The Development of Technology in Taiwanese Agriculture

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I. Introduction

This paper is basically concerned with determining the bias[1] of technical innovation in Taiwan's agricultural sector during the period 1911 to 1964. This is an important topic for a number of reasons. First, in the literature on the theory of induced innovation it has been argued that during Taiwan's colonial period land saving agricultural technology was transferred from Japan. In addition, following this period it has also been argued that the policies followed by the Taiwanese government fostered the further development of land saving technical innovation. However, no actual empirical determination of bias or its cause has been undertaken. Second, Taiwan's agricultural sector has grown very rapidly and as a result has played an important role in the overall development process. Hence an understanding of the process is useful historically and also possibly to today's developing countries. Finally, in the determination of the bias we will apply a relatively new form of production function.

Section two of this paper will discuss, from a historical perspective, the process of development in Taiwanese agriculture.

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[1]The definition of bias used here will be presented and discussed later in this paper.

Section three will present a brief discussion of a CES production function that incorporates technical change. Several hypotheses concerning technical innovation in Taiwan will also be developed. Section four will present and evaluate the results of the empirical estimation. Finally, section five will summarize the paper.

II. Development in Taiwanese Agriculture

Taiwan's most important natural resource is its agricultural land. However, it is quite limited in quantity as well as quality. Only one-fourth of the area is arable and after centuries of continuous use, the natural fertility of its land is low and diminishing. In 1974 Taiwan had a population of more than 15.8 million and a population density of approximately 440 persons per square kilometer. Taiwan's chief agricultural advantage is its subtropical climate which extends the growing season and allows for the cultivation of several crops a year (Ho, pp. 2-3).

Taiwan shares a number of common characteristics other than high population density with many of today's less developed countries. It is located in the semitropical region of the world and the economy was, until recently, based on the production and export of a small number of primary products. In addition it was from 1895 to 1945 a colony of a more economically advanced nation (Ho). There are, however, some significant differences in Taiwan's development experience relative to today's less developed countries. Specifically, Taiwan benefited from the emigration of skilled labor from the mainland. Also, during the colonial period irrigation was expanded and new seeds and modern inputs were applied to agriculture. After World War II a significant land reform was also carried out which significantly improved equity within the agricultural sector and, perhaps, also productivity.

The study of the development experience of Taiwan is very interesting since Taiwan has been very successful in generating agricultural as well as industrial growth. For example, except for a short-run decrease in agricultural output during World War II, Taiwan experienced a long upward trend in farm production between 1913 and 1964 (Lee and Chen, pp. 60-61). The average annual rate of growth for the entire period was three percent and this significantly exceeded the rate of growth of the rural population. Thus there was a significant increase in the per capita availability of food.

Agricultural development in Taiwan can be divided into two time periods: colonial and post colonial. From the time Taiwan became a Japanese colony the Japanese made significant efforts to develop and apply scientific knowledge to agriculture in Taiwan. As early as 1899 the colonial government allocated funds to operate agricultural experiment stations and in 1903 the Taiwan Agricultural Research Institute was established in Taipei, with agricultural improvement stations in strategic farming districts. At first these research organizations were only loosely related, but after 1921 they were all brought under the supervision of the Central Research Institute (Ho, p. 58).

The 1920s also marked the beginning of rapid growth in Taiwanese agriculture. From 1905 until the late 1920s agricultural growth was relatively slow and seems to have been the result of increases in the utilization of land, labor, working capital, and fixed capital. The technology was traditional in nature in that very few nonagricultural inputs were used and technological change, when it occurred, was based primarily on personal knowledge and experiences (Ho, pp. 56-58). In contrast, from the early 1930s to the 1940s agricultural output grew very rapidly, despite the fact that the land to labor ratio deteriorated.[2] This growth was the result of the rapid technological innovation that began to take place in the early 1920's and was in large part due to the application of agricultural science.

