UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

UNDP/UNIDO - NESDB

INDUSTRIAL RESTRUCTURING PROJECT

Thailand

THE MEASUREMENT OF INDUSTRIAL EFFICIENCY AND PRODUCTIVITY

Final Report

Prepared by

Paitoon Wiboonchutikula,

1 April 1986

THE INDUSTRIAL MANAGEMENT CO., LTD.
BANGKOK, THAILAND

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INTRODUCTION

Productivity growth meansures are intended to identify changes in the level of production that cannot be accounted for by changes in the quantity of the corresponding input usage and the characteristics of the original production process. Studies in many developed countries show that productivity growth is an important factor determining the growth of real output of the countries. However, In most countries the importance of productivity growth was not been adequately emphasized until the past decade. This is because during the 1960's most countries experienced stable and respectable rates of growth of real income. In addition the short-run problems of unemployment and inflation could usually be controlled by the manipulation of aggregate demand of the economies, by trading the target of unemployment reduction for another target of low inflation. Since the early 1970's (the period of a series of oil crises) however, economic growth of most countries has slowed down. Besides, frequently inflation and unemployment problems have emerged simultaneously (stagflation). These slow growth and stagflation problems are difficult to be solved by using the traditional technique of demand management adopted in the earlier decades. Economists therefore shift the attention to investigate the problems on the supply or the production side. Many studies on the source of growth of production show that during the period of stagflation productivity of labor also grew very slowly. The slow growth of productivity in turn led to more decline in output growth and more aggravation in the inflation pressure. This implies that the improvement in productivity can not only decrease the above pressure, but it can also elevate the standard of living through the faster growth of output in the economies.

The study of how to improve productivity growth is a complex subject. In most countries, especially in LDCs, reliable data for measuring productivity are scarce. When not much is known about the measurement, it becomes difficult to evaluate the effectiveness of any policy to improve productivty. Having recognized all the needs and difficulty of studying productivity growth, it is important that more research should be done in this field to improve data collection and measurement methods so as to be able to determine factors helping the growth of productivity. This paper attempts three things: First, it measures the productivity growth of the manufacturing industries of Thailand based on the best available data. Second, it provides explanation on the changes in productivity over times. Finally, it decomposes the source of the productivity growth into changes in efficiency and other factors such as technological changes. Before presenting the productivity measurement and analysis the following section will provide a brief survey of various productivity measurement methods. Section 2 discusses the methods chosen to measure output, inputs, and productivity growth of manufacturing sector in Thailand and data sources. Section 3 analyses the estimated TFPG. Section 4 measures efficiency levels of firms of selected manufacturing industries and separates the changes in efficiency from the productivity growth measured in the previous sections. Section 5 is the summary and conclusion.

I. VARIOUS MEASUREMENT METHODS OF PRODUCTIVITY GROWTH

There are three approaches of the measurement of productivity namely, the index number approach, the neoclassical production function specification approach, and the cost function model approach.

1.1. The Index Number Approach

The index number approach has been used extensively by both Denison and Kendrick in the work at the aggregate level. The TFP indexes are the ratio of two separate indexes, one for output and the other for inputs. The output index can be either a simple or weighted average of heterogeneous joint outputs. The input index can be represented by a single factor, say labor, or the weighted average of all physical inputs. When the productivity is measured by the ratio of output index and the input index of a single factor of production, it is called partial factor productivity measure. When it is the ratio of output index and the index of weighted average of all inputs, it is called total factor productivity.

1.1.1 Partial Factor Productivity

If output is defined as value-added (V) which can be produced by two primary factors of production namely labor (L) and capital (K), the partial factor productivity can be either labor productivity or capital productivity.

(1) Labor productivity: $LP = \frac{V}{L}$

(2) Labor productivity growth: $LPG = \frac{\hat{V}}{V} - \frac{\hat{L}}{L}$

(3) Capital productivity: $KP = \frac{V}{K}$

(4) Capital productivity growth: $KPG = \frac{\hat{V}}{V} - \frac{\hat{K}}{K}$

where a hat represents a time derivative.

Labor productivity (in terms of manhours or number of workers) is a more familiar measure because data for the measurement are easier to obtain and it is more interesting to see the changes in real output per workers. In contrast, capital is difficult to measure and the concept of capital productivity is obscure. However, the defect of either partial productivity measure is that the measurement may include the effect of substitution of one factor for another (movement along the same production function) rather than purely technical improvement in production (shift in production function).

1.1.2 Total Factor Productivity

As noted earlier that the measures of productivity growth based on a single input cannot necessarily be due to that particular input. The rise could also be attributed to the increase in capital inputs, to higher rate of capital utilization or to technical change. Thus, the more accurate measurement of productivity should reflect the joint effect of all factors of productions. This leads to the concept of multi-factor (total factor) productivity, with the following general form:

$$(5) \qquad TFP = \frac{Y}{\alpha L + \beta K}$$

where α and β are some appropriate weights, usually represented by labor and capital shares respectively.

There are many approaches for measuring total factor productivity growth (TFPG). The more commonly used ones are Kendrick's and Denison's arithmetic measure[1] and the geometric measure initiated by Solow[2] (discussed in details below). For the arithmetic measure

$$\text{(6)} \qquad TFPG = \frac{V_t/V_0}{(\alpha L_t + \beta K_t)/(\alpha L_0 + \beta K_0)} - 1$$

where the subscripts t and 0 denote the time t and the base period respectively.

In the case when there are multiple outputs and inputs, it is necessary to specify a method of aggregation in order to find the output and input indexes. The method frequently used is the Laspeyres indexing procedure applying to output and inputs.

Suppose the production of Q_1, Q_2......., Q_m is the output of putting in X_1, X_2, ..., X_n into the process of production. The Laspeyres index of output is measured by

$$\text{(7)} \qquad \frac{Q_t}{Q_0} = \frac{\sum_{i=1}^{m} P_{0,i} Q_{t,i}}{\sum_{i=1}^{m} P_{0,i} Q_{0,i}} = \sum_{i=1}^{m} \frac{P_{0,i} Q_{0,i}}{\sum_{i=1}^{m} P_{0,i} Q_{0,i}} \cdot \frac{Q_{t,i}}{Q_{0,i}} = \sum_{i=1}^{m} \gamma_{0,i} \frac{Q_{t,i}}{Q_{0,i}}$$

where $P_{0,i}$ and $\gamma_{0,i}$ are the price and the revenue share of the product Q_i at the base period.

Equation (7) shows that the Laspeyres index of output is in fact the weighted average of $\frac{Q_{t,i}}{Q_{0,i}}$ using the revenue shares at the base period as weights.

The Laspeyres index of inputs is measured by

$$(8) \qquad \frac{X_t}{X_0} = \frac{\sum_{j=1}^{n} P^X_{0,i}\, X_{t,i}}{\sum_{j=1}^{n} P^X_{0,i}\, X_{0,i}}$$

$$= \sum_{j=1}^{n} \frac{P^X_{0,i}\, X_{0,i}}{\sum_{j=1}^{n} P^X_{0,i}\, X_{0,i}} \cdot \frac{X_{t,i}}{X_{0,i}}$$

$$= \sum_{j=1}^{n} W_{0,i} \frac{X_{t,i}}{X_{0,i}}$$

where $P^x_{o,i}$ and $W_{o,i}$ are the rental rate and the value share of input X_i at the base period.

Equation (8) shows that the Laspeyres index of inputs is the weighted average of $\frac{X_{t,i}}{X_{o,i}}$ using the cost shares of the base period as weights.

However, Diewert[3] has shown that the Laspeyres index is inexact except when the underlying production function is linear and all inputs are perfectly substitutable in the production process.

