Improvement in the quality of land can take various forms, such as flood control, soil conservation and the application of new techniques in production. Irrigated land, however, is taken here as the indicator of land improvement.

During the postwar period, irrigated land area remained around 500,000 hectares, which is about 60 percent of the total cultivated land area. It ought to be noted that in recent years, part of the additional irrigated land had been offset by the use of agricultural land for urban and industrial purposes. It was estimated that the paddy land transferred to non-agricultural purposes was around 7,000 bectares in 1953-1966.

Changes in the degree of land utilization can be shown clearly by the increase of crop area. Crop area measures the frequency of land use as well as land area. The increase in crop area is a combined result of the expansion in cultivated land and the more intensive use of land. In Taiwan, since the increment in crop area is greater than the increment in land area, it means that the degree of land utilization has been increased. As mentioned above, the cultivated land increased by less than 60,000 hectares during the postwar period, the crop area expanded by more than 700,000 hectares from 980,000 hectares to 1,686,000 hectares, during the same period. In other words, the expansion of crop area was ten times more than that of cultivated land after the war. Growth of three or four crops a year in many areas has been made possible by development of irrigation, drainage, and flood control measures. In terms of multiple cropping index as the ratio of crop area to cultivated land area, the intensity of land utilization has risen from 118 percent in 1946 to 172 percent in 1952, and to 190 percent in 1965, an increase of 61 percent during the whole study period as shown in Table 8.

2. Labor Input

Labor input generally means services rendered by agricultural workers during a given period of time. Labor input can be measured in either the total number of agricultural workers or the total number of working days. The term "agricultural workers" used here refers to that portion of the agricultural population above 12 years old and available for farm work. Therefore, it is a concept of labor available or labor supply. Another way to measure labor input is the labor requirement of crops and livestock production. Agricultural labor input shown in Table 9 denotes the labor required by crops and livestock and is measured in mandays. It was estimated yearly from farm record keeping

Table 8. Land Utilization in Taiwan 1946-1965

Year	Crop area (Hectare)	Index of Crop Area	Multiple Cropping Index
1946	980,726	100.00	117.88
1947	1,193,583	121.70	143.12
1948	1,346,168	137.26	155.96
1949	1,437,933	146.62	166.26
1950	1,483,518	151.27	170.40
1951	1,483,399	151.26	169.75
1952	1,506,426	153.60	171.95
1953	1,505,854	153.54	172.54
1954	1,519,008	154.89	173.78
1955	1,495,707	152.51	171.33
1956	1,537,621	156.78	175.57
1957	1,563,490	159.42	179.04
1958	1,590,928	162.22	180.08
1959	1,594,101	162.54	181.61
1960	1,596,024	162.74	183.61
1961	1,620,605	165.25	185.90
1962	1,612,457	164.52	184.95
1963	1,612,099	164.38	184.83
1964	1,657,684	169.15	187.90
1965	1,686,024	171.92	189.53

Source: Computed from data in *Taiwan Agricultural Year Book,* PDAF, Provincial Government of Taiwan.

data[8] and different farm surveys carried out in different years. Based on those data, the average working days per hectare and per head of hog were calculated first and then multiplied by the total cultivated land area and total number of hogs to obtain the total agricultural labor input series. Conceptually and statistically, labor input in agriculture is indeed a very difficult problem to handle. Different procedures and approaches were tried to make the estimates based on the average labor input per unit of land or per farm.

Generally speaking, agricultural labor resource can be considered abundant compared with land resource in Taiwan's agriculture. During the past 20 years, the total number of agricultural workers grew by 20 percent, from 1,555,000 persons in 1946 to 1,867,000 persons in 1965, a little less than 1 percent a year. The average cultivated land area shared by each agricultural worker consequently declined from 0.54 hectares to 0.48 hectares. Increased crop area

8) *Report of Farm Record-Keeping Families in Taiwan.* PDAF, Provincial Government of Taiwan.

Table 9. Agricultural Population and Labor Force 1946-1965

Year	Agricultural population (person)	Agricultural workers (person)	Agricultural labor input (1,000 manday)
1946	3,522,880	1,554,942	140,198
1947	3,578,175	1,622,189	161,784
1948	3,779,652	1,665,762	193,939
1949	3,879,581	1,716,941	215,152
1950	3,998,470	1,730,928	220,265
1951	4,160,610	1,728,047	223,125
1952	4,257,136	1,734,737	231,947
1953	4,381,816	1,754,153	236,534
1954	4,488,763	1,753,803	235,697
1955	4,603,138	1,737,106	232,291
1956	4,698,532	1,718,237	240,274
1957	4,790,084	1,709,850	258,342
1958	4,880,901	1,704,615	264,364
1959	4,975,233	1,738,990	262,246
1960	5,373,375	1,754,732	258,371
1961	5,467,445	1,780,910	261,057
1962	5,530,832	1,800,379	259,109
1963	5,611,356	1,833,463	269,256
1964	5,649,032	1,860,933	277,348
1965	5,738,503	1,866,769	291,120
Annual growth rate		0.95	3.92

Source: Agricultural population is taken from data in *Taiwan Agricultural Year Book.* Agricultural workers are computed from data in *Household Registration Statistics of Taiwan,* Dept. of Civil Affairs, Taiwan Provincial Government, 1965. Agricultural labor input is estimated by Rural Economics Division, JCRR, Taipei, Taiwan.

has made possible fuller employment of available labor throughout the year. The annual average working days per worker revealed an upward trend. It was only 90 mandays per worker in 1946, and rose to 156 mandays in 1965; an increase of 73 percent. According to the 1961 agricultural census in Taiwan, most agricultural workers worked only 150 days a year. This is consistent with the above estimate. The increase in working days of agricultural worker also showed a more intensive use of land.

3. Capital input

Capital includes fertilizer, feeds, seeds, pesticides and insecticides, depreciation of farm building, farm implements and equipment, imputed wage of draft cattle as well as fees payment for public irrigation services. The total value of capital

Table 10. Capital Input, 1946-1965

(In Million of NT$ at 1951 constant price)

Year	Capital input	Index
1946	992.2	100.00
1947	1,210.9	122.04
1948	1,576.9	158.93
1949	1,828.5	184.29
1950	1,877.5	189.23
1951	1,876.3	189.10
1952	1,937.5	195.27
1953	2,066.4	208.26
1954	2,144.4	216.13
1955	2,141.2	215.80
1956	2,272.3	229.02
1957	2,429.4	244.85
1958	2,484.4	250.39
1959	2,461.1	248.04
1960	2,421.3	244.03
1961	2,802.1	282.41
1962	2,864.0	288.65
1963	2,802.8	282.48
1964	2,852.7	287.51
1965	2,944.7	296.78
Annual growth rate		5.89

Source: From Appendix Table B.

inputs was compiled at 1951 constant price as presented in Table 10. As shown in the table, capital inputs taking in various forms increased rapidly from NT$992 million in 1946 to NT$2,945 million in 1965, an increase of 197 percent. Increased use of capital inputs obviously was strategic in raising total output in agriculture. A breakdown of the capital components reveals the relative importance of individual capital item and sheds some light on the structural change in capital input. Table 11 shows the percentage share of capital items during the period of 1946-65. (See also Appendix Table B.) Note that chemical fertilizer and pesticides and insecticides increased rapidly during the period under review.

The application of chemical fertilizer increased from 20,000 metric tons in 1946 to 298,000 metric tons in 1950 and then to more than 750,000 metric tons in 1965, and remained the same in the last 5 years. (See Appendix Table C.)

