



## **MEASUREMENT OF TECHNOLOGICAL CHANGE BIASES AND FACTOR SUBSTITUTIONS FOR THE MALAYSIAN RICE FARMING**

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### **ABSTRACT**

Due to a full-fledged initiation of irrigation facilities into all of Malaysia's major designated paddy areas in the late 1970s, the rice farming sector has undergone rapid transformation. In particular, double-cropping has become possible. However, never in the past have studies been undertaken to explicitly incorporate, and thus, investigate this recent phenomenon by means of a macro-type, and time series of cross-section data. Using a translog cost function approach, and by incorporating the seasonal and proximity factors into the analysis, the present paper empirically investigates the production structures underlying Malaysian rice farming for the period 1980-90. The results, though, seem to support Hicks' induced-innovation hypothesis and to some extent, the criticism against the Green Revolution. Perhaps, the method employed here could also be applied to investigate other countries' production structures whose rice farming sector shares similar characteristics to that of Malaysia.

JEL classification: C23, D24, O39

Key words: Production structures, Technological change, Factor substitutions

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### **1. INTRODUCTION**

Malaysian rice farming, before the advent of the Green Revolution in the early 1960s, was primarily preoccupied by small farms and largely devoted to single cropping. During those years the practice of double cropping was essentially in only four states. These include Kedah, Perak and Province Wellesley (later known as Seberang Prai) in the North, and Kelantan in the East Coast. In all these states, however, the percentage of acreage double-cropped was minuscule.

Later, in the 1970s, one crucial turning point in the history of Malaysian rice farming took place. During this period there was a full-fledged initiation of irrigation facilities into virtually all rice-planted states. They are: the Northwest Selangor project (NWSP) in Selangor; Muda Irrigation Project (MIP or MADA) in Kedah; Kemubu Irrigation Project (KIP or KADA) in Kelantan; Kerian Irrigation Project (KEIP), Sungai Manik Irrigation Project (SMIP) and Trans-Perak Irrigation Project, all in Perak; Besut Irrigation Project (BIP) in Trengganu; and, Seberang Prai Irrigation Project (SPP) in Pulau Pinang.<sup>1</sup>

With the availability of such facilities, in addition to main-season, the off-season rice planting has since become possible. Specifically, while before the initiation of the massive irrigation facilities most of the farmers grew only one crop a year between May and November (i.e., after and before the Northeast monsoon), after such initiation rice could be grown between December and May (i.e., the dry season). As a consequence, it is expected that there exist some differences in the production structure between the two cropping seasons, particularly those that are related to biases of technological change and factor substitutions. The difference in production structure caused by the introduction of irrigation facilities, if it exists, is known as the seasonal factor in the present study.

Meanwhile, it is interesting to note that during the 1980s the manufacturing sector had a strong influence on the Malaysian economy. Its contribution to the Gross Domestic Product (GDP) had gradually increased, i.e., from 20 percent in 1980 to 27 percent in 1990. On the contrary, the contribution of agricultural sector to the GDP for the same period showed a decreasing trend, i.e., from 23.8 percent in 1980 to 18.7 percent in 1990. In relation to this, and what makes it more interesting and relevant to the study is that two of Malaysia's most important industrial areas in which electrical and electronic products are produced are located relatively close to two major granary areas mentioned above.<sup>2</sup> While the Petaling Jaya and Shah Alam industrial areas (both situated in the Klang Valley of which Malaysia's capital city, Kuala Lumpur, takes a larger share) are approximately 90 km away from NWSP, Mak Mandin industrial area (which is situated in Pulau Pinang) is just 70 km away from KEIP. It is expected that with, on the one hand, the manufacturing sector showing an increasing influence on the economy, and, on the other, the industrial areas located differently (in terms of distance) among the granary areas, the following economic phenomenon may take place: there will be stiff competition between the manufacturing sector and the rice farming sector to procure

some of the factors of production, especially labor and land, such that there exist some differences in the production structure between the granary areas that are located closer to the industrial areas (NWSP and KEIP) and the ones that are not (MADA and KADA). Because this economic phenomenon had never been empirically investigated before, it will be incorporated and noted as the proximity factor in the paper.

## 2. MALAYSIAN RICE FARMING PRODUCTION STRUCTURES: A BRIEF LITERATURE SURVEY

As a first step to verify whether the factors identified above do actually give significant effects on the production structure of each granary area and season, we compute, based on the Caves, Christensen and Diewert (1982) proposed procedures, the contribution of all factor inputs (machinery, labor, intermediate inputs and land) in terms of percentage to the total cost of production for the 1980-90 period.<sup>3</sup> The results tend to suggest that the contribution of each factor input to total cost is fairly different among granary areas, and between seasons. First, let us take the proximity factor as the basis for comparison. While, for example, the labor input of NWSP (main- and off-seasons) contributed between 18 to 29 percent, the one of KADA (main- and off-seasons) contributed between 31 to 43 percent to the total cost during the entire period. Second, we take the seasonal factor as the basis for comparison. In the case of KADA while, for example, the machinery input of the main-season contributed between 8 to 27 percent, the off-season contributed between 9 to 13 percent to the total cost for the same period.

