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# Developmental Stages and Demand for Factors in Agriculture: the Evidence from Taiwan, 1965-1992*

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This paper is devoted to studying the time variations in the price elasticities of demand for inputs which manifest the changes in production decision. A LKM translog cost function associating with a dynamic adjustment scheme is employed in estimating the elasticities of Taiwan's agricultural sector in the period of 1965-92. A regression model incorporating per capita income and a spline function in time dimension is built to explain the variations. Empirical results indicate that these elasticity series indeed change in the course of economic development. They are likely to be composed by spline sections with each being in conformity to a developmental stage. These stages can be denoted by the major events in the economy which had substantial impacts on factor markets.

## I. Introduction

Economic development induces fundamental changes in the structure of production. These changes can be brought out by technology improvement, expansion of scale, and adjustment in demand for factors, etc. In applied production theory, derived demand for factor signifies the marginal productivity of the factor. Its price elasticity measures the percentage change in input quantity with respect

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to a one percentage change in price given a specific environment. It hence provides a sensitivity estimate about the production decision. Price of an input is determined by the forces of aggregate demand and supply in the input market which vary in the course of development. The decision on input demand as well as the price elasticities could be quite different at various stages of development. For example, an economy might start with a traditional, over-populated rural society at the very beginning. Labour supply is abundant relative to other resources especially the capital. Marginal productivity of labour is extremely low. As the economy becomes more advanced, previously surplus labour might have been absorbed gradually into the growing industrial sector. Domestic capital might have been accumulated through the expansion of saving ability. An increase in capital use generates productivity gains of labour. One would not expect that the demand for labour and its elasticity at this later stage remain the same as before. From the perspective of development implications, the price elasticity of input at equilibrium could be a useful gauge for measuring the relative abundance of primary inputs and also be an appropriate scale for assessing the evolution of underlying production method. Any change in economic environment which would distort the input markets could also be detected by investigating their elasticities.

This paper attempts to analyze the time variations in factor demand in Taiwan's agricultural sector from the time of taking-off to that of driving into maturity. The adjustments to price changes are assumed to be dynamic and modelled by a partial adjustment scheme. This dynamic structure is incorporated in a LKM (labour, capital, and material inputs)[1] translog cost function which is employed to estimate the elasticities of demand for factors. These elasticity series will the be regressed on linear spline variables and per capita GNP, an index of development process, to examine their variations. Special emphasis is

1. When it comes to capital, numerous meanings and measures arise. One of the definitions usually refers to those physical factors, such as equipments and constructions, used in production process which are not only depreciable but also renewable. Land which is almost fixed in short term is usually not depreciable, although it may deteriorate. Due to the difficulty of data handling, we combine both the narrowly defined physical capital and the land into a broader class of capital (K) in this study without affecting the main theme and arguments. See Appendix for further explanation.

placed on their structural changes which mirror the exogenous disturbances on production decision.

There have been a great deal of empirical studies carried out within the framework of translog production or cost function of an aggregate economy or of major sector. Analysis was focused on the issues of derived demand for inputs, productivity changes, technology bias, and effects of energy shocks on production, etc. The seminal work was done by Christensen, Jorgenson, and Lau (1973) who demonstrated the translog functions by using the aggregate data of the U.S., 1929-69. Binswanger (1974a, b) analyzed the U.S. agricultural technology in a wide dimension. Other examples regarding the study on agriculture include the work done by Ray (1982), Ball and Chambers (1982), Antle (1984), Ball (1985), Shoemaker (1988), and Gopalakrishnan et al. (1989), etc. In an empirical study concerning the impacts of energy crisis, Alameda and Mann (1989) took the Puerto Rican economy as example. They bisected the sample period and estimated the elasticities separately in order to compare the structure changes before and after the shock in 1973. Most of other studies examined the production features by merely inquiring into the sign of various elasticities. It is considered that the variations in input elasticities need to be scrutinized by relating them to other variables of economic development and that the structure changes could be tested by a spline function setting.

This paper is arranged as follows. Section II gives a brief survey on Taiwan's economic development. Section III offers a quick review on the translog cost function model as well as its estimation methods. Dynamic scheme of adjustment to the price changes is discussed along side. Estimation results are presented in section IV. In section V, a regression model incorporating linear spline variables is specified for examining the variations in the elasticities. Testing results are presented. Last section is for summary and remarks.