Table 11. Percentage Share of Capital Components in Taiwan 1946 - 1965

Period	Chemical fertilizer	Farm-produced fertilizer	Seeds	Feeds	Pesticides and insecticides	Depreciation	Water fee	Total
1946-50	6.63	46.74	12.67	16.11	0.69	12.47	4.69	100.00
1951-55	18.14	35.56	10.97	21.23	1.27	9.25	3.58	100.00
1956-60	20.36	31.02	9.94	24.79	2.92	7.91	3.06	100.00
1961-65	20.35	27.38	8.82	27.43	6.68	6.72	2.62	100.00

Source: Computed from Appendix Table B.

Traditionally, rice, sugarcane, tobacco, jute and wheat are the major fertilizer-using crops. The consumption of chemical fertilizers on rice during the last 5 years accounted for 80 percent of the total. On the average, in the last few years rice crop consumed annually about 600,000 metric tons of chemical fertilizer, while sugarcane consumed about 100,000 metric tons, and the remaining 50,000 metric tons were used by others. Aside from the consumption of commercial fertilizers, it ought to be noted that farm-produced fertilizers also play an important factor to agricultural production in Taiwan, particularly in the early years after the war. The annual consumption of farm-produced fertilizers increased from 8,427,000 metric tons in 1946-50 to 9,269,000 metric tons in 1961-65. However, significant changes in the composition of total fertilizer application have taken place. The relative importance of chemical fertilizer climbed up from 12 percent in 1946-50 to 43 percent in 1961-65, while the percentage of farm-produced fertilizers decreased from 88 percent to 57 percent during the same period. In other words, chemical fertilizer has been used as a substitute for the farm-produced fertilizer to a great extent after the war. The farm-produced fertilizers concerned here are mainly green manure and compost as shown in Appendix Table C.

The application of pesticides and insecticides also increased rapidly during recent years (See Appendix Tables E and F.) Based on the customs' data, imported quantity of pesticide and insecticide was only about 550 metric tons in 1959, and went up to about three thousand metric tons in 1965. During the period of 1957 to 1965, a total of about 17 million U.S. dollars were spent for pesticides import. Especially the import value was greatly increased in the last two years, i.e., US$3.5 million and US$4.7 million in 1964 and 1965, respectively.

The relative share of feeds in capital component increased from 16.11 percent

in 1946-50 to 27.43 percent in 1961-65. The important feed input consists of rice, sweet potato, corn, cassava and soybeans. (See Appendix Table G.) The total value of feed consumption increased from NT$144 million in 1946 to NT$899 million in 1965. Corn is one of the important feeds, its consumption ascended from 2,900 metric tons in 1946 to 79,200 metric tons in 1965. However, the domestic production was only about 41,000 metic tons in 1965. Sweet potato plays a very important position in the farmers' self-supplied feed input, particularly in hog production. In general, about one half of the total sweet potato production has been used as feed in Taiwan. The total consumption of sweet potato used as feed was about 0.5 million metric tons in 1946 and rose to 1.6 million metric tons in 1965, an increase of 200 percent. In addition to corn and sweet potato, bean cake is also an important hog feed. The average amount of bean cake, including soybean cake and peanut cake, consumed annually was about 100,000 tons in the recent 5 years. Wheat and rice bran and cassava are also common feeds in Taiwan. During the early postwar period, the annual consumption of wheat and rice bran was only about 100,000 metric tons, however, it increased to about 240,000 metric tons in 1965. The portion of total production of cassava and rice used as feed was about 45 percent and 4 percent, respectively, during the period under review. The annual consumption of various major items of feed is shown in Appendix Table G.

The relative share of seeds had declined from 12.67 percent in the total capital input in 1946-50 to 8.82 percent in 1961-65. The total quantity of seeds used annually, however, still showed an upward trend during the postwar period (See Appendix Table D.) The increase in seeds application was partly due to the expansion of crop area and partly due to the extension of closing-plant cultural practice. In spite of the increase in seeds application, it should be noted that the improvement and renewal of seeds, and seed inspection have also been extended widely. Depreciation of farm service buildings, implements and equipment as well as the imputed wages of draft cattle was estimated to be 74 million of N. T. dollars in 1946 and went up to NT$200 million in 1965. Its relative shares, however, declined from 12.47 percent to 6.72 percent of the total during the same period. The number of draft cattle in Taiwan is also presented in Appendix Table H. The relative importance of input categories—cultivated land, labor and capital—has been changed significantly. Table 12 shows the relative shares of input factors in total cost of production. All factor resources of production are valued at the 1951 constant prices which is the same base as those weights used in computing aggregate output series. Imputed

land rental decreased from 14.63 percent in 1946-50 to only 9.16 percent in 1961-65, or 37 percent decrease during the whole period; labor cost also showed a 9 percent decrease, from 41.47 percent in 1946-50 to 37.82 percent in 1961-65, while the total expenses in capital input increased from 43.90 percent to 53.02 percent, or 21 percent increase in the period examined.

Table 12. Percentage Distribution of Input Factor Categories

Period	Cultivated land (a)	Agricultural labor (b)	Capital (c)
1946-50	14.63	41.47	43.90
1951-55	11.53	40.81	47.66
1956-60	10.20	39.85	49.50
1961-65	9.16	37.82	53.02
Average	11.38	39.99	48.63

* Factor cost includes imputed land rental, imputed labor cost and total expenses in capital input. All factors are valued at 1951 constant factor prices.

Source: Computed from Tables 7, 9, and 10.

IV. Changes in Agricultural Productivity

A measurement of the relationship between output product to input resources is commonly referred to as productivity. Productivity of a given input which can be and sometimes is expressed by the ratio of the output per unit of input employed. This rather crude measurement of individual input productivity takes no account of other factors contributing to output. A more meaningful measure is the ratio of output to an aggregate of inputs.

An aggregate input index can then be constructed on the basis of the three conventional categories discussed in the previous section. A commonly used weighted arithmetic formula of aggregate input implies the assumption of a linear and homogeneous production function of the following form:

$$Y = aL + b\,N + c\,K, \qquad (1)$$

where Y stands for the aggregate output, L, N, and K represent the land, labor, and capital inputs in physical units, and a, b and c are the weights attached to inputs, respectively. The aggregate input index is then defined as follows:

$$I_t = \frac{aL_t + bN_t + cK_t}{aL_o + bN_o + cK_o} \qquad (2)$$

where I_t is the aggregate input index relating the time period t to the base period o. The aggregate input index defined above can be computed by multiplying the physical quantities of inputs of period t by the average cost share of each input in production at the base year, or simply by using the constant factor prices of the base period as the weights.

An alternative method in constructing an aggregate input index based on the geometric formula implies the assumption of a log linear production function:

$$Y = A\ L^a\ N^b\ K^c \qquad (3)$$

The aggregate input index may then be expressed in symbols as follows:

$$I_t = \frac{L_t^a\ N_t^b\ K_t^c}{L_o^a\ N_o^b\ K_o^c},$$

or

$$I_t = \left(\frac{L_t}{L_o}\right)^a \left(\frac{N_t}{N_o}\right)^b \left(\frac{K_t}{K_o}\right)^c \qquad (4)$$

where the exponents a, b, and c are the weights attached to each input and they are factor shares in the total cost of production. Total cost of production used here includes imputed land rental, imputed labor cost based on labor working days, and the total cost of capital input as shown in Table 12.

The aggregate input index so computed from the geometric formula defined above is shown in Table 13. The aggregate input index based on the arithmetic formula is also presented in the same table for comparison. It should be mentioned that in the computation of the aggregate input indices, cultivated land, agricultural workers and total capital input are included and the total cost of production is calculated for each year during the period. The arithmetic means of cost share of the input factors in each year are then taken as the weights for the factors in computing the aggregate input index.

Changes in agricultural output are brought about either by changes in input factors used in agricultural production or as a result of technological advancement broadly interpreted. Therefore, the aggregate input index as presented in equation (4) indicates the *expected* output changes or simply the output index in the absence of technical changes. During the period between 1946 and 1965, the average compound rate of increase in the aggregate input index was 3.26 percent per year. Therefore, the output is *expected* to grow also at an annual rate of 3.26 percent in the absence of technical changes.