What were the factors behind the differences in the contribution of each factor input of each granary area and season to the total cost? Would they lead to a sharp contrast in terms of biases of technological change and factor substitutions among the granary areas, and between seasons? In spite of this having become an important issue, empirical studies, which have been specifically undertaken to investigate the proximity and seasonal factors effects on Malaysian rice farming biases of technological change and factor substitutions, are still lacking.<sup>4</sup> Goldman and Squire (1982), for example, in their study of MADA granary area labor use and technical change touched fairly little on the seasonal aspect and largely ignored the proximity aspect. Their main finding, among others, is that the technology embodied in this granary area was labor-saving. Meanwhile, though Haughton (1986) utilized various functional forms such as the translog production function and the quadratic restricted profit function to analyze the Malaysian rice

farming production structure, the study falls short of applying the translog cost function, the latest methodological framework to measure production structure of a production unit.

The present study, however, distinguishes itself from the previous ones in that: (i) instead of using micro-type data, it uses macro-type data; (ii) instead of utilizing time series data, it utilizes time series of cross-section data; (iii) it also incorporates the recently developed method of measuring total bias effect suggested by Capalbo and Antle (1988); and, finally (iv) it employs the translog cost function approach. In fact, this study reports the first measurement of Malaysian rice farming biases of technological change and factor substitutions by explicitly incorporating the seasonal and proximity factors based on the (i)-(iv) empirical study techniques. Since by applying the technique to the Malaysian rice farming data sets the results seem to be economically and econometrically interpretable, we conjecture that the same methodological framework can be applied to other countries whose rice farming sector shares similar characteristics to that of Malaysia. Perhaps, Sri Lanka and Indonesia are potential candidates.

With the above brief introduction and literature survey, the paper proceeds as follows. In section 3, we present a theory of measuring biases of technological change and factor substitutions using a cost function approach. This is followed, in Section 4, by the discussions on the econometric modeling and the sources of data used in this study. In this section also the Capalbo and Antle (1988) proposed procedures to compute the total bias effect is shown. While Section 5 reports the empirical results, Section 6 provides the summary and concluding remarks.

### 3. THE TOTAL COST FUNCTION

To derive the model used in this study, suppose that the production structure for the case of one output – rice ( $Y$ ), and four factor inputs – labor ( $L$ ), machinery ( $M$ ), intermediate inputs ( $U$ ) and land ( $B$ ), can be expressed in the following form:

$$(1) \quad Y = f(X, T)$$

where  $X$  is a vector of  $m$  inputs,  $T$  is time, which indicates the effect of technological change, and  $Y$  denotes output. Assuming that input prices,  $CA_i$ , where  $i = (L, M, U, B)$ , are exogenously determined, the dual cost

function may be written as:

$$(2) \quad C = g(W_L, W_M, W_U, W_B, Y, T)$$

where production cost ( $C$ ) is a function of the input prices of labor ( $W_L$ ), machinery ( $W_M$ ), intermediate inputs ( $W_U$ ), and land ( $W_B$ ), the level of output ( $Y$ ), and time ( $T$ ). We assume that factor markets are competitive<sup>5</sup> and each farm is willing to supply all output demanded at any given price. Thus, input prices and output are treated as exogenous variables while input levels are endogenous. Applying Shephard's lemma to (2) yields,

$$(3) \quad \frac{\partial C(W_L, W_M, W_U, W_B, Y, T)}{\partial W_i} = X_i(W_L, W_M, W_U, W_B, Y, T)$$

Then, multiplying both sides of (3) by  $W_i/C$  and rearranging, the cost share equations of the  $i^{\text{th}}$  factor inputs are obtained as

$$(4) \quad \sum_{i=1}^4 \frac{\partial \ln C}{\partial \ln W_i} = \sum_{i=1}^4 \frac{\partial C}{\partial W_i} \cdot \frac{W_i}{C} = \sum_{i=1}^4 \frac{W_i X_i}{C} = \sum_{i=1}^4 S_i = 1,$$

Note that

where  $\frac{W_i X_i}{C} = S_i$  denotes the cost share of the  $i^{\text{th}}$  input.