It was in the early 1920s that new high yielding varieties of rice were developed and introduced. Until that time the main improvements in yields stemmed from eliminating inferior natural varieties of rice, but these improvements were not great. The breakthrough came with the successful introduction of the higher yielding Japonica varieties of rice, commonly called ponlai rice. The rapid adoption of the new varieties helped to raise the average rice yield in Taiwan from 1,379 kilograms per hectare in

[2]There has been some controversy on this point. Over the time period under consideration labor did grow faster than arable land. However multiple croping also increased. This has led some observers to argue that the effective land to man ratio remained unchanged.

1911-20 to 1,594 kilograms per hectare in 1921-30 and 1,935 kilograms per hectare in 1931-40 (Ho, pp. 59-60). These increased yields resulted from the ponlai varieties being highly responsive to increased application of fertilizer. However, for the fertilizer to be effective, water must be applied at certain periods in the growth to cycle. Recognizing this, several large irrigation facilities were built in the late 1920's. This combination of a new rice variety and water availability led to the significant increase in the application of commercial fertilizer by Taiwanese farmers (Ho, p. 61).

In order to promote the application of the the new seed and fertilizers institutions were needed to disseminate information and to facilitate the adoption of the new innovations. The Farmers Association, first organized near Taipei in 1900 at the initiative of wealthy farmers and landlords, became such a vehicle. With the active support of the government, within a few years Farm Associations existed in every district. Membership and fees were made compulsory for all farm households. This organization ultimately took charge of the extension of new seed varieties, the maintenance of a seed multiplication system, the prevention and control of animal and plant diseases, the training of agricultural technicians, the execution of agricultural surveys, the purchase of fertilizers, seeds, and equipment needed by members, and the management of warehouses. Supporting the Farmers Association were other organizations such as the Small Agricultural Unit and the credit cooperatives.[3]

However, all of these activities took place in an agricultural sector whose basic structure was not significantly altered. During the entire colonial period the ownership of land remained highly unequally distributed. According to a 1920 survey, the lower 42.7 percent of owners held 5.7 percent of the land while the upper 1.5 percent of the owners held 62.1 percent of the land. Although the ownership of land was very unequal, the operational size of the farm remained small, on the average of 1.97 hectares (Ho, p. 42).

World War II caused a significant drop in agricultural pro-

[3]The small Agricultural Unit was developed to serve as a point of contact between farmers and agricultural exporters, while the credit cooperatives made credit more accessible to the countryside.

duction in Taiwan and also brought an end to Japanese colonialization. By 1951 agricultural output had reattained the prewar peak. From 1952 to the late 1960s agricultural output grew at between 4 and 5 percent a year. Much of this growth was again due to the development and application of new seed varieties and the increased application of commercially produced fertilizers. The government invested heavily in the development and operation of a number of research and experimental institutions. In 1960 the number of agricultural research workers per 100,000 people active in agriculture was 29 in Taiwan. By comparison it was 60 in Japan, 4.7 in Thailand, 1.6 in the Philippines, and 1.2 in India. (Ho, pp. 177-178).

Beginning in the 1960s an increasing number of farm workers moved to other occupations and this generally involved moving to urban areas. This resulted in a labor shortage in the agricultural sector in the latter half of the 1960s. As a result, agricultural wages began to rise significantly (Lee and Chen, p. 43). Farmers responded by using such labor saving devices as power tillers, power sprayers, power thrashers, etc (Shen and Wang, pp. 366-416). In other words, agricultural production became increasingly mechanized and labor saving.

Significant change in the structural organization of agriculture also occurred in the postwar period. An extensive land reform program was carried out between 1949 and 1953. The reform was carried out in three stages: compulsory rent reduction, the sale of public land to actual tillers and the compulsory sale of private land to actual tillers. The land reform significantly reduced the degree of inequality in the rural areas, however the basic operational size of farm units remained about the same (Ho, pp. 159-165).