## II. A Brief View on Taiwan's Economic Development

Taiwan is a small island with high density of population but little endowment in natural resources. It has undergone a successful transition in the postwar period, transition from agricultural to industrial and from backward to modern economy. The rapid industrialization and export expansion have brought higher per capita income, stable prices, full employment, and better quality of life. Its average per capita GNP was less than US $150 in 1960 but reached an amazing US $10,000 at the end of 1992. Annual growth rate was about 7.2% in the past three decades. Savings and investment are the core of production and growth. Although it is renowned for its international trade strength in manufacturing and for its huge foreign reserves, agriculture is still an important sector in the economy.[2]

Transition into modern economy is accompanied by both profound structural change and accelerating growth. While the share of output value of manufacturing in GDP rose from 19% in 1961 to the apex of 40% in 1986 (then dropped to 32.9% in 1992), the share of agriculture declined consecutively from 27.5% in 1961 to 3.5% in 1992. As far as the production factors are concerned, they portray an essential change as well. By and large, labour force varied from a situation of surplus to that of shortage and domestic capital accumulated rapidly since the economy took-off in 1960s. The relative prices of these inputs thus altered drastically. In recent years, labour shortage has even turned out to be a severe problem. Structural changes in the economy led to a sharp decline in the labour share of agriculture and an increase in that of manufacturing. In the past three decades, the share of the former slid from 50% to about 12% and that of the latter doubled from 21% to 42%. Such drastic changes in Taiwan's economic structure would definitely be mirrored on the variations in elasticity of factor demand.

Just as in other economies, there are many ups and downs in the case of Taiwan. Since it has to rely on foreign trade for resources supply and product disposal, its major fluctuations are related closely to the international economy. When the world economy is healthy, the Taiwan economy synchronizes with it. The first world-wide energy crisis in early 1970s and the following depression caused Taiwan to suffer severely. As is readily appreciated, the real GNP growth rate was high before 1973 but low (or even negative) afterwards. As far as

2. The data cited in this section are largely from the *National Income Yearbook, Taiwan Area of R.O.C, 1993,* Taipei: DGBAS, and *Basic Agricultural Statistics, ROC, 1992,* Taipei: COA.

agriculture is concerned, the average growth rate of real production was 3.9 percent in 1964-73; but it was -3.68 percent in 1975. The real investment for agriculture declined 16 and 33 percent in 1974 and 1975, respectively. Energy crisis depressed the production by drastically raising the costs in this small, open, and oil-imported economy. Since it radically altered the factor markets, it induced enormous changes in production. In the subsequent years, developmental policy has been focusing on the second phase of import substitution with production of intermediate goods. Several basic construction packages aiming at improving the infrastructure were also completed. It is believed that the patterns of input demand elasticities would be quite different before and after the energy crisis.

Since the late 1985, Taiwan has experienced another change in its economy which exerted substantial impacts on every sector. As a result of huge trade surplus, especially against the U.S., as well as of fast accumulation of foreign reserves, Taiwan was asked to adjust its exchange rate. It appreciated about 35% in the period of 1986-89.[3] Exports were depressed and investment was slowed down. Private investment was only 18 percent of GNP in 1985 and 1986 which was the lowest since the economy took-off in 1960s. Unemployment rate reached a peak of 2.91 percent. Per capital GNP growth rate was a record low of 4.16 percent in 1985. The real investment in agriculture declined 3 percent in 1985 and the growth rate was -0.55 percent in 1986. People's working attitude changed as well. Since the prices of real estate and financial assets soared everyday, many people gave up their regular jobs to engage in speculative markets. Labour wage rates increased rapidly from then on. Entrepreneurs started to complain about the economic environment on the island. Many firms started to move to Mainland China and South-east Asia for cheaper labour and land. In addition to the slowing down of the economy, production structure in Taiwan marked another critical point in the period of 1985-86. While the shares of agriculture in terms of production and employment continued to drop, those of industry reached their peak in 1985 and 1986 and became declining thereafter. The shares of service sector

3. The exchange rate went from 1 US dollar: 39.85 NT dollars at the end of 1985 to 1 US dollar: 26.17 NTdollars at the end of 1989.

outweighed those of industry. Furthermore, the growth target of agriculture was set around zero percent.

## III. The Dynamic Translog Model

As was done in previous studies of the nature of the translog approach, we assume that there exists in Taiwan's agricultural sector a twice differentiable aggregate production function relating the flow of gross output value (Y) to the services of three input: labour (L), capital (K), and raw materials (M). It is assumed to exhibit the properties of monotonicity and quasi-concavity and to embody Hicks-neutral technical progress.[4] Corresponding to such a production function, there is a dual cost function. Homotheticity of production implies that the cost function is separable in output and input prices. Separability would mean that production expansion in aggregate is not constrained by relative factor prices. By employing Shephard's lemma, one can derive that the ratio of partial derivatives of cost function with respect to input prices of two factors is equal to the ratio of derived demands for these two factors. Although production and cost functions are primal-dual in nature, there are several advantages for choosing cost function rather than a production function for parameter estimation as noted by Binswanger (1974a, b).