Next, logarithmically differentiating the right-hand side of (3) with respect to (w.r.t.) time ( $T$ ) yields:

$$(5) \quad \frac{d \ln X_i}{dT} = \frac{\partial \ln X_i}{\partial \ln Y} \cdot \frac{\dot{Y}}{Y} + \sum_{k=1}^4 \frac{\partial \ln X_i}{\partial \ln W_k} \cdot \frac{\dot{W}_k}{W_k} + \frac{\partial \ln X_i}{\partial T}$$

where  $i \neq k$ ,  $i, k = (L, M, U, B)$ . The variables with a dot on top denote a differentiation w.r.t. time ( $T$ ). Equation (5) shows that the growth rate of factor inputs can be decomposed into output effects, price effects,

and technological change effects.

Next, to obtain a relative change in a factor of say,  $i$ th input use, w.r.t. a change in another factor of say,  $j$ th input use, we express the left-hand side of equation (5) in proportional change form:

$$(6) \quad \frac{(d \ln X_i / d \ln X_j)}{dT} = \frac{d \ln X_i}{dT} - \frac{d \ln X_j}{dT} = \frac{\dot{X}_i}{X_i} - \frac{\dot{X}_j}{X_j}$$

Using (5), equation (6) can be rewritten as:

$$(7) \quad \frac{(d \ln X_i / d \ln X_j)}{dT} = \left[ \frac{\partial \ln X_i}{\partial \ln Y} \cdot \frac{\dot{Y}}{Y} - \frac{\partial \ln X_j}{\partial \ln Y} \cdot \frac{\dot{Y}}{Y} \right] \\ + \left[ \sum_{k=1}^4 \frac{\partial \ln X_i}{\partial \ln W_k} \cdot \frac{\dot{W}_k}{W_k} - \sum_{k=1}^4 \frac{\partial \ln X_j}{\partial \ln W_k} \cdot \frac{\dot{W}_k}{W_k} \right] \\ + \left[ \frac{\partial \ln X_i}{\partial T} - \frac{\partial \ln X_j}{\partial T} \right]$$

where  $i \neq k, j; i, j, k = (L, M, U, B)$ . From cost shares  $W_i X_i / C = S_i$  and  $W_j X_j / C = S_j$  where  $i \neq j; i, j = (L, M, U, B)$ , the output effect and the technological change effect of (7) may be further decomposed as follows. Taking natural logarithms of both sides of  $W_i X_i = S_i$  and  $W_j X_j / C = S_j$  respectively, and rearranging we obtain:

$$(8a) \quad \ln X_i = \ln C + \ln S_i - \ln W_i$$

$$(8b) \quad \ln X_j = \ln C + \ln S_j - \ln W_j$$

Using (8a) and (8b), the following relations are obtained:

$$(9a)^6 \quad \frac{\partial \ln X_i}{\partial \ln Y} = \frac{\partial \ln C}{\partial \ln Y} + \frac{\partial \ln S_i}{\partial \ln Y}$$

$$(9b) \quad \frac{\partial \ln X_j}{\partial \ln Y} = \frac{\partial \ln C}{\partial \ln Y} + \frac{\partial \ln S_j}{\partial \ln Y}$$

and

(10a)

$$(10b) \quad \frac{\partial \ln X_j}{\partial T} = \frac{\partial \ln C}{\partial T} + \frac{\partial \ln S_j}{\partial T}$$

Expressing  $\partial \ln X_i / \partial \ln W_k = \eta_{ik}$ , and  $\partial \ln X_j / \partial \ln W_k = \eta_{jk}$ , respectively, and then substituting (9a), (9b), (10a) and (10b) into (7) yields,

$$(11)^7 \quad \frac{(d \ln X_i / d \ln X_j)}{dT} = \left[ \frac{\partial S_i}{\partial \ln Y} \cdot \frac{1}{S_i} \frac{\dot{Y}}{Y} - \frac{\partial S_j}{\partial \ln Y} \cdot \frac{1}{S_j} \frac{\dot{Y}}{Y} \right]$$

$$\frac{\partial \ln X_i}{\partial T} = \frac{\partial \ln C}{\partial T} + \frac{\partial \ln S_i}{\partial T} \left[ \sum_{k=1}^4 \eta_{ik} \frac{\dot{W}_k}{W_k} - \sum_{k=1}^4 \eta_{jk} \frac{\dot{W}_k}{W_k} \right] + \left[ \frac{\partial S_i}{\partial T} \cdot \frac{1}{S_i} - \frac{\partial S_j}{\partial T} \cdot \frac{1}{S_j} \right]$$

The first term on the right-hand side of (11) measures the effect of scale change on the relative factor use (i.e., the scale effect). The second term measures the effect of factor substitutions due to factor price change (i.e., the factor substitutions effect). The last term measures the effect of technological change on relative factor use (i.e., the technological change bias effect).