1.2 The Production Function Approach

Another approach for the measurement of total factor productivity is the Divisia indexing procedure. It is based on the underlying production function $Q = f(X_1, X_2 \ldots . X_n)$, where Q is output and $X_1, X_2 \ldots ., X_n$ are inputs. The production function is assumed to be homogeneous and twice differentiable.

$$(9) \qquad \text{Let } Q(t) = F\left[L(t),\, K(t),\, M(t),\, t\right]$$

where $L(t)$, $K(t)$, $M(t)$ are labor, capital, and intermediate inputs at time t respectively.

Under competitive profit maximizing equilibrium,

$$(10) \quad \frac{\hat{Q}(t)}{Q(t)} = \frac{W(t)L(t)}{P(t)Q(t)} \cdot \frac{\hat{L}(t)}{L(t)} + \frac{\gamma(t)K(t)}{P(t)Q(t)} \cdot \frac{\hat{K}(t)}{K(t)} + \frac{P_m(t)M(t)}{P(t)\,Q(t)} \cdot \frac{\hat{M}(t)}{M(t)} + \frac{F_t(t)}{Q(t)}$$

Without having to estimate the production function or the output elasticities directly, ones can measure the total factor productivity growth (TFPG) from the followings differential equation as if it were an "accounting identity".

$$(11) \qquad \frac{F_t(t)}{Q(t)} = \frac{\hat{Q}(t)}{Q(t)} - \left[\alpha(t)\frac{\hat{L}(t)}{L(t)} + \beta(t)\frac{\hat{K}(t)}{K(t)} + \gamma(t)\frac{\hat{M}(t)}{M(t)} \right]$$

where $\alpha(t)$, $\beta(t)$, and $\gamma(t)$ are labor, capital and raw material shares respectively.

The above equation is the Divisia index of TFPG with continuous time. The discrete approximation of the TFP index will take the following form:

$$(12) \qquad \frac{F_t(t)}{Q(t)} = \left\{ \ln Q(t) - \ln Q(t-1) \right\} - \left[\left\{ \frac{\alpha(t)+\alpha(t-1)}{2} \right\} \left\{ \ln L(t) - \ln L(t-1) \right\} + \left\{ \frac{\beta(t)+\beta(t-1)}{2} \right\} \left\{ \ln K(t) - \ln K(t-1) \right\} + \left\{ \frac{\gamma(t)+\gamma(t-1)}{2} \right\} \left\{ \ln M(t) - \ln M(t-1) \right\} \right]$$

Equation (11) can also alternatively be written as follows for TFPG to be computed by using the input-output coefficients:[4]

$$(13) \qquad \frac{F_t(t)}{Q(t)} = - \left[\sum_{j=1}^{n} \gamma(t)\frac{\hat{a}_j(t)}{a_j(t)} + \alpha(t)\frac{\hat{b}(t)}{b(t)} + \beta(t)\frac{\hat{C}(t)}{C(t)} \right]$$

where $a_j(t) = \frac{M_j(t)}{Q(t)}$, $b(t) = \frac{L(t)}{Q(t)}$, $C(t) = \frac{K(t)}{Q(t)}$,

and $M_j(t)$ is the j-th type of intermediate inputs.

In this form TFPG can be interpreted as the measurement of the changes in the input-output coefficients over time.

TFPG can also be measured by explicitly specifying other various forms of production function. The initial work is done by Solow[5]. He estimates the TFPG based on the Cobb-Douglas production function of value-added (V) with two primary inputs labor and capital. With the additional assumptions of constant returns to scale and Hicks' neutral technical change, the function can be written in the form:

(14) $$V(t) = A(t)L(t)^{\alpha} K(t)^{1-\alpha}$$

and the Divisia index of TFP is

(15) $$\frac{\hat{A}(t)}{A(t)} = \frac{\hat{V}(t)}{V(t)} - \left[\alpha \frac{\hat{L}(t)}{L(t)} + (1-\alpha)\frac{\hat{K}(t)}{K(t)}\right]$$

Following Solow's work, other studies have specified the production function in a more general and flexible forms such as CES, translog, generalized Leontief, and quadratic specifications. Below will present the general form of the translog production function[6].

(16) $$\begin{aligned}\ln Q(t) = {} & \alpha_0 + \alpha_L \ln L(t) + \alpha_K \ln K(t) + \alpha_M \ln M(t) + \alpha_t . t \\ & + \tfrac{1}{2} \beta_{LL} \{\ln L(t)\}^2 + \beta_{LK} \ln L(t) \ln K(t) + \beta_{LM} \ln L(t) \ln M(t) \\ & + \beta_{Lt} \{\ln L(t)\} . t + \tfrac{1}{2} \beta_{KK} \{\ln K(t)\}^2 + \beta_{KM} \ln K(t) \ln M(t) \\ & + \beta_{Kt} \{\ln K(t)\} . t + \tfrac{1}{2} \beta_{MM} \{\ln M(t)\}^2 + \beta_{Mt} \{\ln M(t)\} . t + \tfrac{1}{2} \beta_{tt} . t^2\end{aligned}$$

The output elasticity or the value share of each input is

$$(17)\quad V_L = \frac{\partial \ln Q(t)}{\partial \ln L(t)} = \alpha_L + \beta_{LL}\ln L(t) + \beta_{LK}\ln K(t) + \beta_{LM}\ln M(t) + \beta_{Lt}\cdot t$$

$$(18)\quad V_K = \frac{\partial \ln Q(t)}{\partial \ln K(t)} = \alpha_K + \beta_{LK}\ln L(t) + \beta_{KK}\ln K(t) + \beta_{KM}\ln M(t) + \beta_{Kt}\cdot t$$

$$(19)\quad V_M = \frac{\partial \ln Q(t)}{\partial \ln M(t)} = \alpha_M + \beta_{LM}\ln L(t) + \beta_{KM}\ln K(t) + \beta_{MM}\ln M(t) + \beta_{Mt}\cdot t$$

The Divisia index of TFP with continuous time is

$$(20)\quad V_T = \frac{\partial \ln Q(t)}{\partial t} = \alpha_t + \beta_{Lt}\ln L(t) + \beta_{Kt}\ln K(t) + \beta_{Mt}\ln M(t) + \beta_{tt}\cdot t$$

Finally, the discrete version of the above TFP index is in the form:

$$(21)\quad V_T = \left\{\ln Q(t) - \ln Q(t-1)\right\} - \left[\left\{\frac{V_L(t)+V_L(t-1)}{2}\right\}\left\{\ln L(t) - \ln L(t-1)\right\} + \left\{\frac{V_K(t)+V_K(t-1)}{2}\right\}\left\{\ln K(t) - \ln K(t-1)\right\} + \left\{\frac{V_M(t)+V_M(t-1)}{2}\right\}\left\{\ln M(t) - \ln M(t-1)\right\}\right]$$

Notice that the index of output or each of the factor inputs is itself the Divisia index of its components. For example, the Divisia index of the labor input can be written as:

(22)

$$\ln L(t) - \ln L(t-1) = \sum_j \left\{\frac{V_{Lj}(t)+V_{Lj}(t-1)}{2}\right\}\left\{\ln L_j(t) - \ln L_j(t-1)\right\}$$

where $V_{Lj}(t)$ is the value-share of the j-th compoment of labor input in the total labor compensation.