Table 13. Aggregate Input Index
1946-1965

Year	Aggregate Input Index (Geometrice)	Aggregate Input Index (Arithmetic)
1946	100.00	100.00
1947	112.08	115.20
1948	129.30	140.03
1949	140.68	156.42
1950	143.06	160.03
1951	142.98	160.91
1952	145.51	166.03
1953	150.75	172.46
1954	153.49	175.34
1955	152.78	174.18
1956	156.63	181.84
1957	161.44	193.44
1958	163.22	197.66
1959	163.65	195.97
1960	162.77	193.03
1961	175.84	209.06
1962	178.51	210.94
1963	177.93	211.54
1964	180.77	216.17
1965	183.99	224.11
Annual growth rate	3.26	4.34

Source: See the text.

During the period, land input grew at a rate of 0.35 percent per year, agricultural workers only 0.95 percent, and capital 5.89 percent.

Based on the aggregate input and output series compiled here, changes in aggregate input productivity can be then expressed by the ratio of aggregate output index to the aggregate input index. The result is shown in Table 14 and Figure 4. The average productivity of the aggregate input including cultivated land, agricultural workers and total capital input has increased by a little more than double from 1946 to 1965. The rate of increase is 3.79 percent per year. Although the changes in the aggregate input productivity may explain the general productivity changes in agriculture, it is also desirable to examine the pattern changes in individual input productivity to study the contents and relative shares of the resource components.

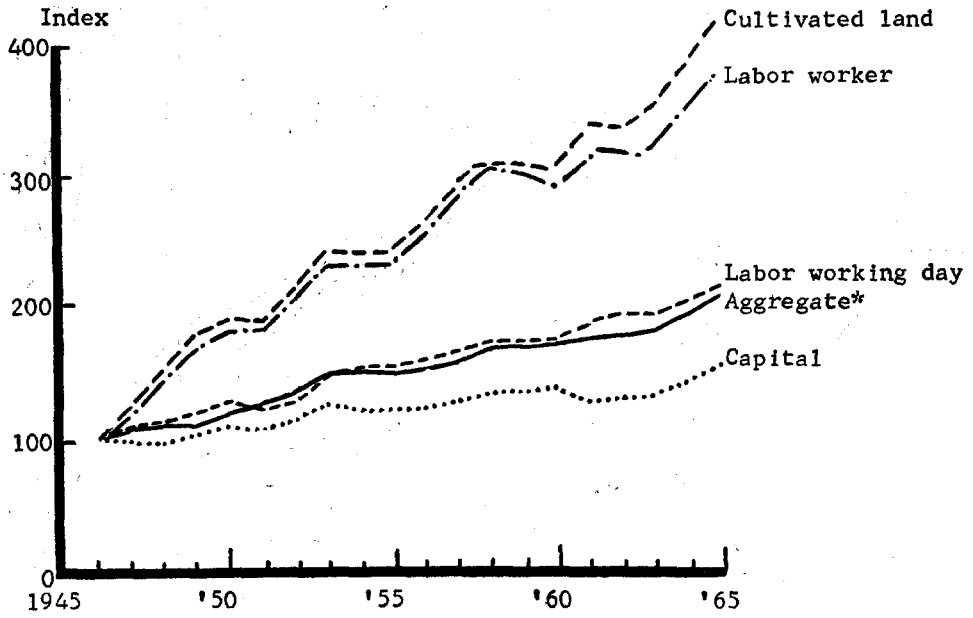
Table 14. Index of Input Productivity

Year	Aggregate Input* Productivity	Land Productivity	Labor Productivity		Capital Productivity
			Worker	Man-day	
1946	100.00	100.00	100.00	100.00	100.00
1947	108.86	123.08	119.49	107.72	101.99
1948	110.13	146.07	142.41	109.56	96.02
1949	110.13	176.32	166.82	119.44	100.00
1950	117.72	191.09	180.92	127.29	106.47
1951	126.58	189.61	181.68	125.19	106.97
1952	134.18	207.79	199.55	132.27	113.93
1953	150.63	240.63	228.94	149.64	123.88
1954	148.10	239.58	228.63	149.73	119.40
1955	149.37	240.57	231.93	152.36	119.90
1956	151.90	255.73	249.75	157.08	120.40
1957	156.96	283.42	275.53	161.50	123.88
1958	167.09	298.69	298.76	168.21	130.85
1959	169.62	304.18	296.11	171.58	133.33
1960	169.62	302.94	288.86	171.76	133.33
1961	170.89	328.00	309.63	184.57	125.37
1962	172.15	333.18	311.53	188.92	124.88
1963	175.95	342.45	314.09	186.94	125.87
1964	188.61	370.93	340.01	198.82	141.29
1965	202.53	408.30	375.39	210.25	151.74
Annual growth rate	3.79	7.86	7.21	4.12	2.22

* Aggregate input includes cultivated land area, agricultural workers and total expense of capital input.
Source: Computed from Tables 4, 7, 9, 10 and 12.

During the period under review, land productivity rose by about 308 percent and labor productivity in terms of agricultural worker by 275 percent, while capital productivity increased by about 52 percent. Recall that the individual factor productivity is measured by dividing the quantity of input factor into the agricultural output valued at the 1951 constant product price. Land productivity refers to the average output produced per cultivated land hectare, labor productivity is on per worker basis and capital per 1951 N.T. dollar. During the period of 1946-65, the average output per hectare of cultivated land increased from NT$2,396 to NT$10,101 at the 1951 constant price. Its productivity grew at the rate of 7.86 percent per year. This is mainly due to the expansion of crop land area as well as the effect of more intensive cultivation. More labor and capital have been invested on land

Figure 4. Factor Productivity



* Including cultivated land, Labor workers and total capital input.
Source: From Table 1.

resource in order to promote the yield. As mentioned previously, cultivated land in Taiwan expanded about 60,000 hectares, however, the crop area expanded by more than 700,000 hectares during the 20 years postwar period. Aside from the expansion of crop land area, unit yield almost doubled during the same period. An explanation in detail will be made in a later section.

Labor productivity used here refers to the average output per agricultural worker. It is estimated that there were about 1.5 millions of agricultural workers in 1946, and it grew to 1.8 millions in 1965, an increase of about 17,000 persons a year. The annual output per worker was NT$1,282 in 1946 and climbed to NT$4,814 in 1965 at the 1951 constant price. In other words, productivity per agricultural worker grew at a rate of 7.21 percent per year during the postwar period. If the labor productivity is measured in terms of working day instead of labor worker, then the productivity per manday increased at the rate of 4.12 percent a year during the same period. The total labor input was about 140 million mandays in 1946 and rose to about 291 million mandays in 1965. The annual growth rate of agricultural workers and that of labor working days were 0.95 percent and 3.92 percent respectively during the period under review. In other words, more working opportunities have been created in agriculture itself.

Capital productivity shows not much changes as land and labor productivities in the period. Except for the three beginning years, the average productivity hovered around NT$2.0 to NT$3.0 per dollar invested. However, during the period under review, capital investment in agriculture increased by three times in constant prices from NT$992.2 million to NT$2,944.7 million as shown in Table 10.