For the purpose of estimation, we choose the translog specification which is one of the most commonly used and sufficiently flexible functional forms. It enables us to calculate the partial elasticities of substitution as well as price elasticities of inputs at various points in time without imposing a priori restrictions. Let $w_i$ indicate the price of input i, t the index of time, and C the total costs. The translog form which is written as a logarithmic Taylor series expansion to the second term of a cost function can be as follows:

4. Binswanger (1974a, b) and Antle (1984) discussed in details about the measurement and treatment of neutral and non-neutral technical changes in the translog setting. Since the issue of technical biases is not the major concern of this paper, we simply assume the Hicks neutrality as did in Alameda and Mann (1989), Ball and Chambers (1982), Berndt and Wood (1975), Ray (1982), and many others.

$$\ln C = \beta_0 + \sum \beta_i \ln w_i + \beta_Y \ln Y + \beta_t \ln t$$
$$+ 1/2[\sum \gamma_{ii}(\ln w_i)^2 + \gamma_{YY}(\ln Y)^2 + \gamma_{tt}(\ln t)^2$$
$$+ \sum_{i \neq j} \gamma_{ij}(\ln w_i)(\ln w_j) + \sum \gamma_{iY}(\ln w_i)(\ln Y)$$
$$+ \sum \gamma_{it}(\ln w_i)(\ln t) + \gamma_{Yt}(\ln Y)(\ln t) \tag{1}$$
$$i, j = L, K, M$$

with $\beta s$ & $\gamma s$ being the coefficients. It is a local approximation of an arbitrary analytic cost function. Following Christensen et al (1973), it is assumed that equation (1) satisfies the conditions of linear homogeneity, monotonicity, and concavity. Linear homogeneity in input prices requires $\Sigma \beta_i = 1$ and $\sum_j \gamma_{ij} = \sum_i \gamma_{iY} = \sum_i \gamma_{it} = 0$. Monotonicity states that the function must be an increasing function of input prices. Concavity in input prices implies that the second derivative Hessian matrix must be negative semi-definite within the proper range of input prices. Further, the symmetry constraint of the cross derivatives requires that $\gamma_{ij} = \gamma_{ji}$, for all i and j.

Differentiating (1) with respect to input prices logarithmically and applying Shephard's lemma generate three linear cost share equations. Each is a function of the logarithm of three input prices, of output, and of time t. Adding a stochastic error term which are assumed to be serially uncorrected and homoscedastic to each equation, they can be written as:

$$S_i = \beta_i + \sum_j \gamma_{ij} \ln w_i + \gamma_{iY} \ln Y + \gamma_{it} \ln t + U_i \tag{2}$$
$$i, j = L, K, M$$

Although the system represented by (1) and (2) has been extensively used to study factor demand and productivity, in their static form they can be too restrictive because they require cost shares of factors to adjust instantaneously, rather than dynamically (with a lag), to input price shocks. For a cost minimizing agent in agriculture facing with substantial adjustment costs, the path to a new equilibrium may inevitably involve lags, as noted by Luh and Stefanou (1991) and Howard and Shumway (1988), etc. Therefore, the convenient analysis of a static production function or its dual cost function may miss important adjustment process which may unfold slowly in response to changes in relative prices. Such a slow adjustment would be particularly significant during and after a period of rapid and large changes in relative prices among inputs. The large price changes would initiate significant long-run changes in demand, but the short-run data would reveal only part of that adjustment. Hence there has been a strong belief that successful analysis of agricultural production, especially with time series data, would depend on an adequate characterization of the dynamics of adjustment of factor demands.

In light of significant adjustment costs, management inertia, or uncertainty, etc., the assumption of static equilibrium would seem indefensible. A more realistic assumption with dynamic structure is built directly into the share models as suggested by Pindyck (1979, pp. 56-58) and applied by Hogan (1989) and Taheri (1994), etc., in studies of energy demand. This dynamic structure utilizes geometric lags and is further based on the partial adjustment mechanism. In other words, producers are assumed to only partially succeed in achieving a desired level of cost share for each input factor at time t. Specifically, a relationship between the long-run target shares at time t ( $S^*_{it}$) and the short-run actual shares at time t ( $S_{it}$) will be described according to the following linear function:

$$S_{it} - S_{i,t-1} = \lambda (S^*_{it} - S_{i,t-1}) \qquad 0 < \lambda < 1 \tag{3}$$

where $\lambda$ represents the rate of adjustment of $S_{it}$ to $S^*_{it}$ which can be estimated, ( $S_{it}$- $S_{i,t-1}$) states the actual change in cost share of factor i, and ( $S^*_{it}$- $S_{i,t-1}$) is the desired change.