## 4. ECONOMETRIC MODELING

### 4.1 THE TRANSLOG COST FUNCTION

In order to compute the terms in the decomposed equation (11), we specify the cost function in translog form. Assuming that the translog cost function is represented by:

$$(12) \quad \ln C = \alpha + \sum_{i=1}^4 \alpha_i \ln W_i + \alpha_Y \ln Y + \frac{1}{2} \sum_{i=1}^4 \sum_{j=1}^4 \gamma_{ij} \ln W_i \ln W_j$$

$$\begin{aligned}
& + \frac{1}{2} \gamma_{YY} (\ln Y^2) + \frac{1}{2} Y_{TT} (T^2) + \sum_{i=1}^4 \gamma_{iY} \ln W_i \ln Y \\
& + \sum_{i=1}^4 \gamma_{iT} \ln W_i T + \gamma_{YT} \ln YT
\end{aligned}$$

The cost-share equations are derived through Shephard's lemma as:

$$(13) \quad S_i + \alpha_i + \sum \gamma_{ij} \ln W_j + \sum_{i=1}^4 \gamma_{iY} \ln Y + \sum_{i=1}^4 \gamma_{iT} T$$

Using (13) and rearranging, the terms in equation (11) can be reduced to:

$$\begin{aligned}
(14) \quad \frac{(d \ln X_i / d \ln X_j)}{dT} &= \left[ \frac{\gamma_{iY}}{S_i} \frac{\dot{Y}}{Y} - \frac{\gamma_{jY}}{S_j} \frac{\dot{Y}}{Y} \right] + \left[ \frac{\gamma_{iT}}{S_i} - \frac{\gamma_{jT}}{S_j} \right] \\
&+ \left[ \sum_{k=1}^4 \eta_{ik} \frac{\dot{W}_k}{W_k} - \sum_{k=1}^4 \eta_{jk} \frac{\dot{W}_k}{W_k} \right]
\end{aligned}$$

where  $i \neq k, j; j, k = (L, M, U, B)$ . Equation (14) will be used to estimate the production structures related to the ones defined in equation (11). We note further, however, if the first term on the right-hand side of equation (14) is added to the second term it will give rise to the definition of total bias effect as proposed by Capalbo and Antle (1988).<sup>8</sup>

As shown by Capalbo and Antle, if the technology is homothetic, then the first term will vanish because  $\partial \ln S_i / \partial \ln Y = 0$  (or in parametric form  $\gamma_{iY} = 0$ ), for all  $i = (L, M, U, B)$ . Meanwhile, in the case of the second term, if the technical change is Hicks neutral, then its effects on the proportional change in requirements for two factor inputs would be identical. However, in this study this term indicates the effect of non-neutral technical change bias or bias of technological change effect. The third term remains as defined before.

If we define  $NB_i = \gamma_{iY} / S_i$ , then the bias due to scale effect is non-homothetically  $i$ th factor-saving, neutral, or factor-using accordingly



as  $NB_i < 0$ ,  $NB_i = 0$ , or  $NB_i > 0$ .

Next, if we define  $TB_i = \gamma_{iY}/S_i$ , then the bias of technological change effect is  $i$ th factor-saving, neutral, or factor-using accordingly as  $TB_i < 0$ ,  $TB_i = 0$ , or  $TB_i > 0$ .<sup>9</sup>

Finally, if we define  $CA_i = NB_i + TB_i$ , then the total bias effect is  $i$ th factor-saving, neutral, or factor-using accordingly as  $CA_i < 0$ ,  $CA_i = 0$ , or  $CA_i > 0$ .

Because we are not only interested in computing the parameters related to technological change bias effect, scale bias effect and total bias effect, but also factor substitutions of equation (14), the following procedures to compute the parameters of the last term of (14) are deemed necessary. Following Bernt and Christensen (1973), the price elasticities of demand for factor inputs can be computed as:

$$(15) \quad \eta_{ii} = S_i \sigma_{ii}$$

$$(16) \quad \eta_{ij} = S_i \sigma_{ij}$$

where  $\sigma_{ii}$  and  $\sigma_{ij}$  are the Allen partial elasticities of substitution and can be obtained using the method of computation suggested by Binswanger (1974):

$$(17) \quad \sigma_{ii} = (\gamma_{ii} + S_i^2 - S_i) / S_i^2$$

$$(18) \quad \sigma_{ij} = (\gamma_{ij} + S_i S_j) / S_i S_j$$

As cost function is used to measure  $NB_i$ ,  $TB_i$ ,  $CA_i$  and  $\eta_{ik}$ , the function should satisfy the following regularity conditions (Diewert, 1978) to represent a well-behaved technology: (i) linearly homogeneous in input prices; (ii) positive and monotonically increasing in input prices; and (iii) concavity in input prices. These theoretical assumptions require the following restrictions on their parameters:

i. linearly homogeneous in input prices:

$$(19) \quad \sum_{i=1}^4 \alpha_i = 1, \quad \sum_{i=1}^4 \gamma_{ij} = \sum_{j=1}^4 \gamma_{ji} = 0, \quad \sum_{i=1}^4 \gamma_{iY} = 0$$

ii. positive and monotonically increasing in input prices:

$$(20) \quad S_i = \frac{d \ln C}{d \ln W_i} \geq 0$$

where  $S_i$  represents the cost share of each factor input.