1.3 The Cost Function Approach

An alternative approach to the measurement of TFPG is based on the cost function dual to the production function.[7] TFP here is defined as minimum costs not accounted for by variations in output and input prices. The cost function is assumed to be homogeneous and twice differentiable. Using C, W, r, P_m, Q and t to denote the cost function, wage rate, capital rental rate, intermediate input price, output, and time respectively, the cost function C can be written as:

$$C = G\ (W,\ r,\ P_m,\ Q\ ,\ t) \tag{23}$$

Under competitive equilibrium,

$$\frac{\hat{C}(t)}{C(t)} = \frac{W(t)L(t)}{C(t)} \cdot \frac{\hat{W}(t)}{W(t)} + \frac{\gamma(t)K(t)}{C(t)} \cdot \frac{\hat{\gamma}(t)}{\gamma(t)} + \frac{P_m(t)M(t)}{C(t)} \cdot \frac{\hat{P}_m(t)}{P_m(t)} + \frac{\Sigma_Q \hat{Q}(t)}{Q(t)} + \frac{G_t(t)}{C(t)} \tag{24}$$

Where Σ_Q is the cost elasticity with respect to output.

The TFPG can then be derived to be the following equation:

$$\frac{G_t(t)}{C(t)} = \frac{\hat{C}(t)}{C(t)} - \left[\frac{W(t)L(t)}{C(t)} \cdot \frac{\hat{W}(t)}{W(t)} + \frac{\gamma(t)K(t)}{C(t)} \cdot \frac{\hat{\gamma}(t)}{\gamma(t)} + \frac{P_m(t)M(t)}{C(t)} \cdot \frac{\hat{P}_m(t)}{P_m(t)} + \frac{\Sigma_Q \hat{Q}(t)}{Q(t)}\right] \tag{25}$$

If we approximate a second-order Taylor serier to the cost function, we can obtain the translog cost function of the following form:

(26)

$$\begin{aligned} \ln C(t) = {} & \delta_0 + \delta_L \ln W(t) + \delta_K \ln \gamma(t) + \delta_M \ln P_m(t) + \delta_Q \ln Q(t) + \delta_t \cdot t \\ & + \tfrac{1}{2}\delta_{LL}\left\{\ln W(t)\right\}^2 + \delta_{LK} \ln W(t) \ln \gamma(t) + \delta_{LM} \ln W(t) \ln P_m(t) \\ & + \delta_{LQ} \ln W(t) \ln Q(t) + \delta_{Lt}\left\{\ln W(t)\right\} \cdot t \\ & + \tfrac{1}{2}\delta_{KK}\left\{\ln \gamma(t)\right\}^2 + \delta_{KM} \ln \gamma(t) \ln P_m(t) + \delta_{KQ} \ln \gamma(t) \ln Q(t) + \delta_{Kt}\left\{\ln \gamma(t)\right\} \cdot t \\ & + \tfrac{1}{2}\delta_{MM}\left\{\ln P_m(t)\right\}^2 + \delta_{MQ} \ln P_m(t) \ln Q(t) + \delta_{Mt}\left\{\ln P_m(t)\right\} \cdot t \\ & + \tfrac{1}{2}\delta_{QQ}\left\{\ln Q(t)\right\}^2 + \delta_{Qt}\left\{\ln Q(t)\right\} \cdot t + \tfrac{1}{2}\delta_{tt} \cdot t^2 \end{aligned}$$

Taking the logarithmic partial derivative with respect to input prices and applying Shephard's Lemma, we obtain

$$U_L = \frac{\partial \ln C(t)}{\partial \ln W(t)} = \delta_L + \delta_{LL}\ln W(t) + \delta_{LK}\ln\gamma(t) + \delta_{LM}\ln P_m(t) + \delta_{LQ}\ln Q(t) + \delta_{Lt}t \quad (27)$$

$$U_K = \frac{\partial \ln C(t)}{\partial \ln\gamma(t)} = \delta_K + \delta_{KL}\ln W(t) + \delta_{KK}\ln\gamma(t) + \delta_{KM}\ln P_m(t) + \delta_{KQ}\ln Q(t) + \delta_{Kt}t \quad (28)$$

$$U_M = \frac{\partial \ln C(t)}{\partial \ln P_m(t)} = \delta_M + \delta_{ML}\ln W(t) + \delta_{MK}\ln\gamma(t) + \delta_{MM}\ln P_m(t) + \delta_{MQ}\ln Q(t) + \delta_{Mt}t \quad (29)$$

$$U_Q = \frac{\partial \ln C(t)}{\partial \ln Q(t)} = \delta_Q + \delta_{QL}\ln W(t) + \delta_{QK}\ln\gamma(t) + \delta_{QM}\ln P_m(t) + \delta_{QQ}\ln Q(t) + \delta_{Qt}t \quad (30)$$

The Divisia index of TFP with continuous time is

$$-U_T = \frac{\partial \ln C(t)}{\partial t} = \delta_t + \delta_{Lt}\ln W(t) + \delta_{Kt}\ln\gamma(t) + \delta_{Mt}\ln P_m(t) + \delta_{Qt}\ln Q(t) + \delta_{tt}\cdot t \quad (31)$$

The discrete approximation of the above TFP index can be written as :

$$-U_T = \left\{\ln C(t) - \ln C(t-1)\right\} - \Bigg[\left\{\frac{U_L(t)+U_L(t-1)}{2}\right\}\left\{\ln W(t) - \ln W(t-1)\right\} + \left\{\frac{U_K(t)+U_K(t-1)}{2}\right\}\left\{\ln\gamma(t) - \ln\gamma(t-1)\right\} + \left\{\frac{U_M(t)+U_M(t-1)}{2}\right\}\left\{\ln P_m(t) - \ln P_m(t-1)\right\} + \left\{\frac{U_Q(t)+U_Q(t-1)}{2}\right\}\left\{\ln Q(t) - \ln Q(t-1)\right\}\Bigg] \quad (32)$$

Footnotes to Section 1

1 See J.W. Kendrick, Productivity Trends in the United States, Princeton University Press for the National Bureau of Economic Research, Princeton, 1961, and E.F. Denison, Sources of Economic Growth in the United States and the Alternatives Before Us, The committee for Economic Development, New York, 1962.

2 See R.M. Solow, "Technical Change and the Aggregate Production Function, "Review of Economics and Statistics, 1957, pp. 312-20.

3 See W.E. Diewert, "Exact and Superlative Index Numbers," Journal of Econometrics, Vol.4, 1976, pp.115-45.

4 See for example, M. Ezaki, "Growth Accounting of the Philippines: A Comparative Study of the 1965 and 1969 Input - Output Tables," The Philippines Economic Journal, No. 29, 1975, pp. 399-435.

5 See R.M. Solow, "Technical Change and the Aggregate Production Function".

6 See for example, F.M. Gollop and D.W. Jorgenson, "U.S. Productivity Growth by Industry, 1947-73," in New Developments in Productivity Measurement and Analysis, edited by J.W. Kendrick and B.N. Vaccara, University of Chicago Press, Chicago, 1980.

7 See for example, D.W. Caves, L.R. Christensen, and M.W. Tretheway, "Flexible Cost Functions for Multiproduct Firms," Review of Economics and Statistics, Vol. 62, 1980, pp. 477-481.

II. THE MEASUREMENT OF TFPG OF THAI MANUFACTURING SECTOR AND DATA SOURCES

The manufacturing sector in Thailand grew at a very fast rate over the past two decades. The share of the sector in GDP increased steadily from 13.6 percent in the 1960s to 18.1 percent in the 1970s. The industries which grew faster in the 1960s were the import substituting industries. The ones which had the more rapid growth in the 1970s were mostly industries producing products to be exported. The rapid growth and structural change of the industrial sector were in reponse to changing government policies. In the 1960s when industrial development planning was in the initial phase, the policy was to promote import substituting industries. Since the early 1970s, however, the policy has been shifted to emphasis on promoting industries of an export - oriented nature.[1]

It is important to study the source of the growth of the manufacturing industries in relation to the changing Industrialization policies. In general, the sources of the industrial growth can be from either the demand or the supply side. Industries grew when there were increases in the demand and the supply of their products over time. The increase in the demand of their products can be accounted for by import substitution, increases in exports, or increases in domestic utilization. On the other hand, the increases in the supply of the products can be due to the increases in real inputs or their productivity over time. Studies on the source of the industrial growth in Thailand on the demand side have been done, for example, in Akrasanee (1974).[2] However, very little is known about the source of the growth on the supply side. Our paper intends to contribute to the latter knowledge, with an additional attempt to link the source of the growth to the changing industrialization and trade policies. Under our approach the rate of growth of the manufacturing sector will be decomposed to be from the increase in physical inputs and the total factor productivity growth (TFPG). In this section we will present the methods chosen to measure real output, physical inputs, and TFPG. It will also discuss the nature and sources of data. The results of the estimation and analysis in relation to the various policies are left to be discussed in the next section.