After solving (3) along with (2), we obtain the following estimated cost share equations:

$$S_i = \beta_i^* + \sum_j \gamma_{ij}^* \ln w_i + \gamma_{iY}^* \ln Y + \gamma_{it}^* \ln t + (1-\lambda) S_{i,t-1} + U_i^* \qquad (4)$$

$$i, j = L,\ K,\ M$$

Notice that $\beta_i^*$, $\gamma_{ij}^*$, $\gamma_{iY}^*$ and $\gamma_{it}^*$ are the 'unrestricted' coefficients to be estimated.[5] This setting is empirically appealing since it does not alter those theoretically required and priori restrictions, such as the adding up conditions: $\Sigma S_i = \Sigma S_i^* = 1$.

The cost share equations being added up to one results in singularity of the disturbance covariance matrix. Therefore, one of them must be eliminated and efficient estimators can be derived from the remaining two. Zellner's (1962) seemingly unrelated regression estimation (SURE) method provides a set of efficient estimators to the linear functions in (4). Kmenta and Gilbert (1968) showed in a series of Monte Carlo experiments that the estimation results will not be invariant to the equation deleted from the system. However, invariance can be attained by iterating the estimation procedure until the estimated coefficients and residual covariance matrix converge. Further, it is shown that the converged estimates will be equivalent to the maximum likelihood estimates and thus be the best linear unbiased estimates.

The price elasticity of demand for inputs (PED) at time t in translog setting can be defined and written as (with $Q_i$ being the quantity of input i and subscript t being omitted):

$$\varepsilon_{ij} = \frac{\partial \ln Q_i}{\partial \ln w_j} = (S_j)(\sigma_{ij}) \qquad i,\ j = L,\ K,\ M \qquad (5)$$

where $S_j$ is the cost share of input j and $\sigma_{ij}$ is the Allen partial elasticity of factor substitution between input i and j. In fact, $\sigma_{ij}$ can be calculated by using the formula:

5. These 'unrestricted' coefficients are related to the 'restricted' coefficients by the adjustment parameter $\lambda$, for example, $\gamma_{ij}^* = \lambda\ \gamma_{ij}$.

$$\sigma_{ij} = \frac{(C)(C_{ij})}{(C_i)(C_j)} = \frac{\gamma^*_{ij}}{(S_i)(S_j)} + 1 \tag{6}$$

where $C_{ij} = \frac{\partial^2 C}{\partial w_i \, \partial w_j}$ and $C_i = \frac{\partial C}{\partial w_i}$.

## IV. Estimation Results

This study covers the entire agricultural sector of Taiwan which includes the farm crops, forestry, fisheries, and animal husbandry. Annual (1965-1992) data used to estimate cost share equations involve aggregate expenditure on each input, input prices, aggregate output, and cost shares of inputs. Data description and sources are compiled in Appendix. Cost share equations in (4) are estimated by using the iterative SURE method with imposing restrictions on parameters and across equations to ensure uniqueness of estimates.[6] Parameter estimates associating with their t-values are presented in Table 1. By judging the model statistics, it is seen that the goodness of fit of the model is highly satisfied.

Estimates pertaining to input price variables under dynamic adjustment scheme, $\gamma^*_{ij}$, indicate the change in cost share of input i due to a small change in logarithm of the price of input j. As shown in Table 1, all estimates are significant at 10%, except $\gamma^*_{LK}$. The relatively low standard errors denote the efficiency of estimates. The cross relations between cost share of i and input price of j (when $i \neq j$) are negative, while own effects (when $i = j$) are positive. Estimates pertaining to output variable, $\gamma^*_{iY}$, indicate the change in cost share of i due to a small change in logarithm of real output Y. In an effort towards both mechanization to replace human labour and scientific innovations to raise output, Taiwan's agriculture has experienced a successful transformation. Hence the estimate of $\gamma^*_{LY}$ reveals to be

6. SAS 6.03 program is applied for estimation. Iterative three-stage least squares (3SLS) method is also tried on the same data set. Identical results are obtained, and as a consequence, the simultaneity is not a problem.

negative, while those of $\gamma^*_{KY}$ and $\gamma^*_{MY}$ are positive. It is seen that the estimated rate of adjustment in cost shares is about one half (0.4932). This implies that in Taiwan's agricultural sector, it takes about two years to reach a full adjustment to the desired level whenever a price change occurs.