This brief review of conditions in Taiwanese agriculture allows us to develop a hypothesis concerning the bias of technical innovation. Agricultural technology is usually divided into two types: mechanical and biochemical. Mechanical technology generally allows for the substitution of capital for labor, does not generally increase land productivity, and is characterized by significant economies of scale. Biochemical technologies usually involve the development of new seed varieties which are highly responsive to increased application of fertilizer and water, are yield increasing in nature, and are generally scale neutral. It is often argued that biochemical innovations also lead to applications of labor for weeding and harvesting operations, although there is some disagreement on this issue (Grabowski, pp. 723-734). Given the fact that during both the colonial and postcolonial time period small scale farming dominated Taiwan and that the government's policy was oriented towards the development of fertilizer responsive seed varieties, it is only logical to hypothesize that innovations which allow fertilizer and other forms of working capital to substitute for land (biochemical) would occur in both periods. In addition, it is likely that the increased application of working capital inputs would increase the need for labor. Hence the technology that was employed in Taiwan during this period would seem to be land savings, labor and working capital using. This is the hypothesis that will be tested in this paper.

The time period covered by this study is 1911 to 1964. The year 1964 was chosen as the end date because it was approximately in the mid-1960's that labor shortages began to occur and, as a result, Taiwanese farmers began to mechanize. It is likely, therefore, that after 1965 that innovations encouraged the substitution of fixed capial (machines) for labor. Whether or not this was indeed the case is a possible future research project.

III. VES Production Function and Technical Change

In order to determine the bias of technical innovation in Taiwan, a modified VES production function will be used (Revankar, pp. 61-71). The basic form of the VES function that will be employed is

$$(1) \qquad Y = A(X_1-\gamma X_2)^{\alpha}(X_2-\delta X_1)^{1-\alpha},$$
$$\text{if } (X_1-\gamma X_2) \text{ and } (X_2-\delta X_1) > 0,$$
$$0 \text{ otherwise},$$

where X_1 and X_2 represent two inputs, Y represents outut, $A > 0$, $0 < \alpha < 1$ and it is expected that γ, and $\delta > 0$ (It is to be understood throughout this paper that output and all inputs have a time subscript that is being omitted for clarity). This is slightly different than the traditional VES function since to a limited degree negative marginal products (and a negative elasticity of substitution) are allowed.[4] This difference is due to using the constraint that $(X_1 - \Upsilon X_2)$ and $(X_2 - \delta X_1) > 0$ (or equivalently $\gamma^{-1} > X_2/X_1 > \delta$) instead of the more usual constraint that $((1-\alpha)+\gamma\alpha\delta)/\gamma > X_2/X_1 > (\alpha \div \delta(1-\alpha)\gamma)/\delta$. However, this modification has the advantage of providing a simple test for input congestion (if the marginal product of an input is negative, congestion is indicated).

The modified VES function used in this paper is, as are all VES functions, weakly disposable[5]. Weak disposability is indicated by the parameters γ and δ being greater than zero. This characteristic means that if both inputs increase proportionately, ceteris paribus, output will not decrease, and if one input increases, ceteris paribus, output may decline. This is in contrast to a strongly disposable function where if both inputs increase proportionately, ceteris paribus, output will increase, and if one input increases, ceteris paribus, output will not decrease. Clearly if the parameters γ and δ are both equal to zero, then the VES function reduces to the traditional strongly disposable Cobb-Douglas function. Figure 1 illustrates this point using unit isoquants. The dotted isoquant GH is strongly disposable, i.e., if X_1 is increased then, ceteris paribus, output will not decrease. Thus the marginal products only asymptotically approach zero. In contrast, the weakly disposable isoquant IJ (solid line) is asymptotic to the rays OA and OB (not a vertical or horizontal line) and hence have marginal products that are zero and within the range set by the rays OA and OB become negative. The slope of ray OB is δ and the slope of ray OA is γ^{-1}.