As shown in the previous section there are many methods for measuring productivity growth. The measurement which is based on multiple factors of production namely TFPG, is better than partial productivity in the sense that it measures the contributions of all inputs on the production. The rate of TFPG is essentially the rate at which real incomes to all factors of production can increase, consistent with unchanged factor shares. A higher rate of TFPG indicates the higher attainable growth rate of real incomes of all factors of production.

TFPG can be measured by the production function approach, or its duality, the cost function approach. The measurement of TFPG using the cost function approach requires yearly data of prices of inputs and output which are not available for our study. For the production function approach, TFPG can be measured based on a general form of production function or on an explicit form such as the Leontief, the Cobb-Douglas, or the translog types. In our study the underlying production function for measuring TFPG is that of a general form Equation (9) . That is it can be any production function with the propertiesofbeing linear homogeneous, twice differentiable, and possible for all inputs to be substitutable in the production of an output.

Based on Equation 9 which is the general form of a production function the discrete approximation of continuous Divisia TFPG index of an industry, say the i-th industry, can be written as follows:

$$(33)\quad \mathbf{TFPG_i} = \{\ln Q_i(t) - \ln Q_i(t-1)\} - [\{\frac{\alpha(t) + \alpha(t-1)}{2}\} \cdot \{\ln L_i(t) - \ln L_i(t-1)\} + \{\frac{\beta(t) + \beta(t-1)}{2}\} \cdot \{\ln M_i(t) - \ln M_i(t-1)\} + \{1 - \frac{\alpha(t) + \beta(t) + \alpha(t-1) + \beta(t-1)}{2}\} \cdot \{\ln K_i(t) - \ln K_i(t-1)\}] .$$

For the TFPG of total industries, denoted by TFPG, the Divisia index approximation is defined as[3]

$$(34)\quad \frac{f_t(t)}{Q(t)} = \sum_{i=1}^{n} \frac{P_i(t)Q_i(t)}{\sum_{i=1}^{n} P_i(t)Q_i(t)} \{\ln Q_i(t) - \ln Q_i(t-1)\} - \left[\frac{\sum_{i=1}^{n} w_i(t)L_i(t)}{\sum_{i=1}^{n} P_i(t)Q_i(t)} \sum_{i=1}^{n} \frac{w_i(t)L_i(t)}{\sum_{i=1}^{n} w_i(t)L_i(t)} \cdot \{\ln L_i(t) - \ln L_i(t-1)\} + \frac{\sum_{i=1}^{n} P_i^m(t)M_i(t)}{\sum_{i=1}^{n} P_i(t)Q_i(t)} \sum_{i=1}^{n} \frac{P_i^m(t)M_i(t)}{\sum_{i=1}^{n} P_i^m(t)M_i(t)} \cdot \{\ln M_i(t) - \ln M_i(t-1)\} + \left\{1 - \frac{\sum_{i=1}^{n} w_i(t)L_i(t) + \sum_{i=1}^{n} P_i^m(t)M_i(t)}{\sum_{i=1}^{n} P_i(t)Q_i(t)}\right\} \cdot \sum_{i=1}^{n} \frac{P_i(t)Q_i(t) - w_i(t)L_i(t) - P_i^m(t)M_i(t)}{\sum_{i=1}^{n} \{P_i(t)Q_i(t) - w_i(t)L_i(t) - P_i^m(t)M_i(t)\}} \cdot \{\ln K_i(t) - \ln K_i(t-1)\} \right].$$

In estimating the TFPG from equation 33, we first need to measure real output, real inputs, and the shares of all factors of production for successive years. The industrial census conducted by the National Statistical Office of Thailand (NSOT) is a major source for data on production, intermediate inputs, number of workers, the stock of fixed assets, depreciation, and the wage bill.[4] However, there is good reason to believe that these data dramatically understate the growth of output for many industries. As a result the NSOT data were supplemented with data from the Ministry of Industry (MOI), the Ministry of Commerce (MOC), the Bank of Thailand (BOT), and the National Economic and Social Development Board (NESDB).[5]

NSOT census data are available for the years 1963, 1968, 1970, 1975, 1976, 1977 and 1979. The data for all variables except for fixed assets and depreciation are available at both three- and five-digit ISIC aggregation levels in the published census of the NSOT. The lack of data on fixed assets and depreciation at the five-digit ISIC level made it impossible to estimate the TFPG of industries at the more disaggregated five-digit ISIC level.

The NSOT census is in actuality a sample that is drawn from all firms with 10 or more workers. The response rate of the NSOT census sample is about 75 percent, although it varies from year to year and industry to industry. The Ministry of Industry has data on output by commodity groups. The data cover all firms with 10 or more workers. One can aggregate the Ministry of Industry commodity data into estimates of total output for five-digit ISIC industries and find the growth rates of total output for three-digit ISIC industries by methods described in the following Section 2.1.

There are significant discrepancies between the growth rates of real output of the three-digit ISIC industries reported by the NSOT and that implied by the aggregation of the Ministry of Industry commodity data on commodity output. Our estimates of TFPG are based on the Ministry of Industry data because they cover more firms. However, the Ministry of Industry data cover only total output and contain no information about factor inputs, so we need to compute data on factor inputs. For each year with NSOT census data, we estimate data on factor inputs for three-digit ISIC industries by adjusting NSOT data on all factor inputs by the ratio of our estimate of total output based on our aggregation of data from the Ministry of Industry to output data reported by the NSOT.

For each year without census data we were able to compute estimates of total three-digit industry output from aggregating output data from the Ministry of Industry. Data on inputs were estimated by applying a variant of the procedure described above. Estimates for any specific input were derived by multiplying our output estimate by the ratio of the input to output where the ratios were derived from interpolation of NSOT data. This procedure is explained more precisely in equation (35) below.

For each industry,

$$X_{i\ell}(t) = Y_i^M(t) \cdot \frac{X_{i\ell}^N(t)}{Y_i^N(t)} \tag{35}$$

where

$X_{i\ell}(t)$ = estimate of input or variable ℓ of the i-th industry for year t

$Y_i^M(t)$ = the Ministry of Industry estimate of total output of the i-th industry

$X_{i\ell}^N(t)$ = estimate of input or variable ℓ of the i-th industry for year t based on NSOT data (see below)

$Y_i^N(t)$ = estimate of output of the i-th industry for year t based on NSOT data (see below)

$i = 1, 2, \ldots, n$, $t = 1, 2, \ldots, T$

ℓ = raw material input, wage bill, fixed assets and depreciation.

$$X_{i\ell}^N(t) = e^{\varepsilon_{i\ell} t} X_{i\ell}^N(0) \tag{36}$$

$$Y_i^N(t) = e^{\varepsilon_{Y_i} t} Y_i^N(0) \tag{37}$$

where

$X_{i\ell}^N(0)$ = NSOT data on input or variable ℓ of the i-th industry for base census year 0

$Y_i^N(0)$ = NSOT data on output of the i-th industry for base census year 0

$g_{i\ell}$ = annual continuous growth rate computed from $X_{i\ell}^N(0)$ and $X_{i\ell}^N(t)$

g_{Y_i} = annual continuous growth rate computed from $Y_i^N(0)$ and $Y_i^N(t)$.