- iii. concavity in input prices. A sufficient condition for concavity of the cost function in input prices is that the Hessian matrix of second partial derivatives w.r.t. factor prices be negative semi-definite. An equivalent test of concavity is that the symmetric matrix of Allen partial elasticities of substitution be negative semi-definite (Nautiyal and Singh, 1986). A necessary condition for the matrix to be negative semi-definite is that all of the Allen elasticities of substitution be negative.

For econometric estimation, the cross-equations equality and the linear homogeneity restrictions defined in (19) are imposed *a priori* on the translog cost function (12), and on the cost-share equations (13). This allows us to drop arbitrarily any one of the four cost-share equations. In the present study, the cost-share equation of land was omitted. The estimates of the coefficients of this equation can be obtained by using the parameter relationships of the linear homogeneity restrictions, once the system of the remaining cost-share equations have been estimated. Given this set of conditions, we choose the iterative seemingly unrelated regression (ISUR) method.

## 4.2 DATA SOURCES

The main sources of data used for the study were gathered from published statistics and reports by each granary area development authority. The variables required to estimate the cost function model are the total cost, the quantity of output, and the prices and cost-shares of the four factors of production, namely labor ( $L$ ), machinery ( $M$ ), intermediate inputs ( $U$ ) and land ( $B$ ). We processed the collected data for each granary area and season according to the variable requirements where such variable index computation was based on Caves, Christensen and Diewert's (1982) proposed procedure.

## 5. EMPIRICAL RESULTS

Table 1 reports the complete results of the parameter estimates of the

translog cost function. The  $R$ -squared ( $R^2$ ) for the cost function and the three cost-share equations,  $S_L$ ,  $S_M$ ,  $S_U$ , were 0.992, 0.866, 0.621 and 0.600, respectively, indicating a fairly good fit of the model.

TABLE 1  
Parameter Estimates of the Translog Cost Function for Malaysian  
Rice Farming, 1980-90

Coefficient	Estimate	$t$ -statistics	Coefficient	Estimate	$t$ -statistics
$\alpha$	3.30	117.17	$\gamma_{LU}$	0.42	5.97
$\alpha_L$	0.34	75.69	$\gamma_{LB}$	-0.26	-2.28
$\alpha_M$	0.13	24.78	$\gamma_{MU}$	0.18	1.07
$\alpha_U$	0.26	64.40	$\gamma_{MB}$	0.10	0.50
$\alpha_B$	0.27	3.75	$\gamma_{UB}$	0.02	0.11
$\alpha_Y$	0.41	5.69	$\gamma_{LT}$	-0.03	-4.35
$\alpha_T$	-0.01	-0.35	$\gamma_{MT}$	0.10	1.14
$\gamma_{LL}$	-0.37	-4.61	$\gamma_{UT}$	0.01	1.92
$\gamma_{MM}$	-0.48	-2.80	$\gamma_{BT}$	0.58	0.14
$\gamma_{UU}$	-0.63	-3.25	$\gamma_{LY}$	-0.05	-0.10
$\gamma_{BB}$	0.13	0.64	$\gamma_{MY}$	0.04	5.55
$\gamma_{YY}$	-0.26	-3.44	$\gamma_{UY}$	-0.04	-7.80
$\gamma_{TT}$	0.10	2.37	$\gamma_{BY}$	0.08	0.04
$\gamma_{LM}$	0.20	2.60	$\gamma_{YT}$	-0.43	-0.10

Note: Coefficients for land ( $B$ ) were obtained using the parameter restrictions of linear homogeneity.

As can be seen from the table, the linear homogeneity and monotonicity conditions are both satisfied by the model. This is shown

by  $\sum_{i=1}^4 \alpha_i = 1$  and  $\alpha_i > 0$  or  $S_i > 0$ , for all  $i = (L, M, U, B)$  respectively.

The latter condition was estimated at the approximation point.

Table 2 presents the overall overview results of parameter estimates of Allen partial elasticities of substitution. As evident from the table, the concavity condition, as indicated by the own Allen partial elasticities of substitution which are all negative, is also satisfied by the model. Since the model satisfies the basic regularity conditions, we conclude that the estimated cost function represents well-behaved technology.