Separate accounts have been made above on the productivity changes in different factors. During the 20-year period, the largest increase was registered by land productivity, then labor productivity and capital productivity showed an increase of 2.22 percent per year.[9]

Table 15. Labor Productivity and Its Contributing Factors

Year	Index of Labor Productivity (Y/L)	Index of Capital Productivity (Y/K)	Index of Capital Intensity (K/L)	Index of Land-labor Ratio (L/N)
1946	100.00	100.00	100.00	100.00
1947	119.49	101.99	121.71	96.07
1948	142.41	96.02	153.14	96.82
1949	166.82	100.00	177.20	94.21
1950	180.92	106.47	180.80	94.02
1951	181.67	106.97	179.97	94.58
1952	199.55	113.93	185.41	94.39
1953	228.93	123.88	198.57	92.90
1954	228.63	119.40	205.62	93.08
1955	231.93	119.90	205.62	94.02
1956	249.74	120.40	217.43	95.33
1957	275.53	123.88	233.19	95.51
1958	298.75	130.85	235.71	96.82
1959	296.10	133.33	235.04	94.39
1960	288.86	133.33	233.53	92.52
1961	309.62	125.37	269.40	91.59
1962	311.52	124.88	275.36	90.47
1963	314.08	125.87	269.32	88.97
1964	334.00	141.29	271.08	88.60
1965	375.38	151.74	277.45	89.16
Annual rate of change	7.21	2.22	5.52	−0.60

Source: Computed from Tables 4, 7, 9, and 10.

9) If farm-produced fertilizers were excluded from capital input, the total capital investment in Taiwan would incease five times from NT$ 443.3 million to NT$ 2,289.5 million durig 1946-65, and its productivity hence showed a decrease of 0.71 percent per year.

The factor productivities discussed so far are average productivity. However, the magnitude of a factor productivity depends on not only the quantity of the factor used but also the quantity of other resources with which it is used. Therefore, more attention should be given to the relationships among factors. The relationships between labor productivity and capital productivity are to be examined here. Land productivity and its contributing factors will be discussed in the following section.

Labor productivity, particularly per worker, is usually conceived as an important indicator of the level of economic progress. As labor resource is theoretically considered as a primary factor of production which can be distinguished clearly from capital in the form of intermediate goods and land as a natural factor, it is necessary to analyze the changes in productivity per agricultural worker in relation to that of capital and land.

As stated previously, the productivity of a factor depends not only on quantity of the specific factor employed but also on quantity of other resources used. Therefore, labor productivity will be influenced by the amount of capital investment per laborer as well as the magnitude of labor-land ratio. This relationship can be shown by symbols. Let Y be the aggregate farm output, L, N, and K stand for land, labor and capital inputs respectively. Then Y/L, Y/N and Y/K will represent the factor productivities as defined above. Labor productivity can be expressed in the following form:

$$Y/N = (Y/L)\ (L/N)$$

Similarly, land productivity can be written as:

$$Y/L = (Y/K)\ (K/L)$$

Combining these two plain relations, the result is simply:

$$Y/N = (Y/K)\ (K/L)\ (L/N),$$

where L/N stands for cultivated land area per agricultural worker, K/L indicates the capital investment per unit of land or capital intensity, and L/N the land-labor ratio. Labor productivity per worker equals to the product of capital productivity, capital intensity and land area per worker. Recall that labor productivity per agricultural worker increased at a rate of 7.21 percent per year during the period of 1946-65, capital productivity increased at an annual rate of 2.22 percent, capital investment per unit of cultivated land increased rapidly at a rate of 5.52 percent a year, while the cultivated land per agricultural worker decreased at the rate of 0.60 per year during the same period. Based

on these arithmetics, the rapid rise of capital intensity (K/L) is the main contributing factor to the increase in labor productivity during the postwar period. In spite of the decrease in land-labor ratio, labor productivity can still be increased through capital investment on land. Therefore, under the condition of limited land resource and abundant labor workers in Taiwan's agriculture, increase of capital investment in agriculture is one of the effective means to increase the level of labor productivity as well as land productivity. However, in order to make capital investment profitable, new technology in agricultural production and new resource must be discovered and developed.

V. Technological Changes in Agriculture of Taiwan

Changes in agricultural production are brought about by either changes in input used or changes in factor productivity as a result of technical changes in agriculture. If the production function is truly homogeneous of degree one and remain constant over time, the changes in the level of output can then be fully accounted for by the changes in factors used. The aggregate output index can be, therefore, expressed by the aggregate input index. However, since the aggregate production function shifts up and down due to the technical change over time, production function should be defined in a dynamic form.

By using a dynamic production function, Professor Solow has made an ingeneous contribution to the analysis of technical change.[10] The mathematical formulation underlying the Solow method will be summarized below.

Let Q represents output and K and L represent capital and labor inputs respectively, then the dynamic production function can be written as:

$$Q = F(L, K; t) \qquad (1)$$

The variable t for time appears in F to allow for technical change. Technical change (t) is defined broadly to express any kind of shift in the production function. In the case of *neutral* technical change, i.e., shift in the production function leaves the marginal rate of substitution among factor inputs unchanged, then the production function (1) takes the form:

$$Q = A(t)\ f(L,K) \qquad (2)$$

10) Robert M. Solow: "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics.* Aug. 1957, pp. 312-320.

Differentiate (2) totally with respect to t and then divide by Q, and one obtains:

$$\frac{\dot{Q}}{Q}=\frac{\dot{A}}{A}+A\frac{\partial f}{\partial L}\frac{\dot{L}}{Q}+A\frac{\partial f}{\partial K}\frac{\dot{K}}{Q}, \qquad (3)$$

where dots indicate time derivatives. Now define a and b as $\frac{\partial Q}{\partial L}\frac{L}{Q}$ and $\frac{\partial Q}{\partial K}\frac{K}{Q}$, the production elasticity of labor and capital respectively, and substitute into (3), obtaining the following result:

$$\frac{\dot{Q}}{Q}=\frac{\dot{A}}{A}+a\frac{\dot{L}}{L}+b\frac{\dot{K}}{K} \qquad (4)$$

If all factor inputs are assumed to be paid at their marginal products and the production function be a linear homogeneous, then for empirical estimation, a and b can be replaced by the observed relative factor shares, and a series of annual measures of technical change can be then derived from (4). Let $\overline{Q}$, $\overline{K}$, $\overline{L}$ and $\overline{A}$ stand for annual rates changes of Q, K, L and A respectively, and a and b be the weights assigned to L and K, then the annual rate of technical change can be expressed as follows:

$$\overline{A}=\overline{Q}-a\overline{L}-b\overline{K}.$$

Taking into consideration of technical change over time, the form of static production function (3) assumed in the previous section cannot still be the form as:

$$Y=AL^a\ N^b\ K^c.$$

Instead, it must be expressed in a dynamic form in the case of neutral technical change as:

$$Y_t=A(t)\ L_t^a\ N_t^b\ K_t^c \qquad (5)$$

A(t) represents any kind contribution of technical change to output at time t. Let r be the rate of technical change in discrete approximation, then equation (5) can be written as:

$$Y_t=A(o)\ (1+r)^t\ L_t^a\ N_t^b\ K_t^c \qquad (6)$$

Dividing (6) by Y_o, the base year output, one obtains the output index, X_t, which can be written as:

$$X_t=\frac{Y_t}{Y_o}=(1+r)^t\left(\frac{L_t}{L_o}\right)^a\left(\frac{N_t}{N_o}\right)^b\left(\frac{K_t}{K_o}\right)^c$$

or $$X_t = (1+r)^t \cdot I_t, \qquad (7)$$

Where I_t is the aggregate input index as defined previously. Therefore, changes in output is apparently due to changes in technology and changes in factor inputs. In the absence of technical change, the aggregate input index is expected to be equal to the *expected* output index, X_{et}. In symbols, it is

$$X_{et} = I_t$$

Now let Y_{et} stands for expected output in the year t, then the difference between the actual observed output and the expected output measures this part of the observed output that is left unexplained by the changes in conventional inputs. In symbols, it can be expressed as follows:[11]

$$Y_t - Y_{et} = Y_t - I_t\ Y_o \qquad (8)$$

where Y_o is the output at the base year. From (8) the *unexplained* output series due to technical change defined broadly can be calculated and the rate of technical change, r, can also be obtained from equation (7). The empirical results are shown in Tables 16 and 17.