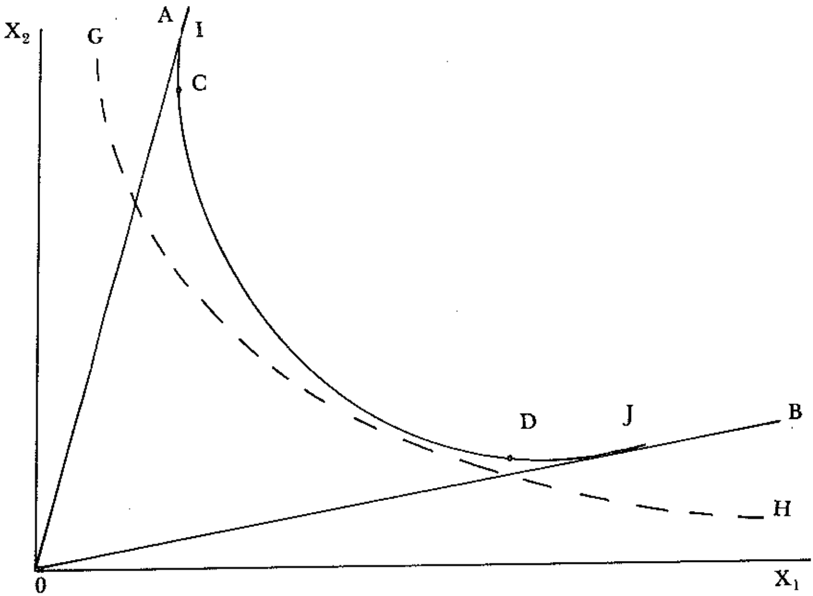
Two brief digressions seem appropriate. First, in allowing for weak disposability it is important to remember that what is being modeled is not the desired relations between inputs and output but the observed relation. Hence, if production in the area of negative marginal products is detected (above point C or to the right of point D) there should be no inference that this is of the producers' choice, but only that congestion has occurred (it

[4]The elasticity of substitution can as a result also become negative. However, since the marginal product of both inputs cannot be negative at the same time, a positive elasticity of substitution implies that one is operating in the efficient portion of the isoquant.

[5]For a good discussion of weak disposability and a proof that the VES function is weakly disposable.

Figure 1

DIFFERENCES IN PRODUCTION FUNCTIONS



maybe due to factors outside of their control). Second, if producers are operating on a weakly disposable production function, this does not necessarily imply that the marginal product of some input in negative (operation between points C and D on isoquant IJ is the locus of points where both marginal products are positive), but rather that it is possible for congestion to occur. It clearly depends where, on the isoquant, production is occurring.

Since the feasible range of production is contained between the rays OA and OB in Figure One, one feature of the weakly disposable VES function is that the feasible range can be allowed to expand over time (Färe and Jansson, 1984) (for the input congestion to disappear, so that the possibility of a negative marginal product diminishes over time). This can be accomplished by modifying equation (1) to read

$$(2) \qquad Y = A(X_1 - \gamma X_2 \exp(\eta t))^{\alpha}(X_2 - \delta X_1 \exp(\nu t))^{1-\alpha},$$

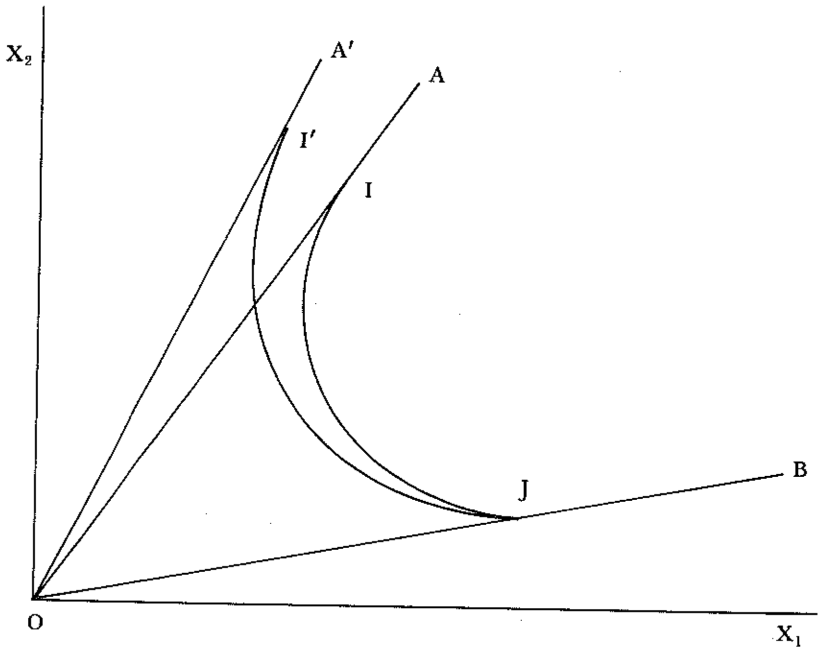
$$\text{if } (X_1 - \gamma X_2 \exp(\eta t)) \text{ and } (X_2 - \delta X_1 \exp(\nu t)) > 0,$$