TABLE 2  
Allen Partial Elasticities of Substitution for Malaysian Rice Farming,  
1980-90: An Overall Overview

Parameter	Estimate	<i>t</i> -statistic	Behavioral Pattern
$\sigma_{LL}$	-5.04	-19.61	OAPES
$\sigma_{MM}$	-34.74	-3.08	OAPES
$\sigma_{UU}$	-12.36	-4.76	OAPES
$\sigma_{BB}$	-0.88	-0.29	OAPES
$\sigma_{LM}$	5.43	3.18	Substitutes
$\sigma_{LU}$	5.79	6.44	Substitutes
$\sigma_{LB}$	-1.77	-1.28	Complements
$\sigma_{MU}$	6.45	3.08	Substitutes
$\sigma_{MB}$	3.83	0.66	Substitutes
$\sigma_{UB}$	1.33	0.46	Substitutes

Note: OAPES=Own Allen Partial Elasticities of Substitution

It is also obvious from Table 2 that three factor inputs are substitutable pairs and they are all statistically significant. They are: labor-machinery pair ( $\sigma_M$ ); labor-intermediate inputs pair ( $\sigma_{LU}$ ); and machinery-intermediate inputs pair ( $\sigma_{MU}$ ). This means that any increase in the price of say, labor, both machinery and intermediate inputs are possible candidates to be substituted for labor.

We turn our attention to scale bias, technological change bias and total bias effects. Table 3 indicates to us that only two parameters are statistically significant at the 5 percent level, each representing bias of technological change and total bias effects. In both cases, labor is factor-saving biased. On the other hand, while machinery is factor-using in the case of total and technological change biases, intermediate inputs are factor-saving biased in the case of scale bias. They are all statistically significant at the 20 percent level. The intermediate inputs' factor-saving is worth interpreting. In this case it means that, on average, a 1 percent increase in output resulted in only 0.2 percent increase in the demand for intermediate inputs.

Except for intermediate inputs, the results appearing from Tables 2 and 3 seem to suggest that, on average, Malaysian rice farming is progressing in a way consistent with Hicks' induced-innovation hypothesis.

Next, Table 4 reports the detailed scenario of behavioral patterns of each farming classification in terms of Allen partial elasticities of

substitution. While the results pertaining to labor-machinery and, to some extent, labor-intermediate inputs pairs are consistent with ones of the overall overview (Table 2), the machinery-intermediate inputs pair is not. In the case of the latter pair, the results are split. On the one hand, the input pair is complementary for old and new projects, while on the other, it is a substitutable pair for main season. The results of the estimated parameters discussed here are all statistically significant. Thus, we may infer that in both old and new projects any decrease in the price of machinery tends to increase the demand for intermediate inputs.

TABLE 3  
Technological Change Bias Effect ( $TB_i$ ), Scale Bias Effect ( $NB_i$ ) and Total Bias Effect ( $CA_i$ ) for Malaysian Rice Farming, 1980-90: An Overall Overview

Parameter	Estimate	<i>t</i> -statistic	Classification of Bias Effect
$TB_L$	-0.090	-3.49	factor-saving
$TB_M$	0.070	1.42	factor-using
$TB_U$	0.060	0.34	factor-using
$TB_B$	0.020	0.14	factor-using
$NB_L$	-0.000	-0.03	factor-saving
$NB_M$	0.003	0.50	factor-using
$NB_U$	-0.002	-1.37	factor-saving
$NB_B$	0.000	0.04	factor-using
$CA_L$	-0.090	-3.69	factor-saving
$CA_M$	0.780	1.44	factor-using
$CA_U$	0.050	0.03	factor-using
$CA_B$	0.020	0.14	factor-using

Note: Parameters of  $CA_i$  were computed by adding the parameter estimates of ( $TB_i$ ) to ( $NB_i$ ).

Finally, Table 5 shows the estimated parameter results related to scale bias, technological change bias and total bias effects of each farming classification. As can be seen from the table, the results of the technological change bias effect are consistent with the overall overview shown in Table 2. That is, labor is a factor-saving input. Nevertheless, the results of the scale bias effect are split between the off- and main-seasons. While in the off-season intermediate inputs are factor-using, they are factor-saving in the opposite season. Thus, in the former season

any increase in rice output will call for an increasing demand for intermediate inputs. All of the estimated parameter results discussed here are statistically significant. It is also worth noting that when the parameters were computed according to Capalbo and Antle's proposed procedures the results have slightly changed. Specifically, labor remained as a factor-saving input and statistically significant, but intermediate inputs in all farming classifications became neutral and statistically insignificant.

TABLE 4  
Allen Partial Elasticities of Substitution for Malaysian Rice Farming,  
1980-90: A Detailed Overview

Parameter	Behavioral Patterns	
	Complements	Substitutes
$\sigma_{LM}$	N.A.	MS*, OP*, NP*, OS
$\sigma_{LU}$	OP	MS*, OS*, NP*
$\sigma_{LB}$	OS, OP, NP, MS	N.A.
$\sigma_{MU}$	OP*, OS, NP*	MS*
$\sigma_{MB}$	N.A.	OS, OP, NP, MS
$\sigma_{UB}$	OP	MS, OS, NP

**Notes:** OS=Off-season; MS=Main-season; NP=New Project; OP=Old Project;

\* Indicates the coefficients are statistically significant at least at the 10% level;

N.A. = Not Applicable.