Note that the number of workers was estimated by dividing the estimate of the wage bill (described above) by nominal wage rates obtained from the NSOT census. Real capital input was estimated by applying the estimates of fixed assets and depreciation (described above) to the procedures described in Section 2.3 below.

2.1 Real Output

The computation of the growth rates of physical output of three-digit ISIC based on the Ministry of Industry commodity data together with the NSOT census data was done by the following procedure. First, we used relative prices to aggregate the Ministry of Industry data on commodity output to measure output of each five-digit ISIC industry. Second, we used the resulting output data to compute the continuous growth rate of each five-digit ISIC industry. Then, finally, we measured the growth rate of real output of the three-digit ISIC industry as a weighted average of the growth rates of the relevant five-digit ISIC industries, i.e., those with the same first three digits, using value shares in the three-digit ISIC industry as weights. The value shares were obtained from the NSOT census so as to be consistent with factor input data of three-digit industries obtained from the NSOT.[6] This method of measuring growth rates of real output was the approximation of the continuous Divisia index of real output.[7] The procedure of the estimation of the rate of growth of real output of each three-digit ISIC industry is described more precisely below.

Let

$Y_i(t)$ be the NSOT's value of production of the i-th three-digit ISIC industry at time t

$Y_{ij}(t)$ be the NSOT's value of production of the j-th five-digit in the i-th three-digit ISIC industry at time t

$Q_{ij}(t)$ be the all-firm physical output of the j-th five-digit in the i-th three-digit ISIC industry at time t

$Q_{ijk}(t)$ be the all-firm physical output of the k-th commodity categorized in the j-th five-digit which belongs to the i-th three-digit ISIC industry at time t

$P_{ijk}(t)$ be the relative price of $Q_{ijk}(t)$

$q_{ij}(t)$ be the continuous growth rates of $Q_{ij}(t)$

and $q_i(t)$ be the continuous growth rate of output of the i-th three-digit ISIC industry at time t

where $i = 1, 2, \ldots, n$

$j = 1, 2, \ldots, m$

$k = 1, 2, \ldots, \ell$

and $t = 1, 2, \ldots, T$

to obtain the following.

First, we obtained the NSOT's value of production of three-digit

ISIC industries. Each industry's production value at any period was found by aggregating the period's production values of all five-digit ISIC industries whose industrial codes share the same corresponding first three digits, i.e.,

$$(38) \qquad Y_i(t) = \sum_{j=1}^{n} Y_{ij}(t) \; .$$

Second, we obtained the all-firm physical output of five-digit ISIC industries. Each industry's physical output at any period was found by aggregating the quantities of commodities which are grouped under the same five-digit ISIC industrial code by using their relative prices as weights, i.e.,

$$(39) \qquad Q_{ij}(t) = \sum_{k=1}^{z} P_{ijk}(t) \, Q_{ijk}(t) \; .$$

Third, we obtained the continuous growth rates of output of five-digit ISIC industries. Each industry's annual growth rate was the difference between the natural logarithm of output between two successive periods, i.e.,

$$(40) \qquad q_{ij}(t) = \ln Q_{ij}(t) - \ln Q_{ij}(t-1) \; .$$

Finally, we obtained the growth rates of output of three-digit ISIC industries. Each industry's annual growth rate was found by weighted-averaging all the five-digit ISIC industries' continuous growth rates of output which belong to the same corresponding three-digit category by using their value shares as weights, i.e.,

$$(41) \qquad q_i(t) = \sum_{j=1}^{m} \frac{Y_{ij}(t)}{Y_i(t)} q_{ij}(t) .$$

2.2 Real Intermediate Inputs

The growth rate of real intermediate inputs for each three-digit ISIC industry can be obtained by aggregating the continuous growth rates of all purchased inputs measured in real terms using their value share in total intermediate inputs as weights. Thus, if the values of different types of purchased inputs used in industries were available, we would deflate each of them by its own price deflator and aggregate their growth rates with proper weights to obtain the growth rate of real intermediate inputs. Unfortunately, the values of purchased inputs reported in the NSOT's industrial census were all in an aggregated form without breaking them into types. The alternative was to deflate these aggregated figures by appropriate deflators to obtain real intermediate inputs and then find the continuous growth rates. In our study, the deflator of intermediate inputs used in each industry was found by weighted-averaging the deflators of "major" purchased inputs used in the industry where weights are their corresponding value shares in total intermediate inputs.[9] That is, by letting

$DM_i(t)$ be the deflator of intermediate inputs of the i-th three-digit ISIC industry at time t

$DM_{ij}(t)$ be the deflator of the j-th intermediate input used in the i-th three-digit ISIC industry at time t

and $RM_{ij}(t)$ be the j-th intermediate input used in the i-th three-digit ISIC industry at time t

. where

$i = 1, 2, \ldots, n$

$j = 1, 2, \ldots, m$

we obtain

$$(42) \qquad DM_i(t) = \sum_{j=1}^{m} \frac{RM_{ij}(t)}{\sum_{j=1}^{m} RM_{ij}(t)} DM_{ij}(t) .$$

The source of data for deflators $DM_{ij}(t)$ was the Ministry of Commerce's wholesale price indexes of industries and the base year was 1968.[10] The value shares were computed from the input-output table for 1975 which is currently the only one available.[11] If more finished raw material products such as parts and components whose relative prices increased over time were substituted by firms' own production done by employing basic metals, labor and capital whose relative prices increased more slowly that the former, use of fixed weights from the 1975 input-output table will generate some biases in the measurement of deflators $DM_{ij}(t)$ for the years before and after 1975. The biases are that before 1975 the deflators and the growth of real intermediate inputs will be overestimated, while the TFPG will be underestimated. On the other hand, after 1975 the biases are in the opposite direction. However, if the changes in the weights over time are not pronounced (as found in the case of Turkey in Krueger and Tuncer, 1981),[12] the biases will not be significant and our method should provide an accurate measurement of real intermediate inputs and their growth.

2.3 Real Capital Stock

Capital stock is classified into two types: first, buildings and structures; second, machinery, equipment and vehicles. For each type at any period, real capital stock was obtained by adding current gross investment at constant prices to the real capital stock of the previous period excluding real depreciations in that period.

That is, if we let

$K_{ij}(t)$ be the real capital stock of the j-th type of the i-th industry at time t

$GI_{ij}(t)$ be the gross investment flow on the j-th type of capital of the i-th industry at time t

$PI_j(t)$ be the investment deflator of the j-th type of capital at time t

and δ_{ij} be the rate of depreciation of the j-th type of capital stock of the i-th industry

where $i = 1, 2, \ldots, n$

$j = 1, 2, \ldots, m$

and $t = 0, 1, 2, \ldots, T$

then we obtain

$$(43) \qquad K_{ij}(t) = \frac{GI_{ij}(t)}{PI_j(t)} + (1 - \delta_{ij})K_{ij}(t-1)$$

By a process of iterative substitution of $K_{ij}(t-1)$ in equation (43) we can write

$$(44) \qquad K_{ij}(t) = (1 - \delta_{ij})^t K_{ij}(0) + \sum_{s=1}^{t} (1 - \delta_{ij})^{t-s} \frac{GI_{ij}(t-s)}{PI_j(t-s)}$$

where $K_{ij}(0)$ is the initial real capital stock of the j-th type of the i-th industry.

In our estimation of real capital stock, we defined the rates of depreciation as the reciprocal of the economic life of different types of capital. The real capital stock estimation therefore requires a yearly measurement of four kinds of variables, namely, gross investment flows, investment deflators, initial real capital stock and the economic life of the two types of assets. The measurement methods and data sources of these variables are described below.