$$0 \text{ otherwise,}$$

where t denotes time, exp is the exponential function, and η and ν should be less than zero. In order to understand this modified function assume for the moment that ν equals zero and refer to Figure Two. Since η is negative as time increases exp (ηt) becomes smaller. Since the slope of ray OA for model (2) is $(\gamma \exp(\eta t))^{-1}$ (recall that it was γ^{-1} for model 1), the slope of ray OA has increased (become steeper) to OA′ (in Figure 2). Hence, the unit isoquant shifts out to be asymptotic to OA′ (from IJ to I′J).[6] Hence, if t is used as a proxy for technical innovation (as it would occur over time) $\eta < 0$ would indicate that technical innovation allows greater possibilities of substituting input X_1 for input X_2. A similar analysis can be done if $\delta < 0$.

Figure 2

TECHNOLOGICAL CHANGE



[6] This shifting of the unit isoquant can be seen by taking the partial derivative of equation (2) with respect to X_2. Since $\eta < 0$ the marginal product of X_2 increases, ceteris paribus, as t increases.

However, in order to properly model the agricultural sector in Taiwan and meaningfully discuss the effects of technological change, a three, not two, input must be analyzed. The relevant three inputs are land (L), labor (N), and capital (K) (taken to include farm machinery, which was minimal before 1965, farm animals, fertilizer and seed). The extension of model (2) to the three input case is

$$(3) \qquad Y = A[L-\gamma_1 K \exp(\eta_1 t)-\gamma_2 N \exp(\eta_2 t)]^{\alpha} [N-\delta_1 K \exp(\gamma_1 t)-\delta_2 L \exp(\nu_2 t)]^{\beta} [(K-\lambda_1 N \exp(\omega_1 t)]^{1-\alpha-\beta},$$

$$\text{if } [L-\gamma_1 K \exp(\eta_1 t)-\gamma_2 N \exp(\eta_2 t)], [N-\delta K \exp(\nu_1 t) -\delta_2 L \exp(\nu_2 t)],$$

$$\text{and } [K-\lambda_1 N \exp(\omega_1 t) - (\lambda_2 L \exp(\omega_2 t)] > 0,$$

$$0 \text{ otherwise},$$

where $A>0$, $0<\alpha<1$, $0<\beta<1$, $(\alpha+\beta)<1$, and it is expected that γ_1, γ_2, δ_1, δ_2, λ_1, and λ_2 should be greater than or equal to zero and η_1, η_2, ν_1, ν_2, ω_1, and ω_2 should be less than or equal to zero.

However, since this function involves 15 parameters and since land has been the main constraining factor in Taiwanese agriculture up through 1964 (and remaining relatively fixed), a simpler form of the model was used for estimation. The simplified model is

$$(4) \qquad Y = A[L-\gamma_1 K \exp(\eta_1 t)-\gamma_2 N \exp(\eta_2 t)]^{\alpha} K^{\beta} N^{1-\alpha-\beta},$$

$$\text{if } (L-\gamma_1 K \exp(\eta_1 t)-\gamma_2 N \exp(\eta_2 t) > 0,$$

$$0 \text{ otherwise},$$

where the parameters are as previously defined. Model (4) contains only 7 unknown parameters and since it allows for congestion in capital or labor (the two variable resources) relative to land, it captures the essence of model (3).