In Table 2 we tabulate the price elasticities of demand for inputs. They measure the sensitivity of derived demand with respect to a small change in input price. They are, of course, negative in sign as predicted by economic theory. PED(K) has the largest mean value in absolute terms, while PED(M) has the smallest one. But PED(L) varies slightly more than the other two in terms of coefficient of variations in the sample.

Since the realized input price elasticity provides a measure about the sensitivity of input usage as well as the relative abundance of production factors which varies along time, it is hypothesized that the elasticity series should be able to reveal further information about the development process. The rest of the paper will be devoted to examining the time variations in the PED series. Special interest is given to the effects of major external events, such as energy shock in early 1970s and currency revaluation in late 1980s, which could have imposed substantial impacts on factor prices.

## V. Testing the Time Variations in the PED Series

External forces will usually disturb the production decision by ill-turning the supply and demand situations in factor markets. Typical example is the oil embargo in 1973-74 which drastically altered the relative prices between basic inputs in almost all economies. Many studies notice the impacts of external disturbances on production. The common way of handling the issue, for example by Alameda and Mann (1989), is to divide up the sample period and to estimate the production or cost function separately. Estimating separately is similar to saying that the economy has discontinuity in production process at the break point. Diewert and Wales (1992) proposed a model of production in a normalized quadratic form which incorporates either linear or quadratic spline in a time variable. The system was estimated by using aggregate Japanese data for the period 1955-87. It was found that the generalized model has desirable approximate properties with respect to the spline variables. Wang (1995) employed a translog cost function model in estimating the elasticities of substitution of Taiwan's manufacturing and then applied the spline function setting to testing their variations.

Given the PED series, we propose to use a linear spline function to identify the existence of structural breaks. Spline function is a continuous piecewise device whose pieces are polynomial segments of degree n. The joint points are called knots. Given the knot points, it is possible to detect the structural breaks by testing the change in slope of the spline function. Linear spline function (polynomial of degree 1) which in general is sensitive to all of the data permits both the intercept and slope to change between two periods, but subject to the condition that continuity in the time dimension be maintained.[7] Assume that there are two knot points occurring at time *a* and *b*. The model used to test the structural breaks in the PED series can be specified as follows:

$$y_t = c_0 + c_1 + x_t + d_1 z_{1t} + d_2 z_{2t} + d_3 z_{3t} + \varepsilon_t \tag{7}$$

where $y_t$ indicates the PED series, $x_t$ is the economic variable, $z_{jt}$ are linear spline time variables which are designed as

$$z_{1t} = t$$

$$z_{2t} = \begin{cases} 0 & \text{if } t < a \\ t - a & \text{if } t \geq a \end{cases}$$

$$z_{3t} = \begin{cases} 0 & \text{if } t < b \\ t - b & \text{if } t \geq b \end{cases}$$

and $c_0$, $c_1$, and $d_j$ are coefficients. $d_1$ denotes the time slope before knot *a*. $d_2$ indicates the change in time slope from before *a* to between

7. For further discussion about the linear spline function and its applications, see Poirier (1973), Poirier and Garber (1974), and Suits et al. (1978).

$a$ and $b$. $d_3$ represents the change in time slope from between $a$ and $b$ to after $b$. The disturbance terms $\varepsilon_t$ are assumed to follow the assumptions of a classical normal linear regression model.[8] We shall use this specification to test the time variations in the PED series. Logarithm of per capita GNP measured in US dollar (lnGNPC) will be adopted as a development indicator. A switching regime regression is first applied to each series to identify the possible structural changes.[9] It shows that the structural break points occur at the time in accordance with the major events, such as the world-wide energy crisis and the drastic revaluation in exchange rate.

Two selected regression results with different knot point combinations of each PED(·) are presented in Table 3. Generalized least squares (GLS) method adjusting for autocorrelation of residuals is applied. Maximum of loglikelihood values and other test statistics are also included. Since the sample correlation between time trend (t) and lnGNPC is as high as 0.99584, variable t has to be deleted to avoid the problem of multicollinearity.