Recall that during the period 1946-1965, land input increased at an average rate of 0.35 percent per year, labor input measured in total number of workers grew 0.95 percent per year, and capital 5.89 percent. Increase in the aggregate input is at an average rate of 3.26 percent per year. Therefore, the rate of growth in agricultural output is also *expected* to be 3.26 percent per year in the absence of technical change. However, the actual observed growth rate of agricultural output during the period under review is as high as 8.25 percent per year. The difference between the actually observed and the expected rate of growth in agricultural output, 4.99 percent per year, can be attributed to "technical change." In other words, it appears that of the 8.25 percent annual growth in agricultural output during the period, 60.48 percent (4.99 of 8.25 percent) is due to the changes in technology, and the remaining 39.52 percent is attributed to the increases in inputs used.[12]

11) It is to be noted here that $Y_{et} = I_t \cdot Y_o$

12) The expected output series used here is calculated by multiplying the base year output by the aggregate input index which is constructed on the basis of the geometric formula as explained in the previous section. If the arithmetic formula is used in constructing the aggregate input index, then the growth rate of the expected agricultural output would be only 4.34 percent per year instead of the 3.26 percent based on the geometric formula. Therefore, the discrepancy between the observed output and the expected output based on the arithmetic formula becomes smaller than that based on the geometric formula. Therefore by the arithmetic formula, 47.39 percent of the annual growth rate of the actual output would be attributed to the technical changes and only 52.61 percent to the changes in factors used.

Table 16. Observed, Expected and Unexplained Output 1946-1965

(Unit: Millions of NT$ in 1951 constant price)

Year	Observed Output Y_t	Expected Output $Y_{et}=I_t \cdot Y_o$	Unexplained Output Y_t-Y_{et}
1946	1,993.7	1,993.7	0
1947	2,485.6	2,234.7	250.9
1948	3,041.7	2,578.8	463.7
1949	3,672.6	2,804.9	067.7
1950	4,015.5	2,852.3	1,163.2
1951	4,025.6	2,850.7	1,174.9
1952	4.438.6	2,901.2	1,537.4
1953	6,149.5	3,005.7	2,143.8
1954	5,141.7	3,060.3	2,081.4
1955	5,166.4	3,046.1	2,120.3
1956	5,502.5	3,122.9	2,379.6
1957	6,041.0	3,218.8	2,822.2
1958	6,530.1	3,254.3	3,275.8
1959	6,602.8	3,262.9	3,339.9
1960	6,499.4	3,245.3	3,254.1
1961	7,070.5	3,505.9	3,564.6
1962	7,192.0	3,559.1	3,632.9
1963	7,384.3	3,547.6	3,836.7
1964	8,113.1	3,604.2	4,508.9
1965	8,985.7	3,668.4	5,317.3
Annual growth rate	8.25	3.26	

Source: The observed output series, Yt, is taken from Table 4; input index, It, from Table 13 based on the geometric formula, Yo=NT$1,993.7 million.

As shown in Table 16, the difference between the observed and expected output is getting larger all the time, and the portion of the observed output which can be accounted for by the changes in any kind of technical improvements was registered to be 59 percent in 1965 as shown in Table 17. The technology index, A(t), is also shown in the table. It appears that the over-all result of technical change broadly defined for the postwar period is an average upward shift of about 4.83 percent per year, and the cumulative upward shift in the production function was about 145 percent during the period under review. Considering the period of recovery and rehabilitation from 1946 to 1952 the average rate of technical progress was 7.34 percent per year. While in the planned period of 1952 to 1965, the technical change was at a rate of 3.02 percent per year. However, the choice of the

Table 17. Percentage of Unexplained Output to Observed Output and Technology Index, A(t)

1946-1965

Year	% of Unexplained Output to Observed Output $(Y_t - Y_{et})/Y_t$	Technology Index A(t)
1946	—	100.00
1947	10.10	111.23
1948	15.25	118.50
1949	23.63	130.94
1950	28.97	140.78
1951	29.18	141.21
1952	34.64	153.00
1953	41.63	171.33
1954	40.80	168.01
1955	41.04	169.60
1956	43.25	176.20
1957	46.72	187.68
1958	50.17	200.66
1959	50.58	202.36
1960	50.07	200.27
1961	50.42	201.68
1962	50.51	202.07
1963	51.96	208.15
1964	55.58	225.11
1965	59.18	244.95
Annual growth rate		4.83

* A(t) can be obtained by the following procedure: In equation (7),

$$\frac{Y_t}{Y_o} = (1+r)^t I_t$$

Let $Y_{et}=I_t \cdot Y_o$ as the expected output, then the above equation can be rewritten in the following form:

$$\frac{Y_t}{Y_{et}}=(1+r)^t$$

By setting $A(o)=100$ and using the relation $A(t)=A(o)(1+r)^t$, one can successively derive A(t) series as shown here.

Source: Computed from Table 16.

period for comparison is significant. For example, in the planned period if 1951 is taken as the base year instead of 1953, then the average annual rate of technical change would be 3.68 percent instead of 3.02 percent. Table 18 summarizes the rates of technical progress for different alternative choices of

Table 18. Rates of Technical Progress for Different Periods

Period	Compound Rate of Technical Progress	Period	Compound Rate of Technical Progress
1946—65	4.83%	1952—56	3.59%
1946—52	7.34%	1956—60	3.25%
1953—65	3.02%	1960—63	2.96%
1952—65	3.68%	1964—65	8.80%

Source: The rate of technical process computed from the formula:
$A(t)=A(o)(1+r)^t$.

period for the purpose of comparison.

As repeatedly explained before, land resource is the most limiting factor in Taiwan's agriculture. Both remarkable expansion of crop area and multiple cropping have played very important roles in the agricultural development of Taiwan. Crop area increased by 72 percent during the entire period, while the multiple cropping index rose from 118 in 1946 to 190 in 1965, an increase of 61 percent or at a rate of 2.53 percent a year. Aside from the expansion of crop area and the intensity of land utilization, growth in agricultural output would not have been possible at such a rapid rate in Taiwan without the considerable improvement in crop yield. Index of crop yield per unit of land climbed up by 96 percent during the postwar period, and increased at a rate of 3.63 percent per year. Among various groups of agricultural products, the unit yield of fruits went up rapidly by about 171 percent or at a rate of 5.39 percent per year during the period of 1946-65. Next come the special crops which recorded an 138 percent increase with an annual growth rate of 4.67 percent. Food crops also showed a 90 percent increase during the period. The details are shown in Table 19.

The indices of major crop yields shown in Table 19 indicate the yield per unit of crop area. The yields of major crops are shown in Table 20. All the major crops listed in the table have shown significant improvement in yields during the period and all have surpassed the peak level attained in the prewar period. The yield per hectare of brown rice in 1965 was higher than that in the prewar peak by 36 percent, yield of sweet potato 4 percent, 20 percent for peanut, 51 percent for wheat, 90 percent for soybean, 45 percent for tea, 46 percent for pineapple, 18 percent for banana and 8 percent for sugarcane.