In the three variable model one cannot simply examine η_1 and η_2 to determine the bias of technological change. However, by using the Hicksian (Ferguson, pp. 217-219) definition of technological change, technological progress can be classified as land using (labor saving) if the marginal rate of technical substitution between land and labor ($MRTS_{LN}$ $\frac{\partial Y}{\partial N} \Big/ \frac{\partial Y}{\partial L}$) decreases, ceteris paribus. Similarly it would be classified as labor using (land saving) if $MRTS_{LN}$ increases, ceteris paribus. As a result, by taking the derivative of $MRTS_{LN}$ with respect to t and evaluating the derivative at any point in time, the type of technological progress being observed at that point in time can be ascertained. For example if $\partial MRTS_{LN}/\partial t > 0$ this implies that $MRTS_{LN}$ is rising due to the passage of time and thus technical change is labor using (land saving). The reverse holds when $\partial MRTS_{LN}/\partial t < 0$. Since it has been suggested earlier in this paper (bottom of page six) that within Taiwan (from 1911-1964) working capital was substituted for land and increased the need for labor, the direction of technological progress should be of the land saving (labor and working capital using) type. Thus we would expect to find that $\partial MRTS_{LN}/\partial t > 0$ and $\partial MRTS_{LK}/\partial t > 0$. This is the hypothesis that will be tested.

One further comment is necessary concerning the use of the modified weakly disposable VES production function to test the direction of technological progress. The most common method of measuring the direction of technological progress is to use the translog production function. A useful by-product of that analysis is the ability to test for the convexity of the cost function (or production function). Unfortunately to easily estimate the translog production function requires either the expenditure share (for the production function) or the price (for the cost function) of each input. Often, as in the case of Taiwan from 1911 to 1964, neither of these are available. Although the translog function can be estimated directly this involves the joint estimation of 15 parameters (May and Denny, pp. 759-774) (whey symmetry is imposed) which may lead to a severe multicollinearity problems. In these cases the alternate method being proposed and used in this paper should prove extremely useful. In addition, much as the translog technique gave the useful by-product of being able to test for the convexity of the cost function, the modified weakly disposable VES production function allows one to test for input congestion.

IV. Empirical Estimation Results

In order to estimate model (4) it is assumd that it has an additive disturbance term u_t, and that jointly the u_t's are independently and identically distributed with a mean of zero and a covariance matrix of σ^2 I. With this addition, model (4) was estimated for the years 1911 to 1964 (Hayami, Ruttan and Southworth) using nonlinear least squares. Since γ_2 was statistically insignificant, the term involving γ_2 was dropped and the model was reestimated[7]. The results are presented in Table 1.

Table 1

RESULTS OF ESTIMATION

Parameter	Estimate	Asymptotic Standard Error	95 Percent Interval*	
A	1.444	0.068	1.329	INF
γ_1	6.195	1.557	3.585	INF
η_1	-0.045	0.013	-INF	-0.023
α	0.070	0.035	0.011	INF
β	0.643	0.090	0.492	INF

Total Sum of Squares (uncorected) = 8241117
Error Sum of Squares = 92706

*one-tail confidence interval INF -- Infinity

Each of the estimated parameters has the correct sign and is statistically significant.[8] Since γ_1 is significant and positive, the VES form of the production functions is supported. In addition, the fact that η equals -.045, implies that technological progress is shifting the isoquant at the rate of 4.5 percent per year. Finally, since $L/K < (\alpha+\beta)\gamma_1 \exp(\eta_1 t)/\beta$, input congestion is occurring in capital (operating with a negative marginal product for capital) from 1925 to 1932. This last result is totally plausible if one recalls that the new varieties of rice were developed in the 1920s and

[7]The results of this earlier estimation are available from the authors upon request.