Firstly, in the PED(L) equations, we see a significantly positive relation between the elasticity and the per capita income level. As income grows, the long run trend of elasticity decreases in absolute terms. It implies the flexibility of using labour reduces as the economy becomes more mature. However, the trend reversed after the energy crisis in early 1970s and even further after the currency revaluation in late 1980s as can be seen by the negative coefficients of the two spline segments. Secondly, as far as the PED(K) is concerned, the results indicate that the price elasticity of demand for capital becomes larger (in absolute values) in the course of development. As capital accumulates along with economic growth, producers are allowed with greater flexibility in using capital. The trend of the PED(K) series reversed after the energy shock. And it decreased (in absolute terms) further after the currency revaluation which is denoted by the second knot point. Finally, in the PED(M), the elasticity of demand for raw materials increases (in absolute terms) as the economy grows,

8. These assumptions are subject to test in empirical applications. See Poirier & Garber (1974) for discussion.

9. The preliminary test includes only the spline time variables and is done by using Microfit 3.0 software. It can be viewed as a complete specification. Due to space limitation, results will not be given in details. For theoretical reasoning and estimation technique of switching regression, see Goldfeld and Quandt (1973).

although the coefficients are not significant at 10% level. This might be due to product versatility and technology improvement which make producers have more alternatives in choosing raw materials and fertilizer, etc. The coefficient of the spline variable after the first knot is negative (although not significant at 10% level) and that after the second one is positive. In summary, judging by the goodness of fit statistics, such as the $\overline{R}^2$ and log-likelihood value, the model so specified is highly acceptable. Per capita income along with spline variables can explain most of the variations in the input elasticity series in agriculture. The knot points selected to indicate the structural breaks in production decision are indeed compelling. Their time slopes are significant at 5% level, except the first knot in the PED(M).

It has been argued that it is crucial to include the spline setting in the regression model in order to explore the authentic relationship between the evolution of PED series and economic growth. Table 4 presents the results of the restricted version of the specification which includes only the income variable as regressor. As indicated by the joint F-test, the null hypothesis that the coefficients of both spline time variables equal zero is rejected at 5% level in all PED series. Validity of incorporating spline variables to denote the structural changes is justified and the restricted version without these variables is spurious. We can thus propose that any study regarding the relationship of production to the development process needs to consider the possible structural changes.

## VI. Summary and Concluding Remarks

Time variation in the price elasticities of demand for inputs which manifest the changes in production decision and relative abundance of factors are investigated in this paper. A well defined LKM translog cost function associating with a dynamic adjustment scheme is used to estimate the PED series for Taiwan's agricultural sector. It is found that all the PED series are not monotonically or smoothly developed. They are rather full of fluctuations and structural changes. A regression model incorporating an income variable and a linear spline function in time dimension is built to examine the variations. Structural breaks are identified being coincident with two major exogenous disturbances. The PED series are likely to be composed by spline sections. Each section is in conformity to a developmental stage. The first one which was before the first world-wide energy crisis comes together with the period of production with labour intensive technology. The second stage was the period between the energy crisis in 1973-94 and the currency revaluation in late 1980s. The economy transformed to a capital-intensive production phase and had to adjust to high oil prices. Agricultural production became more mechanized in this period. In the third period which started from the time of currency appreciation on, the economy is moving towards the high-technology industries and business related services. The major agricultural produces are shifting from staple foods to cash crops.

Several remarks are worth mentioning. (1) A fast growing economy like Taiwan is usually characterized by rapid changes in production. These changes in a sense can be revealed by the variations in elasticity of factor demand. Attempting to analyze these variations will provide some insights into the developmental process. By employing a linear spline setting, it is found that not only does such a representation have a significant explanatory power on the variations but also does allow us to scrutinize the effects of exogenous shocks. Regression without such spline setting may not be appropriate to model the production related features. (2) With regard to Taiwan's agriculture, obvious structural breaks in the PED series exist. As far as the structural breaks are concerned, it is thought that the analytical framework presented in this paper is more appropriate than those of first dividing up the observational period and then estimating the function separately. Estimating the function separately is similar to assuming that the economy has discontinuity in production process at the break point. It is an assumption of being hard to justify to be convincing. (3) It is argued that non-linear spline function might also be a good specification for the issue of this type. However, due to limitation of degree of freedom, it can not be tested in this paper.