## 6. SUMMARY AND CONCLUDING REMARKS

Using a translog cost function approach we estimated the production structures that are related to factor substitutions, scale bias, technological change bias, and total bias effects of Malaysian rice farming. We presumed that the proximity and seasonal factors contributed differently to farmers' behavior towards utilization of factors of production. From the results discussed in Section 5, we may extract at least three major findings. They are:

i. Irrespective of area and season (i.e., irrespective of proximity and seasonal factors), labor is factor-saving biased. This finding is at variance with one of Goldman and Squire's (1982) whose finding indicates that labor was factor-using in the MADA granary area. The reason for such a different finding between theirs and ours is possibly due to the period when the study was undertaken. Goldman and Squire undertook the study in 1981 where the data used for the analysis covered

TABLE 5:  
Technological Change Bias Effect ( $TB_i$ ), Scale Bias Effect ( $NB_i$ ) and  
Total Bias Effect ( $CA_i$ ) for Malaysian Rice Farming, 1980-90: A  
Detailed Overview

Parameter			Classification of Bias Effects		
$TB_i$	$NB_i$	$CA_i^{\#}$	$TB_i$	$NB_i$	$CA_i$
$TB_L^1$	$NB_L^1$	$CA_L^1$	factor-saving*	factor-using	factor-saving**
$TB_M$	$NB_M$	$CA_M$	factor-using	factor-saving	factor-using
$TB_U$	$NB_U$	$CA_U$	factor-using	factor-saving**	factor-using
$TB_B$	$NB_B$	$CA_B$	factor-saving	factor-using	factor-saving
$TB_L^2$	$NB_L^2$	$CA_L^2$	factor-saving*	factor-saving	factor-saving*
$TB_M$	$NB_M$	$CA_M$	factor-saving	factor-using	factor-saving
$TB_U$	$NB_U$	$CA_U$	factor-using	factor-using	factor-using
$TB_B$	$NB_B$	$CA_B$	factor-using	factor-saving	factor-using
$TB_L^3$	$NB_L^3$	$CA_L^3$	factor-saving*	factor-using	factor-saving*
$TB_M$	$NB_M$	$CA_M$	factor-using**	factor-using	factor-using**
$TB_U$	$NB_U$	$CA_U$	factor-using	factor-saving*	factor-using
$TB_B$	$NB_B$	$CA_B$	factor-using	factor-using	factor-using
$TB_L^4$	$NB_L^4$	$CA_L^4$	factor-saving*	factor-using	factor-saving*
$TB_M$	$NB_M$	$CA_M$	factor-saving	factor-saving	factor-saving
$TB_U$	$NB_U$	$CA_U$	factor-using	factor-using*	factor-using
$TB_B$	$NB_B$	$CA_B$	factor-using	factor-saving	factor-using

**Note:** 1 = Old Project; 2 = New Project; 3 = Main-Season; 4 = Off- Season

$\#$  Parameters of the third column for all farming classifications were computed by adding the parameters of the first to the second column.

\* and \*\* are the coefficients that are statistically significant at the 5% and 20% levels, respectively.

the period before 1980. We, however, undertook the study with the data covering the 1980-90 period. Taking these findings into consideration, one may infer that labor utilization has shifted from once being factor-using to then being factor-saving. We may also conclude from this finding that the proximity and seasonal factors contribute indifferently to farmers' behavior towards labor utilization during the period under survey. Labor, to reiterate, is factor-saving in all farming classifications. Perhaps, there are two reasons for this. First, this is due to better education that the young generation had received which in turn had allowed them to seek better jobs in the surrounding urban and industrial areas. Thus, it is left to the old generation to work on paddy fields. Second, better techniques of rice cultivation introduced by the

respective regional authorities which were, among others, intended to save labor cost, have also contributed to labor-saving bias technology adopted by the farmers. Direct seeding, which has gradually replaced the older technique, generally known as transplanting, is one of the examples. The former technique saved between 20 to 30 percent of labor man-hours employed, and thus labor cost (Ministry of Agriculture, 1982).

ii. As evident from Table 4, irrespective of farming classifications, machinery and intermediate inputs are labor substitutable pairs. Thus, no matter where the farmers operate their farms (i.e., regardless of the proximity factor) and no matter when they grow the paddy (i.e., regardless of the seasonal factor), faced with a labor shortage problem, machinery and intermediate inputs can always be substituted for labor.