[8]Precisely, using a one-tailed asymptotic confidence interval, zero is not contained within a 95 percent confidence interval.

were not extensively applied until the early 1930s. Prior to that time much of the agricultural growth in Taiwan stemmed from additional applications of working capital and growth was rather slow. Our results show that by the late 1920s Taiwan had reached the limit in using this approach to agricultural growth, i.e. the marginal product to increased applications of working capital became negative. However, as the new varieties rice were extensively applied, the marginal product of capital (which includes seed) once again became positive in the early 1930s.

The results of evaluating the derivatives of the various marginal rates of technical substitution with respect to time are given in Table 2. These results show that from 1911 to 1964 technological change in Taiwan has been labor using (land saving), since $\partial \text{ MRTS}_{LN} / \partial t > 0$ for all years, i.e., $\frac{\partial Y}{\partial N} \Big/ \frac{\partial Y}{\partial L}$ has been rising throughout the period. In addition, it is interesting to note that technical change became increasingly labor using, land saving from the early 1920's until the mid 1930's. Then the degree to which technical innovation was labor using/land saving begins to steadily decline. This is likely due to the fact that beginning in the early 1920's arable land per worker actually fell, meaning that the land constraint on agricultural growth was becoming quite severe. Of course after World War II and the recovery the land constraint became less and less of a problem and labor shortages begin to develop. Thus one might suspect that technical innovation would become less land saving/labor using and it indeed has. In fact, after 1964 one might hypothesize that technical change may have become land using and labor saving (this would be reflected in a negative sign for $\partial \text{ MRTS}_{LN} / \partial t$). This is a topic for future research.

Examining Table 2 again, one finds that $\partial \text{MARTS}_{LK} / \partial t$ and $\partial \text{ MRTS}_{NK} / \partial t$ are both positive throughout the period. Thus both $\frac{\partial Y}{\partial K} \Big/ \frac{\partial Y}{\partial L}$ and $\frac{\partial Y}{\partial K} \Big/ \frac{\partial Y}{\partial N}$ were rising. This implies that technical progress was working capital using with respect to both land and labor. The extent to which technical innovation was working capital using and labor saving rose dramatically from the mid 1920's to the early 1930's, but declines steadily for the rest of the period. The rise in the mid 1920's through the mid 1930's was likely due to the fact during this period commercially produced

Table 2

EVALUATING THE DERIVATIVES (WITH RESPECT TO TIME) OF THE MARGINAL RATES OF TECHNICAL SUBSTITUTION

Year	$\partial MRTS_{LN}$	$\partial MRTS_{LK}$	$\partial MRTS_{NK}$	Year	$\partial MRTS_{LN}$	$\partial MRTS_{LK}$	$\partial MRTS_{NK}$
1911	1.14	5.35	.20	1938	1.22	1.61	.13
1912	1.15	5.20	.19	1939	1.10	1.54	.10
1913	1.14	4.90	.16	1940	1.02	1.47	.07
1914	1.09	4.68	.15	1941	.98	1.41	.06
1915	1.12	4.48	.16	1942	.91	1.35	.04
1916	1.22	4.28	.24	1943	.87	1.29	.04
1917	1.20	4.10	.23	1944	.71	1.23	.02
1918	1.10	3.92	.19	1945	.74	1.18	.01
1919	1.15	3.75	.17	1946	.73	1.13	.01
1920	1.12	3.58	.12	1947	.65	1.08	.01
1921	1.14	3.43	.14	1948	.55	1.03	.01
1922	1.28	3.28	.31	1949	.52	.99	.02
1923	1.41	3.14	.44	1950	.54	.94	.02
1924	1.42	3.00	.60	1951	.54	.90	.02
1925	1.56	2.87	3.27	1952	.51	.86	.02
1926	1.54	2.74	1.99	1953	.49	.83	.01
1927	1.68	2.63	11.04	1954	.50	.79	.01
1928	1.69	2.51	86.78	1955	.49	.76	.01
1929	1.61	2.40	2.97	1956	.49	.76	.01
1930	1.67	2.30	271.52	1957	.44	.69	.01
1931	1.64	2.20	23.17	1958	.42	.66	.01
1932	1.49	2.10	1.60	1959	.41	.63	.01
1933	1.50	2.01	1.05	1960	.40	.60	.01
1934	1.45	1.92	.70	1961	.41	.58	.01
1935	1.34	1.84	.50	1962	.40	.55	.01
1936	1.29	1.76	.32	1963	.40	.53	.01
1937	1.29	1.68	.21	1964	.39	.51	.01