2.3.1 Investment Data

The time series of gross nominal investment data are not available. We estimated them by making use of the NSOT's revised industrial census data, to represent all firms, of net book values of fixed assets and depreciations during the year.[13] The gross nominal investment at a period was defined to be the change in net book values from the previous period plus the depreciations in that period. That is, by letting

$NBV_{ij}(t)$ be the net book value of the j-th type of capital of the i-th three-digit ISIC industry at time t

and $D_{ij}(t)$ be the depreciations of the j-th type of capital of the i-th three-digit ISIC industry during the period t,

the gross nominal investment on the j-th type of capital of the i-th industry at period t, $GI_{ij}(t)$ can be defined as

(45) $$GI_{ij}(t) = NBV_{ij}(t) - NBV_{ij}(t-1) + D_{ij}(t-1)$$

where $i = 1, 2, \ldots, n$; $j = 1,2,\ldots,m$; $t = 1,2,\ldots,T$

2.3.2 Investment Deflators

Since the estimated gross investment series of each type of asset obtained above were at current prices, they had to be deflated by appropriate investment deflators to obtain gross investment in real terms for estimating real capital stock in equation (44). The deflators for buildings and structures were from wholesale price indexes of construction materials; those for machinery, equipment and vehicles were from the weighted average of the indexes of machinery and equipment, and transport equipment whose weights are their value share of total investment in them.[14] The price indexes of all assets were from the Ministry of Commerce[15] and the base year was 1968.

2.3.3 Initial Capital Stock

According to our method of estimating real capital stock with gross investment increasing along its time trend, it is noticeable from equation (44) that the further back the initial year of capital stock we have, the better estimates of the present capital stock we can obtain. This is because with the passage of time the investment of previous periods constitutes a smaller and smaller portion of the current capital stock. Should there be any errors in the investment data of initial years, these will affect our estimates of the current stock minimally.

For Thailand, the earliest year the relevant data available for estimating initial capital stock by manufacturing industry is 1949. In 1949 data from the National Economic and Social Development Board[16] existed on total fixed capital formation of the aggregated industrial sector, but these data were not separated into industries or type of capital stock. In order to find fixed capital formation of each industry to represent nominal investment of the initial year of 1949, we prorated the total fixed capital formation by each industry's share in total value-added of the sector.[17] Each industry's value-added in 1949 was estimated by multiplying the industry's value-added per employee figure by its number of workers. The data on value-added per employee by industry were obtained from the United Nations Industrial Development Office (1963),[18] and those on the number of workers by industry were from Thailand's 1949 census (National Economic Council, Central Statistical Office, 1952).[19]

After obtaining the total initial investment or capital of the initial year for each industry, we separated it further into components of buildings and structures; and machinery, equipment and vehicles. The proportion of each component was the average of the proportions across years estimated from all the available census data.

Using the initial year of investment of 1949, we see that the 1949 fixed capital formation is less than 10 percent of the capital formation in 1963 and three percent of that in 1979. With the depreciation rates described in the following section, any possible errors in the estimates of initial capital stock will be embodied in a small portion of the estimates of capital stock of 1963 to 1979. In fact, the errors, if any, of the estimates of initial investment in machinery, equipment and vehicles almost vanished by 1963. Meanwhile, those of the buildings and structures estimates are embodied in no more than five percent of the estimates of capital stock in 1963 and one to two percent in 1976.

2.3.4 Economic Life of Assets

Between two types of assets,

buildings and structures are much more durable than machinery and equipment. Based on Krueger and Tuncer's estimates,[20] the average life of structures is about 33 years. On the other hand, machinery and equipment have an average life of about 15 years. Since the life of a structure does not vary much across industries compared to machinery and equipment, we assumed all industries had the same life of 33 years for structures, but the life of machinery and equipment varied with industries. The life for each industry was estimated from Park's estimates for U.S. industries.[21] The average life of U.S. machinery and equipment is longer than Thailand's, so Park's estimates were scaled down so that the weighted average for the whole manufacturing sector is 15 years.

2.4 Labor Input

A better measurement of labor input of an industry is man-hours classified by different qualities of laborers, such as age, sex and education. Its growth rate can be obtained by aggregating the weighted continuous growth rates of laborers of different quality groups using the wage bill for each group as weights.[22] However, due to the lack of the above data, we decided simply to use the number of workers employed in each industry during the year as the measurement of labor input. The data source was the NSOT's industrial census. It should be noted that without adjusting for labor quality, our estimates of the growth of labor input can be overestimated and the TFPG underestimated for two reasons. First, man-hours per worker may decrease over time. Second, since female employment in the manufacturing industries grew faster than male employment over time especially in the 1960s, labor input may be overestimated over time insofar as female workers represent increases in employment of less skilled labor, a result suggested by lower wage rates. However, any overestimation of the labor input growth could well be offset by the opposite bias which is due to failure to take into account the increases in labor quality from the improvement in education and training.

2.5 Factor Shares

In computing the TFPG from equation (33), we needed to have the share of each factor of production in each year. The shares of intermediate inputs was computed by dividing the value of intermediate inputs by the value of total production. The value of intermediate inputs included the cost of raw materials and fuel energy used. The labor share was obtained by dividing expenditures on labor by the value of total production. The labor expenditure included wages and salaries, bonuses, piecework payment, overtime payment, and all other fringe benefits. The share of capital was defined as the remainder of intermediate input and labor shares in total production. All the data of value of production and expenditures on intermediate inputs and labor are from the NSOT's industrial census.

The weights for finding the continuous rate of growth of real input in each year from equation (33) is the moving average of the current and previous year's shares. However, in computing the TFPG for subperiods 1963-1970, 1970-1976, 1976-1979 and the entire period of 1963-1979, the weight of each input is the average of the factor shares during the respective periods.

Footnotes to Section 2

1 For more details see Narongchai Akrasanee, "Trade Strategy for Employment Growth in Thailand", in Trade and Employment in Developing Countries, 1, Individual Studies, ed. Anne O. Krueger et, al. (Chicago: University of Chicago Press, 1981), pp. 393 - 433 and Paitoon Wiboonchutikula, "The Growth of Thailand in a Changing World Economy: Past Performance and Current Outlook", Southeast Asian Affairs, 1984. Institute of Southeast Asian Studies, Singapore, pp. 326-339.

2 See Narongchai Akrasanee, "Import Substitution and Sources of Industrial Growth in Thailand, 1960 - 69, " Thai Economic Review, January, 1974.

3 M. Ezaki shows that equation (34) is equivalent to the weighted average of all industries' TFPG rates where the weights are their output value shares. See M. Ezaki, "Growth Accounting of Postwar Japan: The Input Side," The Economic Studies Quarterly, Japan, December 1976. pp. 193-215.

4 National Statistical Office of Thailand (NSOT), Report on Industrial Census: Whole Kingdom, Bangkok, 1964, 1969 and 1971; and NSOT, Industrial Census: Whole Kingdom, Computer Files, Bangkok, 1972, 1975 and 1976.

5 See Industrial Economic and Planning Division, Ministry of Industry, Industrial Statistics, Bangkok, 1978; Division of Commodity and Marketing Research, Ministry of Commerce, Report on Industrial Research, Bangkok, various reports; National Economic and Social Development Board, Industrial Development Planning of Thailand, 1977-1981, Bangkok, various publications.

6 The value shares obtained from the NSOT data and Ministry of Industry data are, however, not significantly different in most industries.