**Table 1 Coefficient Estimation for the Translog Cost Function of Taiwan's Agriculture, 1965-92.**

| Parameter | Estimate | t-value | Parameter | Estimate | t-value |
|---|---|---|---|---|---|
| $\beta_L^*$ | 3.14916 | 4.738*** | $\gamma_{LY}^*$ | -0.24046 | -4.582*** |
| $\beta_K^*$ | -0.60019 | -1.520 | $\gamma_{KY}^*$ | 0.06561 | 2.055* |
| $\beta_M^*$ | -2.05578 | -4.163*** | $\gamma_{MY}^*$ | 0.17485 | 4.384*** |
| $\gamma_{LL}^*$ | 0.09516 | 2.847*** | $\gamma_{LT}^*$ | 0.02647 | 1.136 |
| $\gamma_{LK}^*$ | -0.00723 | -0.438 | $\gamma_{KT}^*$ | -0.03715 | -2.523** |
| $\gamma_{LM}^*$ | -0.08793 | -2.591** | $\gamma_{MT}^*$ | 0.01068 | 0.693 |
| $\gamma_{KK}^*$ | 0.03240 | 2.608** | $\lambda$ | 0.49322 | 4.667*** |
| $\gamma_{KM}^*$ | -0.02517 | -1.735* | | | |
| $\gamma_{MM}^*$ | 0.11310 | 2.665** | | | |

Notes: 1. ***, ** and * indicates the significance of estimate at the 1%, 5% and 10% levels, respectively.

2. The sum of $\beta_i^*$ is equal to unity after adjusting for the estimated $\lambda$.

3. Other statistics for the model estimations are: D-h

| Share equation | sse | $\overline{R}^2$ | D-h |
|---|---|---|---|
| Labour Cost | 0.6097896 | 0.7368 | 2.3880 |
| Capital Cost | 0.3040207 | 0.9255 | 1.8002 |
| Materials Cost | 0.2318657 | 0.9601 | -0.0612 |

The system weighted $R^2$ is 0.9636 with 44 degrees of freedom.

**Table 2 Price Elasticities of Demand for Factors of Taiwan's Agriculture, 1965-92.**

| Year | PED(L) | PED(K) | PED(M) |
|---|---|---|---|
| 1965 | -0.36251 | -0.54972 | -0.28934 |
| 1966 | -0.36295 | -0.55144 | -0.29249 |
| 1967 | -0.36585 | -0.55332 | -0.30075 |
| 1968 | -0.36147 | -0.55737 | -0.29625 |
| 1969 | -0.33580 | -0.58744 | -0.28664 |
| 1970 | -0.33764 | -0.58711 | -0.28949 |
| 1971 | -0.33667 | -0.59109 | -0.29344 |
| 1972 | -0.34474 | -0.59050 | -0.30476 |
| 1973 | -0.34437 | -0.60675 | -0.31836 |
| 1974 | -0.30863 | -0.61613 | -0.28849 |
| 1975 | -0.30193 | -0.62158 | -0.28887 |
| 1976 | -0.31924 | -0.62250 | -0.31122 |
| 1977 | -0.32495 | -0.62636 | -0.31953 |
| 1978 | -0.31411 | -0.63302 | -0.31932 |
| 1979 | -0.32493 | -0.63389 | -0.32500 |
| 1980 | -0.31554 | -0.63788 | -0.32497 |
| 1981 | -0.31994 | -0.63838 | -0.32646 |
| 1982 | -0.32272 | -0.63700 | -0.32620 |
| 1983 | -0.32670 | -0.63700 | -0.32691 |
| 1984 | -0.32617 | -0.63972 | -0.32736 |
| 1985 | -0.31584 | -0.63992 | -0.32739 |
| 1986 | -0.32423 | -0.63947 | -0.32739 |
| 1987 | -0.33465 | -0.63658 | -0.32740 |
| 1988 | -0.34821 | -0.63448 | -0.32647 |
| 1989 | -0.35601 | -0.62995 | -0.32611 |
| 1990 | -0.34731 | -0.63580 | -0.32616 |
| 1991 | -0.35854 | -0.63384 | -0.32343 |
| 1992 | -0.35320 | -0.63349 | -0.32561 |
| mean | -0.33553 | -0.61435 | -0.31307 |
| cv(%) | -5.46836 | -4.96982 | -5.09351 |

Note: CV stands for coefficient of variations.
Source: calculated by author.