Table 19*. Indices of Crop Yield, 1946-1965

Year	Food Crops	Special Crops	Fruits	Vegetables	All Crops
1946	100.00	100.00	100.00	100.00	100.00
1947	97.93	90.92	151.03	91.74	98.37
1948	98.42	115.97	133.32	90.96	102.73
1949	105.47	140.52	126.52	87.63	111.73
1950	117.81	131.45	136.90	87.32	118.73
1951	118.00	131.24	133.62	86.09	118.56
1952	124.73	144.03	132.64	87.98	125.74
1953	131.59	183.76	144.44	88.92	138.72
1954	137.41	170.40	141.11	88.40	139.86
1955	135.22	194.70	158.77	90.13	144.03
1956	145.02	183.24	145.41	90.96	147.92
1957	149.67	191.24	163.51	93.93	153.67
1958	156.65	196.41	170.10	94.12	159.70
1959	154.27	209.83	169.86	93.72	160.66
1960	159.36	193.32	185.92	96.24	161.80
1961	166.27	211.02	190.26	99.29	170.33
1962	169.73	194.70	197.98	99.40	169.82
1963	168.94	202.43	196.71	99.23	170.78
1964	185.21	211.31	252.10	102.64	186.23
1965	190.30	238.33	271.28	108.35	196.27
Annual Growth Rate	3.45	4.67	5.39	0.43	3.63

* Crop yield index was calculated by weighted arithmatic average of individual crop. Total value of each crop product in 1951 was used as the weights.

Source: Computed from *Taiwan Agricultural Year Book*, PDAF, Taiwan Provincial Government, 1952, 1958, and 1966 editions.

The rises in crop yield are made possible through the propagation and distribution of seeds of superior varieties, the increasing application of chemical fertilizers, pesticides and insecticides as well as the improvement in irrigation facilities and changes in farm practices.[13]

The relationships among land productivity, multiple cropping index and crop yield can now be examined. From what has been discussed previously, it should be clear that the fundamental factors increasing the land productivity in Taiwan lies in the intensified degree of land utilization and rises in yield per

13) In his 1964 book of *Agricultural Development on Taiwan Since World War II*, Dr. T. H. Shen, Chairman of JCRR and plant breeder by profession has written in details the technical achievements in Taiwan's agriculture in the last one and one half decades.

Table 20. Yields of Major Crops in Taiwan

Unit: kg per hectare

Year	Brown rice	Sweet potato	Peanut	Wheat	Soybeans	Tea	Pineapple	Banana	Sugarcane
Peak befor the War*	2,242	12,829	1,008	1,396	650	380	14,251	14,016	79,039
1946	1,585	7,558	736	659	487	82	5,458	5,235	27,801
1952	1,998	8,953	741	1,139	602	263	10,730	6,811	49,003
Average of 1953-56	2,182	10,238	740	1,266	678	286	12,360	7,430	71,837
Average of 1957-60	2,417	12,535	956	1,815	849	335	16,047	8,319	74,624
Average of 1961-64	2,747	12,413	1,035	1,834	984	477	18,750	10,657	71,364
1965	3,038	13,377	1,214	2,113	1,236	551	20,830	16,478	85,730

* Taken from *Taiwan Agricultural Statistics, 1901-1955*, by JCRR, Taipei, Taiwan, 1956.

Source. *Taiwan Agricultural Year Book*, PDAF, Taiwan Provincial Government, 1952, 1958 and 1966 editions.

unit of crop area. The raise of multiple cropping index and crop yield through more intensive land utilization will be the only practical way to increase agricultural production since land is a limited resource in Taiwan. During the 20 years from 1946 to 1965 under review, the average annual growth rate of yield per crop area was 3.61 percent, and multiple cropping index, 2.53 percent. The increase of multiple cropping index and the high growth rate of unit yield accounted for a greater land productivity which showed an annual growth rate of 7.87 percent during the postwar period. However, taking the recent decade into consideration, the expansion of crop area was not so much as that in the early part of the period under review. For example, the multiple, cropping index increased by 46 percent in 1946-52, and only 10 percent in 1952-65, while the index of crop yield increased by 26 percent in 1946-52 and 56 percent in 1952-65. This suggests that the enhanced land productivity during the postwar period was due mainly to the increases in the unit crop yield.

It would be interesting to know the effects on agricultural output by the intensified degree of land use through expansion of crop area. It is to be noted here that the method and procedure used above in deriving the aggregate input index make no allowance for the changes in degree of intensity of land utilization through crop area expansion. Cultivated land area taken as an input in constructing the aggregate input index reflects only the expansion of cultivated land area. It takes no account of the intensive use of the same piece of land

in the year. Thus, if crop area, which measures both cultivated land area and the frequency of its utilization, is taken as the land input in making the aggregate input index, then thus derived aggregate input index will indicate the changes in both extensive and intensive use of land. The difference between these two indices will then represent the effect of changes in intensive use of land through the increase in multiple cropping index.

Let I'_t represents the new aggregate input index by using crop area as land input, then as explained above, in the absence of technical change. As what we have indicated previously,

$$X_t = I_t$$

or $$Y_{et} = I_t \cdot Y_o$$

similarly, $$Y'_{et} = I'_t \cdot Y_o$$

i. e., the expected output in year t is equal to the aggregate input index with land input measured in terms of crop area multiplying by base-year output. Then it follows that:

$$Y'_{et} - Y_{et} = (I'_t - I_t) \cdot Y_o , \qquad (9)$$

where $Y'_{et} - Y_{et}$ represents the expected output due to the changes in the intensity of land use expressed in increases of multiple cropping index.[14] The empirical results are shown in Table 21. By comparing the increase in output due to land intensity as shown in Table 21 to the unexplained output shown in Table 16, the proportion of unexplained output due to the changes in intensified degree of land use can then be estimated.

As shown in Table 22, the proportion of unexplained output can be accounted for by the changes in intensive use of land resource has shown a decreasing trend during the postwar period. In the beginning of the period under review, 13.8 percent of the unexplained output was due to the changes in the degree of land use. It dropped down to only 4.7 percent in the period of 1960-65. This is consistent with what has been presented above that the enhanced agricultural output after World War II is mainly due to the increases in crop yield, rather than the land intensity through changes in multiple

14) Using the symbols defined above, it is clear that $Y_t - Y_{et}$ represents a part of output unexplained by taking *cultivated* land as factor input, while $Y_t - Y'_{et}$ stands for unexplained output in terms of using *crop area* as land input. Therefore, the difference between these two "unexplained" outputs as shown in (9) measures the effect of changes in multiple cropping index.

cropping index.

Table 21. Unexplained Output Due to Changes in Intensity of Land Use

Year	Aggregate Input I'_t	Aggregate Input I_t	Increase in Output Due to Land Intensity $Y'_{et}-Y_{et}$ (In million of NT$)
1946	100.00	100.00	0
1947	114.58	112.08	50
1948	133.49	129.30	84
1949	146.30	140.68	112
1950	149.20	143.06	122
1951	149.03	142.98	121
1952	151.90	145.51	127
1953	157.43	150.75	133
1954	160.43	153.49	138
1955	159.42	152.78	132
1956	163.89	156.63	145
1957	169.30	161.44	157
1958	171.28	163.22	161
1959	171.90	163.65	164
1960	171.19	162.77	168
1961	185.20	175.84	187
1962	187.91	178.51	187
1963	187.29	177.93	187
1964	190.45	180.77	197
1965	194.22	183.99	204

Source: See the text.

Table 22. Proportion of Unexplained Output Assignable to Land and Labor Intensities

Period	Proportion	
	Land*	Labor
1948–50	13.8%	10.93%
1951–55	7.5%	16.81%
1956–60	5.3%	22.17%
1960–65	4.7%	22.07%

* Calculated by the following formula:

$$(Y'_{et} - Y_{et}) \div (Y_t - Y_{et})$$

Source: Computed from Tables 16 and 21.