7 See the discussion on Divisia Index numbers in E.R. Berndt, "Aggregate Energy, Efficiency, and Productivity Measurement," Annual Review of Energy, 1978, pp. 225-73; C.R. Hulten, "Divisia Index Numbers;" and S. Star and R.E. Hall, "An Approximate Divisia Index of Total Factor Productivity." It should also be noted here that the estimation of real output growth rates by the Divisia Index is better than estimating the growth rates from price-deflated output of three-digit ISIC industries for the following reasons. First, it avoids the familiar price index problems. Second, it is free from the aggregation problem of the price indexes and value of output of the industries.

8. When commodities' production values and quantities are both available, commodity prices are found by dividing the production values by the quanticies. But when productior values are not available, prices of imports or exports are used instead to represent the prices of commodities. The sources of all these data are the same as in footnote 5.

9 The "major" purchased inputs include all inputs whose shares in total purchased inputs are at least as much as one percent, and at the same time, the sum total of whose values is at least as small as 90 percent. The rule can be shown to provide us with the estimates of real intermediate inputs which are very close to the ones using the deflators of "all" purchased inputs.

10 The price indexes represent the basket of both domestic and imported goods. The source is Division of Price Index, Ministry of Commerce, Wholesale Price Index of Thailand, Bangkok, 1978.

11 The input-output table is from Thailand Input-Output Joint Project: NESDB, IDB (Tokyo), and NSOT, Basic Input-Output Table of Thailand, 1975, Bangkok, 1980.

12 See A.O. Krueger and B. Tuncer, "Estimating Total Factor Productivity Growth in a Developing Country," World Bank Staff Working Paper, No. 422, Washington, D. C. 1981.

13 See the detailed discussion in the introduction of this section.

14 On the average, the weights of transport equipment, and machinery and equipment are about one-third and two-thirds, respectively. The data source is NSOT, Industrial Census: Whole Kingdom, various years.

15 See Division of Price Index, Ministry of Commerce, Wholesale Price Index of Thailand.

16 See NESDB, National Income Account of Thailand, Bangkok, 1952. Note also that the NESDB's data on total fixed capital formation of 1949 are for the entire manufacturing sector. We estimate that about one-half of the capital formation was from firms with 10 or more workers. The estimation is done based on information from the NSOT's 1963 industrial census. In the census, it was estimated that over one-half of the value of fixed assets of the industrial sector in 1963 was from firms with 10 or more workers.

17 Note that the closer each industry's capital-output ration is to the capital-output ratio of total industries, the better is the estimation used above.

18 See United Nations Industrial Development Office, United Nations, The Growth of Industry, 1938-1961, National Tables, New York, 1963.

19 See National Economic Council, Central Statistical Office, Statistical Yearbook of Thailand, Bangkok, 1952.

20 See A.O. Krueger and B. Tuncer, "Estimating Total Factor Productivity Growth of a Developing Country."

21 See W.R. Park, Cost Engineering Analysis, New York: John Wiley and Sons, 1973.

22 See, for example, Nishimizu and Hulten's estimation of the Japanese growth in M. Nishimizu and C.R. Hulten, "Source of Japanese Economic Growth, 1955-1971," The Review of Economics and Statistics, August 1978,pp. 351-361.

III. THE ESTIMATION AND ANALYSIS OF TFPG OF THAI MANUFACTURING INDUSTRIES

3.1 TFPG as a Source of Real Output Growth

Table 3.1 shows the rates of growth of real output, real inputs and the TFPG of all manufacturing industries with 10 or more workers in the period of 1963 - 1979, including three subperiods of 1963 - 1970, 1970 - 1976, and 1976 - 1979. For the entire period of 1963 - 1979, real output grew at the rate of 14.06 percent per year. When separated into two main sources of growth, namely, the accumulation of real inputs and their TFPG, the table shows that the latter source was still minor despite the high real output growth. In fact, the TFPG contributed only 1.02 percentage points out of the 14.06 percent of the real output growth rate. In other words, a substantial part of real output growth was due to the increases in total real inputs whereas less than eight percent was due to TFPG which measures the increases in the savings of inputs used in the production of a unit of output.[1]

This estimate of the TFPG is rather low compared to the estimates of many DCs such as US and Japan. In the US the estimated rates of TFPG of the aggregated manufacturing sector are about 1.82 percent (Kendrick, 1980) in the past two decades. In Japan it was on the average of about 2.04 percent (Hulten and Nishimizu, 1981) for all the disaggregated industries. They all accounted for about 17 percent of real output growth. The TFPG comparison with other LDCs is more difficult because so far not many studies have been done. It is due partly to the paucity of data. Although there are some TFPG estimates that are for economy-wide, those for the manufacturing sector are very scarce. Moveover, those that are available are usually estimated by different methodologies, varying periods of time, and different scopes of the manufacturing sector. Above

Table 3.1: GROWTH RATES OF REAL OUTPUT, INPUTS, AND TOTAL FACTOR PRODUCTIVITY OF TOTAL MANUFACTURING INDUSTRIES, 1963 - 1979

Input Shares in Production

Year	Intermediate	Labor	Capital
1963 - 70	.6062	.0807	.3131
1970 - 76	.6387	.0790	.2823
1976 - 79	.6525	.0677	.2798
1970 - 79	.6538	.0680	.2782
1963 - 79	.6422	.0748	.2830

Continuous Annual Growth Rates in Percent of

Year	Output	Input			Weighted Input				
		Intermediate	Labour	Capital	Intermediate	Labor	Capital	Total Inputs	TFP
1963 - 70	18.79 (100.00)	19.81	14.36	16.71	12.01 (63.92)	1.16 (6.17)	5.23 (27.83)	18.40 (97.92)	0.39 (2.08)
1970 - 76	11.70 (100.00)	10.47	8.64	10.03	6.69 (57.18)	0.68 (5.81)	2.91 (24.87)	10.28 (87.86)	1.42 (12.14)
1976 - 79	11.26 (100.00)	13.84	1.54	1.25	9.03 (80.19)	0.10 (0.89)	0.35 (3.11)	9.48 (84.19)	1.78 (15.81)
1970 - 79	11.48 (100.00)	11.25	6.64	6.88	7.36 ([illegible].11)	0.45 (3.92)	1.91 (16.64)	9.72 (84.67)	1.76 (15.33)
1963 - 79	14.06 (100.00)	14.35	9.46	11.02	9.21 (65.50)	0.71 (5.03)	3.12 (22.19)	13.04 (12.75)	1.02 (7.25)

Source: National Statistical Office of Thailand, Report of Industrial Census: Whole Kingdom, various years (see details in Section 2)

Notes : Figures in parentheses are ratios of growth rates of inputs and TFPG to growth rate of real output in percentages.

all, they are mostly at the highly aggregated level of industrial classification. For example, Chen estimated the TFPG rates of the aggregated manufacturing sector of the four fast growing countries in Asia, namely, Hong Kong, South Korea, Taiwan and Singapore, to be 2.29, 3.47, 3.59 and 3.75, respectively, during the 1960s. They all, however, accounted for only 12 to 18 percent of the rate of growth of real output of the sector which is also low compared to the DCs' standard. At a more disaggregated level, Krueger's estimate of the average TFPG in the Turkish manufacturing industries was about 2.10 percent during 1963 - 1976 or accounted for about 17 percent of real output growth[2]. Tsao Yuan's estimate of TFPG in the Singapore industries during 1970 - 1979 was about 0.69 percent or accounted for about four percent of real output growth[3].