fertilizers were rapidly being substituted for farm produced fertilizers. This likely reduced the demand for farm labor since farm produced fertilizers are labor intensive (gathering manures, grass, etc.) while commercially produced fertilizers are capital intensive. This same phenomenon also occurred in the development of Japanese agriculture (Nghiep, pp. 687-693). The steady decline in the extent to which technical innovation created opportunities for the substitution of working capital for labor probably reflects the increasingly limited possibilities for pursuing this possibility.

As was in the previous paragraph, technical innovation also increased the possibilities of substituting working capital for land.

However, the extent to which it did so steadily decreased throughout the period, i.e., the size of $\partial \, MRTS_{NK} / \partial t$ declines. This most likely reflects the fact that land was becoming less and less of a constraint on the growth process in agriculture.

V. Conclusion

In this short paper a brief review of the agricultural experience of Taiwan for the period 1911 to 1964 was presented. As a result of this review, it was hypothesized that technical innovation during this time period was labor using relative to land and capital using relative to labor and land. In order to test this hypothesis a weakly disposable VES production function incorporating technical change was estimated using nonlinear least squares. The results confirm the hypothesis made in the paper. In addition, it seems that 1964 represents an important turning point in Taiwan's agricultural development. More specifically, although up until that point in time technical innovation was labor using, land saving, it was becoming increasingly less so. This seems to correspond to the point in time when labor was becoming the relatively scarce input in Taiwan. However, additional research concerning this post 1964 period is necessary to confirm this proposition.

References

Färe, R. and L. Jansson, "Technological Change and Weak Disposability of Inputs," *Zeitschrift für Nationalökonomie*, 34, 1984.

________, "On VES and WDI Production Functions," *International Economic Review*, 16, 1975.

Färe, R. and B.J. Yoon, "On Capital-Land Subsitution in Urban Housing Production," *Journal of Urban Economics*, forthcoming.

Ferguson, C.E., *The Neoclassical Theory of Production and Distribution*, Cambridge University Press, Cambridge, 1971.

Grabowski, R., "The Implications of an Induced Innovation Model," *Economic Development and Cultural Change*, 27, July 1979.

Hayami, Y., Ruttan, V. and H. Southworth, ed., *Agricultural Growth in Japan, Taiwan, Korea, and the Philippines*, The University Press of Hawaii, Honolulu, 1979.

Ho, Samuel P.S., *Economic Development of Taiwan, 1860-1970,* Yale University Press, New Haven, 1978.

Lee, T.H. and Y.E. Chen, "Agricultural Growth in Taiwan 1911-1972," in *Agricultural Growth in Japan,* Yujiro, H., Vernon, R. and H. Southworth, eds., *Taiwan, Korea, and the Philippines,* The University Press of Hawaii, Honolulu, 1979.

May, J.D. and M. Denny, "Factor-Augmenting Technical Progress and Productivity in U.S. Manufacturing," *International Economic Review,* 20, 1979.

Nghiep, L.T., "The Structure and Change in Technology in Prewar Japanese Agriculture," *American Journal of Agricultural Economics,* 61, Nov. 1979.

Revankar, N.S., "A Class of Variable Elasticity of substitution Production Functions," *Econometrica,* 39, 1917.

Shen, T.H. and Y.T. Wang, "Technological Adjustments," Shen, T.H., ed., *Agriculture's Place in the Strategy of Development: The Taiwan Experience,* Joint Commission on Rural Reconstruction, Taipei, 1974.