Similarly, in the construction of the aggregate input index (I_t) shown in Table 11, the number of total agricultural workers was used as labor input which makes no allowance for the changes in degree of intensity of labor utilization. Conceptually, the increases of rate of utilization of Taiwan's farm labor could be considered as the result of technical progress. If the total number of working days of farm labor was taken as labor input instead of number of workers, then thus derived aggregate input index will reflect not only the number of workers but also the intensive use of labor workers. The difference between these two indices will then represent the effect of changes in rate of labor utilization through the general technical progress. The empirical results are shown in the last column of Table 22. The proportion of unexplained output can be accounted for the changes in intensive use of agricultural workers has shown an increasing trend during the postwar period. In the beginning of the period, only 10.93 percent of the unexplained output was due to the changes in the degrees of labor use. It increased to 22.07 percent in the period of 1960-65. In other words, the expansion of working opportunity of farm labor after World War II has played an important role in the enhanced agricultural output, rather than the increase of total number of agricultural workers.

VI. Summary

The agricultural output index based on the 1951 constant price as constructed in this paper indicates an annual average growth rate of 8.25 percent during the postwar period 1946-65. During the period of reconstruction, 1946-52, there was an average annual growth rate of 14.27 percent, and the average rate of 4.75 percent for the period of 1953-65. By 1952, agricultural output had caught up with the peak record at 1939 before World War II. Changes in the composition of agricultural output reflect both the supply shift as well as the changes in demand conditions for agricultural products. Agricultural products with high income elasticites, such as fruits, livestock and poultry products, and special crops have gained in relative shares of total production.

The gain of agricultural output can be explained partly by looking at the aggregate measure of inputs and partly by the changes in technological advancement broadly defined. Land input in terms of cultivated area increased by only 7 percent during the whole period from 1946 to 1965. However, crop land area expanded by 72 percent during the same period. A significant change

in land utilization through a more intensive use of land took place during the postwar period. Methods of intensive farming included multiple cropping, increasing the density of plants and animals per hectare, and development of more rapidly maturing varieties and inter-tillage as well as improvement of irrigation facilities. Measured in labor working days required by crops and livestock and poultry production, labor input increased by 108 percent during the period under review. The number of agricultural workers gained only 20 percent during the same period. A comparison of the number of agricultural workers with labor input (mandays) indicates that the agricultural labor force worked more days per year as the intensity of land use increased. Capital input consists of chemical and farm-produced fertilizers, feed, seed, pesticides and insecticides, depreciation of buildings and farm equipment and water fee also showed a rapid increase by about 3 times during the postwar period. Taking into consideration of all factor inputs together, the aggregate input index, which contains cultivated land area, labor workers and capital, increased at an average rate of 3.26 percent per year. Under the particular method employed and assumptions made in this study, the aggregate input index also represents the output index in the absence of technical change.

By comparison between the output index and the aggregate input index, it has been found that the average productivity of aggregate input gained by 103 percent from years 1946 to 1965, an average rate of 3.79 percent per year. The notable features in Taiwan's agriculture were the sharp rises of land productivity which shot up by about 300 percent and the productivity of labor measured in terms of working days climbed by 110 percent, while the productivity per worker increased at a faster rate by 275 percent during the postwar period. That is, capital input coupled with intensified land use allowed farmers to work harder and more effectively. However, capital productivity showed only an increase by 2.22 percent per year during the same period.

In addition to the increases in factor inputs, changes in agricultural output in Taiwan is also brought about partly by the technological change defined broadly. Based on the method employed and assumptions made, it is estimated that the rate of technical change averaged about 4.83 percent per year, and the cummulative upward shift in the production function was 145 percent during the whole period 1946-65. As explaind above, the difference between actual output and expected output of growth in agriculture, 4.99 per year, can be attributed to technical changes broadly interpreted. In other words, of the 8.25

percent annual growth in output, about 60 percent is due to the changes in technology, and the remaining 40 percent can be attributed to the increase in inputs used.

The intensification of land utilization and the gain in the crop yields have played a very important role in agricultural development in Taiwan. During the period under review, crop area increased by 72 percent and the multiple cropping index increased by 61 percent. Irrigation was the critical factor affecting land utilization and multiple cropping since rainfall in Taiwan is not distributed uniformly throughout the year. In addition to the expansion of irrigation facilities, varietal improvement in seeds and greater application of fertilizers are important factors to raise yield per unit of crop area. The aggregate crop yield per unit of crop land increased by 96 percent during the postwar period, an increase at a rate of 3.61 percent per year. According to the estimates made in this study, about 14 percent of the unexplained output was due to the change in multiple cropping in the beginning of the postwar period, while it dropped to 5 percent at the end of the period. This suggests that the enhanced output depends more and more on gain in crop yield rather than by the changes in multiple cropping during the postwar period.

Economic development is far more than a merely technological or physical transformation of inputs into increasing outputs. The improvement in transportation facilities, public health conditions and the general socio-economic development are important and have served to enhance agricultural development. However, their contributions can not be easily assessed statistically.

Appendix Table A. Agricultural Production in Taiwan 1946-1965

Unit: 1,000 M.T.

Year	Rice	Sweet potato	Wheat	Soybean	Peanut	Sugarcane	Tea	Banana	Pineapple
Prewar peak record	1,402	1,770	7	7	31	11,770	17	219	39
1946	894	1,331	1	4	37	899	3	53	20
1947	999	1,783	4	10	47	297	7	124	25
1948	1,068	2,003	6	12	53	2,359	8	110	28
1949	1,215	2,166	10	12	53	5,442	10	98	27
1950	1,422	2,201	19	13	57	5,270	10	117	28
1951	1,485	2,022	15	13	61	2,849	11	100	27
1952	1,570	2,090	16	15	60	4,274	12	107	28
1953	1,642	2,277	14	17	60	7,857	12	96	29
1954	1,695	2,557	15	20	66	6,130	13	98	28
1955	1,615	2,437	19	24	67	5,802	15	85	30
1956	1,790	2,568	27	26	82	5,062	13	59	35
1957	1,839	2,693	36	33	94	6,916	15	92	39
1958	1,894	2,958	40	42	96	7,253	16	111	42
1959	1,856	2,894	43	44	97	7,862	17	104	43
1960	1,912	2,979	46	53	102	6,436	17	114	53
1961	2,016	3,234	44	54	105	7,655	18	130	55
1962	2,113	3,080	42	53	95	5,856	20	135	67
1963	2,109	2,148	19	53	91	6,064	21	132	79
1964	2,247	3,348	20	58	116	6,407	18	268	102
1965	2,348	3,131	24	66	126	9,178	21	452	114

Source: From *Taiwan Agricultural Year Book*, Provincial Department of Agricultural and Forestry (PDAF), Taiwan Provincial Government, 1952, 1958, and 1966 editions

Appendix Table B. Capital Input, 1946-1965

In Million of NT$ and in 1951 Price

Year	Fertilizer		Seeds	Pesticides and insecticides	Feeds	Draft cattle	Depreciation	Irrigation fees	Total	Index
	Chemical	Farm Produced								
1946	15.3	548.9	138.5	6.2	144.0	42.9	3.11	65.3	992.2	100.00
1947	69.4	521.1	170.0	9.5	222.6	45.7	103.6	68.9	1,210.8	122.03
1948	67.6	869.8	198.0	4.8	241.1	47.6	76.5	71.4	1,576.8	158.91
1949	115.5	809.1	218.4	12.8	272.6	54.9	272.7	72.4	1,828.4	184.28
1950	228.4	750.2	223.5	18.1	325.7	46.8	211.4	73.4	1,877.5	189.32
1951	263.8	743.9	217.3	16.7	367.3	57.5	136.3	73.5	1,876.3	189.10
1952	337.0	748.5	222.0	14.6	363.3	58.8	120.9	72.5	1,937.6	195.28
1953	375.7	729.1	225.6	18.8	455.0	59.9	128.8	73.5	2,066.4	208.26
1954	443.9	689.8	227.6	31.4	488.6	62.3	128.4	72.3	2,144.3	216.12
1955	424.0	703.7	223.1	47.5	484.5	63.2	123.5	71.8	2,141.3	215.81
1956	471.2	744.0	228.9	43.0	521.7	63.5	126.1	73.8	2,272.2	229.01
1957	497.3	789.4	238.6	54.6	581.6	63.5	130.4	74.0	2,429.4	244.85
1958	527.0	755.5	242.4	72.5	615.9	64.1	132.7	74.2	2,484.3	250.38
1959	522.4	752.6	242.0	77.4	605.1	64.2	123.7	73.6	2,461.0	248.03
1960	439.5	702.1	247.4	104.3	667.3	64.2	122.0	74.6	2,421.4	244.04
1961	526.7	869.6	246.4	123.7	775.2	63.8	122.4	74.3	2,802.1	282.41
1962	554.9	902.0	245.3	157.6	736.4	62.4	130.8	74.7	2,864.1	288.66
1963	580.5	851.4	250.2	177.5	684.6	60.0	125.2	73.3	2,802,7	282.47
1964	659.5	628.6	254.9	225.7	817.8	58.4	133.0	74.8	2,852.7	287.51
1965	581.3	655.2	261.1	268.3	899.2	57.0	146.4	76.2	2,944.7	296.78