iii. From the empirical results of scale bias effect, intermediate inputs are found to be factor-using in the off-season, and factor-saving in the main-season and for old projects. This tends to suggest that seasonal and, to some extent, proximity factors play a significant role in influencing farmers' behavior towards intermediate inputs utilization. The finding which suggests that the intermediate inputs are factor-using in the off-season is worth elaborating. With this finding the criticism against the Green Revolution seems to be justifiable. Pinstrup and Hazell (1985), for example, have pointed out that "the Green Revolution is based on a combination of varieties with high yield potential (HYVs), fertilizers, irrigation and in some cases chemical pesticides and mechanization." To put it differently, this says that each component of the intermediate inputs; irrigation, HYVs, agri-chemicals and fertilizers (in the present study, all of these inputs are grouped together and called intermediate inputs), must be utilized all at once, and the more output to be produced (in the off-season), the greater the amounts of intermediate inputs required. In the event of the non-existence of one of the intermediate input components, the rice production will be below the expected level. In many ways, farmers who operate the land outside the granary areas are at a disadvantage mainly because in these areas one of the intermediate input components is unavailable, namely irrigation. The Beranang area, as cited by Devendra and Abdul Aziz (1994), is a classic example of such a case.

Given these findings, the following policy implications are deemed conceivable.

i. Since labor has been identified as factor-saving, and machinery



and intermediate inputs have been identified as labor substitutable pairs, this could provide a basis for the government to implement policies related to the utilization of these factor inputs – labor, machinery and intermediate inputs. For instance, faced with a shortage of labor which is possibly due to increasing demand from the manufacturing and/or construction sectors (i.e., the two main contributors to Malaysia's rapid economic growth which had been growing at the rate of more than 8 percent for eight consecutive years in the late '80s to early '90s), it is either machinery or intermediate inputs which could be used for labor substitutions. However, as pointed out by Ayob Sukra (1986), when machinery was used, a number of problems emerged. He indicated the non-availability of suitable hardware for specific field conditions such as deep water, soft soil, wet harvest, small plot leveling, and dry tillage on heavy clay as the examples. These conditions, in many ways, had hampered the widespread use of machinery services in some of the granary areas. Hence, in the future it seems that the intermediate inputs will be in a better position, in some granary areas, to be substituted for labor if the latter input is in shortage.

ii. As indicated by the third finding, the intermediate inputs are factor-using in the off-season. Now, if the rice production is to be increased in this season, a corresponding increase in the utilization of intermediate inputs is undoubtedly necessary. Thus, a policy, which is specifically designed to make a leeway for farmers to have access to more fertilizers, high quality seeds and agri-chemical inputs (apart from irrigation facilities) during the off-season cultivation is recommended. Since fertilizers and seeds are fully and partially subsidized, respectively, by the government, the only option left is to sell the agri-chemicals (by private dealers) at a price which is more affordable by all types of rice cultivators – the owner cultivators, tenant-owner cultivators and tenant cultivators.

#### ENDNOTES

1. However, in this study we will focus on the first four projects, which together account for more than 80 percent of Malaysia's rice planted area and 85.0 percent of Malaysia's total rice production.
2. The exact location of the major granary areas and industrial areas mentioned throughout this paper can be found in Devendra and Abdul Aziz (1994).

3. The complete results which show each granary area and each season's factor input contributions to the total cost in percentage terms will be extended to interested reader(s), upon request.
4. With the inclusion of the seasonal and proximity factors into the analysis, we can now classify Malaysian rice farming as follows: (i) Old Project (OP) - MADA and KADA; (ii) New Project (NP) - NWSP and KEIP; (iii) Main Season (MS); and, (iv) Off Season (OS). A detailed description of each classification can be found in Abdullah (2000).
5. The reality of Malaysian rice sector factor markets is available in Abdullah (2000).
6. The term which involves a differentiation of  $W_i$  w.r.t.  $Y$  does not appear here because when we differentiated equation (3) w.r.t. time ( $T$ ) to obtain equation (5), we assumed that  $Y$  and  $W_i$  were given. Thus, as a result  $W_i$  naturally vanishes from equation (9a). This procedure applies to  $W_i$  as well.
7. The terms  $\partial \ln C / \partial \ln Y$  and  $\partial \ln C / \partial \ln T$  derived in equations (9a), (9b), (10a) and (10b), respectively, do not appear in equation (11) because they are eliminated upon substractions.
8. Specifically, according to Capalbo and Antle (1988), the scale effect, i.e., the first term of equation (14), occurs due to the movement along the expansion path, and the bias effect, i.e., the second term, occurs due to the shift in the expansion path.
9. We note further that these two forms of bias measurement, i.e.,  $NB_i$  and  $TB_i$  indicate the magnitudes and directions of the effects of non-homotheticity and non-neutral technological change on the relative uses of factors of production, respectively (Kuroda, 1987).

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