**Table 3 Selected Regressions of the PED Series**

| | Equations | | | | | |
|---|---|---|---|---|---|---|
| | PED(L) | | PED(K) | | PED(M) | |
| | (1) | (2) | (1) | (2) | (1) | (2) |
| Intercept | -.5374$^{***}$ | -.5482$^{***}$ | -.2961$^{***}$ | -.3116$^{***}$ | -.2535$^{***}$ | -.2486$^{***}$ |
| | (-12.85) | (-10.32) | (-7.827) | (-9.365) | (-7.406) | (-7.028) |
| lnGNPC | .0326$^{***}$ | .0347$^{***}$ | -0.048$^{***}$ | -.0457$^{***}$ | -.00731 | -.00817 |
| | (4.820) | (3.987) | (-7.864) | (-8.558) | (-1.317) | (-1.429) |
| Knot Points: | | | | | | |
| 1974 | | -.0050$^{***}$ | .0040$^{***}$ | | | |
| | | (-2.931) | (3.364) | | | |
| 1975 | -.0048$^{***}$ | | | .0038$^{***}$ | -.00196 | -.00156 |
| | (3.238) | | | (3.425) | (-1.572) | (-1.271) |
| 1985 | | | | | .0040$^{***}$ | |
| | | | | | (2.888) | |
| 1986 | -.0053$^{**}$ | | .0048$^{***}$ | .0045$^{***}$ | | .0041$^{**}$ |
| | (-2.796) | | (3.618) | (3.336) | | (2.629) |
| 1987 | | -.0062$^{**}$ | | | | |
| | | (-2.675) | | | | |
| SEE | .0019082 | .0022033 | .0007100 | .0007011 | .0011689 | .0012087 |
| $\overline{R}^2$ | .72947 | .68763 | .95973 | .96024 | .78006 | .77256 |
| Max log-likelihood | 90.7139 | 88.7727 | 104.0603 | 104.2310 | 97.3303 | 96.8778 |

Notes: 1. Estimated by GLS, Cochrane-Orcutt iterative method.
2. t- values are in parentheses below coefficients.
3. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

**Table 4 Regressions of the Restricted Version of PED Series**

| | Equations | | |
|---|---|---|---|
| | PED(L) | PED(K) | PED(M) |
| Intercept | -0.28437*** | -0.58625*** | -0.23770*** |
| | (-3.5202) | (-5.7508) | (-12.5378) |
| lnGNOC | -0.0030176 | -0.00623 | -0.01041*** |
| | (-0.6242) | (-0.5512) | (-4.1262) |
| sse | 0.0030176 | 0.0009388 | 0.0015049 |
| $\overline{R}^2$ | 0.60785 | 0.95120 | 0.74044 |
| Max Log-likelihood | 84.5271 | 100.2896 | 93.9194 |
| Joint F-test | 69.7663a*** | 4.0685b** | 3.4494c** |

Notes: 1. t-values are in parentheses below coefficients.
2. Of the joint F-test values, a is based on (1) of PED(L), b is on (2) of PED(K), and c is on (1) of PED(M) in Table 3.
3. ***, ** and * indicates significance at the 1%, 5% and 10% levels, respectively.
4. The 5% significance value for $F_{(2,24)}$ is 3.40 and 1% value is 5.61.

## Appendix

**data sources:**

1. DGBAS: National Income Yearbook, Taiwan Area, ROC. (NIY)
2. DGBAD: Commodity-Price Statistics Monthly, Taiwan Area, ROC. (CPSM)
3. DGBAS: Survey of National Wealth, 1988, Taiwan Area, ROC. (SNW)
4. COA: Basic Agricultural Statistics, ROC. (BAS)

**Descriptions:**

1. Total cost of agricultural production is defined as the sum of payments to labour, capital services, and material inputs. Cost share of each input is calculated correspondingly.
2. Net value of production in real terms is obtained by subtracting the indirect taxes and depreciation from the gross value of production and then by deflating with the output price index.
3. The capital stock defined in this study includes buildings and attached facilities, structural construction, transport equipments, machineries, animals and plants, as well as the land, which is usually fixed in the short term and not depreciable. The stock at the end of each year ($K_t$) is calculated from the relation $K_t = K_{t-1} + I_t - D_t$, where $I_t$ and $D_t$ are the gross investment and depreciation occurred in year t, respectively. Capital stock in1988 is used as base which is drawn from SNW. To obtain the actual capital services, we adjust the existing stock by the utilization rate which is approximated by that of the Taiwan Power Co. Price of capital services is obtained by using average method, namely dividing the quantity of capital utilized into the total payments to capital owners.
4. Total expenditure on labour is the product of hourly wage rate and the quantity of labour employed. Payroll of the hired male workers

is used as wage rate. Total employment includes both the hired and family labour. Total quantity of labour input is measured by total working hours of all employment in a year. 240 hours per month is used as an average of working hours.

5. Total payments on materials and intermediates in nominal values and the price indices of intermediate inputs are extracted directly from CPSM and NIY.

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