Source: Estimated by Rural Economics Division, JCRR, Taipei, Taiwan.

Appendix Table C. Fertilizer Consumption in Taiwan 1946-1965

Year	Total Consumption* 1,000 M. T.		Consumption per crop hectare kg.	
	Chemical	Farm Produced	Chemical	Farm Produced
1946	20	6,575	20	6,704
1947	90	6,307	76	5,284
1948	88	10,523	65	7,817
1949	150	9,744	105	6,777
1950	298	8,985	201	6,057
1951	344	8,892	232	5,994
1952	439	8,948	292	5,940
1953	490	8,720	325	5,791
1954	578	8,292	381	5,459
1955	553	8,392	369	5,611
1956	614	8,872	399	5,770
1957	648	8,385	415	5,363
1958	687	8,983	432	5,646
1959	681	8,959	427	5,614
1960	573	8,348	359	5,231
1961	686	10,315	424	6,365
1962	723	10,696	448	6,629
1963	757	10,094	469	6,258
1964	860	7,466	518	4,499
1965	758	7,771	449	4,609

* Refers to Crop year.

Source: Computed from data in *Taiwan Statistical Data Book,* CIECD, 1966 and *Taiwan Agricultural Year Book,* Provincial Department of Agricultural and Forestry (PDAF), Taiwan Provincial Government, 1966.

Appendix Table D. Quantity of Seeds Consumed by Major Crops 1946-1965

Unit: 100 Metric ton

Year	Rice	Sugarcane	Wheat	Peanut
1946	303	1,073	1	102
1947	361	4,987	3	130
1948	377	7,542	5	147
1949	395	7,513	8	154
1950	415	5,907	11	167
1951	429	7,363	9	170
1952	419	5,271	9	162
1953	432	5,375	8	165
1954	426	1,799	7	188
1955	418	2,866	8	192
1956	437	3,816	7	197
1957	441	1,673	12	207
1958	431	2,691	14	208
1959	441	2,315	14	198
1960	436	2,999	15	201
1961	437	2,669	13	197
1962	451	2,759	12	193
1963	445	4,422	10	195
1964	443	3,400	6	202
1965	454	3,116	7	207

Source: Computed by multiplying the average quantity of seed used per hectare by the crop area each year.

Appendix Table E. Quantity Imported of Pesticides and Insecticides 1957-1965

Unit: Metric ton

Year	Insecticides	Pesticides	Incense	H.H.C.	Disinfectant	Total
1957	—	—	—	—	—	460.5
1958	—	—	—	—	—	122.1
1959	—	—	—	—	—	550.8
1960	546.6	217.5	31.3	36.2*	36.1	867.7
1961	793.4	212.7	37.0	2.7	4.6	1,050.6
1962	803.7	332.1	42.8	1.7	11.1	1,191.4
1963	605.8	293.7	61.9	0.5	13.8	975.7
1964	1,341.1	596.4	86.5	1.1	15.3	2,043.4
1965	2,160.7	704.6	77.0	12.0	29.6	2,983.9

* D. D. T.
Source: Statistics of Trade Compiled by Inspectorate General of Customs, Taiwan, China.

Appendix Table F. Value of Pesticides and Insecticides Imported in Taiwan, 1957-1965

Unit: 1,000 U.S.$

Year	Value of Imports*	Exchange Settlement**
1957	783	1,016
1958	177	442
1959	754	693
1960	1,123	1,176
1961	1,289	1,550
1962	1,589	1,726
1963	1,333	1,794
1964	2,725	3,462
1965	4,240	4,708
Total	14,212	16,559

Source: * Statistics of Trade. By Inspectorate General of Customs.
** Foreign Exchange Statistics by Bank of Taiwan.

Appendix Table G. Consumption of Feeds in Taiwan, 1946-1965

Unit: 1,000 Metric Ton

Year	Rice	Sweet potato	Wheat bran	Bean cake	Rice bran	Corn	Cassava
1946	17.9	147.7	0.3	8.7	54.4	2.9	18.5
1947	30.0	789.0	1.9	10.1	60.7	3.1	44.5
1948	32.0	893.8	1.9	9.9	65.0	2.8	34.1
1949	36.4	969.7	3.3	12.7	73.8	2.0	50.0
1950	56.9	988.5	6.2	22.0	86.4	2.5	44.9
1951	74.2	899.8	9.0	37.8	90.3	2.4	44.4
1952	62.8	933.2	5.6	39.7	95.5	2.6	43.7
1953	65.7	1,024.3	28.9	58.6	99.8	3.0	51.4
1954	67.8	1,159.6	47.1	50.2	103.1	4.1	46.9
1955	64.6	1,100.9	44.6	56.7	98.2	3.5	58.5
1956	71.6	1,173.6	53.5	56.4	108.8	5.3	54.3
1957	73.5	1,236.9	70.4	66.0	111.8	8.9	60.0
1958	75.8	1,369.2	67.9	72.1	115.2	7.3	69.9
1959	74.3	1,338.4	64.5	71.3	112.9	12.7	66.3
1960	76.5	1,376.3	80.6	86.3	116.3	10.7	71.5
1961	80.7	1,665.3	77.4	112.1	122.6	13.4	101.5
1962	83.7	1,581.6	73.9	98.2	128.5	14.6	100.6
1963	82.9	960.9	97.2	98.9	128.2	24.8	97.6
1964	87.8	1,723.1	75.0	112.9	136.6	31.6	108.8
1965	90.9	1,609.7	100.0	125.9	142.8	79.2	119.1

Source: Estimated from data in "Taiwan Food Balance Sheet", JCRR, 1946-1966.

Appendix Table H. Number of Draft Cattle in Taiwan 1946-1965

Unit: Head

Year	Buffalo	Yellow and Hybrid Cattle	Total
1946	230,679	48,037	278,716
1947	245,553	50,921	296,474
1948	254,814	54,543	309,357
1949	294,645	61,679	356,324
1950	293,543	70,167	363,710
1951	300,123	73,465	373,588
1952	311,103	71,002	382,105
1953	315,261	73,613	388,874
1954	325,861	78,659	404,520
1955	328,553	81,681	410,234
1956	329,829	82,611	412,440
1957	328,844	83,502	412,346
1958	328,915	87,453	416,368
1959	326,587	90,572	417,159
1960	324,516	92,606	417,122
1961	318,162	96,046	414,208
1962	308,921	96,135	405,056
1963	292,640	96,808	389,448
1964	282,242	96,831	379,073
1965	273,090	97,280	370,370

Source: Computed from *Taiwan Agricultural Year Book*, PDAF, Taiwan Provincial Government, 1952, 1958, and 1965 editions.