Although the rate of TFPG of Thailand was low for the entire period of 1963 - 1979, compared to the DCs and a few available estimates of LDCs, Table 3.1 shows that it had increased over the two decades. During the 1960s (1963 - 70), it was about 0.39 percent or accounted for two percent of the 18.79 real output growth rate. During the early to mid 1970s (1970 - 76) it was increased to 1.42 percent or about 12 percent of the 11.70 rate of growth of real output. By the late 1970s (1976 - 79) it accelerated to 1.78 percent or about 15 percent of the 11.26 percent of real output growth. In other words, the increase in real inputs as a source of real output growth had declined over time to be compensated by the acceleration of the TFPG rates. This finding is in fact similar to the Hayami-Ruttan study on the agricultural productivity growth of an LDC, namely, the Philippines, during 1950-1969 (Hayami-Ruttan, 1979). They found that during the early period of agricultural development from 1950 to 1959, real farm output could grew rapidly despite the low TFPG by exploiting the relatively elastic supply of uncultivated land while applying more labor and other inputs in response to the increase in market demand. However, after uncultivated land became more limited in the mid-1960s as land opening proceeded, the TFPG rate as a source of the growth of real farm output increased to compensate for the decline in the rate of growth of real inputs relative to output. In our study of the TFPG of manufacturing industries in Thailand, it may be that real output can grow more quickly during the initial period of industrialization of 1963 - 1970 than during the latter period despite the low TFPG by combining the relatively abundant raw material resources with labor and capital inputs for production. However, as raw material inputs become more expensive relative to other inputs in the latter period, the TFPG rate must accelerate to offset the decline in real raw material growth rate in order for real output to expand at a high rate.

3.2 The TFPG and Increases in Raw Material Prices

Michael Bruno shows that if output is produced by the combination of three factors of production - labor, capital and intermediate input - and intermediate input is employed optimally to the level at which its marginal product is equal to its relative price, then the production function can be expressed in terms of the two remaining labor and capital factors and the relative intermediate input prices. In this model, in the short run, when capital is fixed, if labor employment is also somehow constant, then an increase in the relative intermediate input prices will affect real factor incomes like the Hicks-neutral technical regress. That is, there will be an inward homothetical shift in the factor-price frontier in the factor-cost space or, equivalently, an outward homothetical shift in the isoquant in the primary input space.[4]

In the case of Thailand, the TFPG of almost all industries was retarded by the increases in energy prices and other raw material prices in both the early and the end of the 1970s. During the period 1972 - 1974. Although there was a control on the prices of petroleum products for industrial use the prices increased more than twofold or about 71 percent a year (see Table 3.2). The average price of other major intermediate products of the industrial sector such as textile materials, pulp paper, chemical materials, and basic metals (especially the imported ones) increased at the rate of over a quarter percent per year.[5] These price increases slowed down the TFPG of some industries sooner, but some with a lag. However, the increases in energy prices alone were unlikely to have had that much impact on the slowdown of the TFPG because the cost of energy in the value of production of all industries was only a few percent before 1973 and jumped to the maximum of no more than five to six percent later.[6] What affected them more were first, the accompanying increases in the prices of other raw materials whose share in total production was over one-half (see Table 3.2), especially among the heavier import-substituting industries. Second, the decreases in demand for all products in the early 1970s. Both shocks made it difficult for industries to expand as evidenced from the decreases in the growth of industrial output to the average rate to 8.51 percent per year during the period. Meanwhile, capital and labor inputs were not able to adjust fast enough in the short run. In this period, some capital stock which was accumulated as a fast rate in the late 1960s to the early 1970s was left under utilized.[7] On the other hand, due to the rise of labor unions in the early 1970s, some industries such as textiles and clothing had difficulties in lowering employment in response to the decline in production. All these made real output decline faster than real input, and the result was a substantial decline in the TFPG in many industries

Table 3.2: GROWTH RATES OF REAL OUTPUT, INPUTS, AND TOTAL FACTOR PRODUCTIVITY OF TOTAL MANUFACTURING INDUSTRIES IN FOUR SUBPERIODS

Period	Factor Share			Annual Percentage Growth Rates of:					Annual Percentage Increase of imported oil prices
	Intermediate	Labor	Capital	Output	Intermediate	Labor	Capital	TFP	
1963 - 72	0.6169	0.0811	0.3020	17.19	18.57	14.54	16.11	0.41	
1972 - 74	0.6381	0.0823	0.2796	8.51	6.41	12.48	12.35	-0.06	70.77
1974 - 77	0.6423	0.0721	0.2856	14.26	14.30	-2.02	0.52	5.07	8.41
1977 - 79	0.6583	0.0631	0.2786	8.63	11.68	5.43	4.39	-0.62	20.93

Source: National Statistical Office (same as Table 3.1), and Bank of Thailand, Annual Report, various years.

during 1973 - 1974. However, during 1974 - 1977, when aggregate demand increased and all inputs were adjusted better to the chocks, TFPG rose again. During the period, output increased at 14.26 percent a year, labor input declined at 2.02 percent, capital input increased slowly at 0.52 percent, and TFPG accelerated to 5.07 percent a year.

In the late 1970s when there was another steep increase in energy prices combined with the slower growth of demand, TFPG declined again for the same reason as the period of the early 1970s. During 1977 - 1979, energy prices increased at over 20 percent a year. Output grew at less than 9 percent a year, but total real inputs grew at 9.25 percent. As a result TFPG rate was declined to negative 0.62 percent.

3.3 Comparison of TFPG of Import-Substituting and Exporting Industries

Import-substitution policies in Thailand to encourage domestic industrial production were introduced in the late 1950s and continued throughout the decade of the 1960s. The government protected new industries from foreign competition by imposing higher tariffs on imports competing with them and, at the same time, imposed lower tariffs on raw materials and capital inputs used in production. The rationale for the policies was mainly for the survival of these newly established industries during some initial period of production when their costs were higher than the products' imported prices. Advocates of the policies believe that over the passage of time when some factors such as learning-by-doing, externalities, indivisibilities and so on can be realized or corrected such that the total average costs decline, they would be viable without any more protection. This, in turn, suggests that after some initial period of production, inputs per unit of output of these protected industries should decline. Moreover, the decline should be at a rate faster than other unprotected industries.[8] In other words, one would expect the TFPG of the protected import-substituting industries to be higher than others for the advocates of the policies to be correct.

In Thailand during the whole period of 1963 -1979, according to Table 3.3, on the average of all protected import-substituting industries, TFPG was lower than the average of all industries, and it was much lower than that of non-import-competing and exporting industries. The annual rate of TFPG of import-competing industries was almost nil. However, for non-import-competing industries, it was about 1.22 percent a year which accounted for about eight percent of the growth of its real output. For exporting industries, it was about 1.26 percent and accounted for about nine percent of the real output growth.

When comparing the TFPG of the import-competing industries between the two subperiods of the 1960s and 1970s, we found that it declined in the later decade as contrasted with other industries which experienced an increase in the TFPG over the two decades. In other words, for import-competing industries, over time the dominant sources of growth of real output were either from the accumulation of raw materials or capital input. When comparing the percentages of this input growth relative to real output growth between the two subperiods, they were even higher in the latter subperiod than the first subperiod of the 1960s when

Table 3.3: GROWTH RATES OF TOTAL FACTOR PRODUCTIVITY RELATIVE TO REAL OUTPUT OF INDUSTRIES BY TRADE CATEGORIES, 1963 -1979

	Import-Competing Industries			Non-Import-Competing Industries		
	Growth Rates of		Ratio of TFPG to	Growth Rates of		Ratio of TFPG to
Year	Output (%)	TFP (%)	Output Growth (%)	Output (%)	TFP (%)	Output Growth (%)
1963 - 70	19.44	0.37	3.76	19.31	0.25	1.29
1970 - 79	13.09	-0.40	-3.31	11.25	1.98	17.60
1963 - 79	15.88	0.01	0.06	14.78	1.22	8.25

Exporting Industries

	Growth Rates of		Ratio of TFPG to	
Year	Output (%)	TFP (%)	Output Growth (%)	Export Growth
1963 - 70	16.35	0.65	3.54	9.65
1970 - 79	11.77	1.72	14.61	14.50
1963 - 79	14.00	1.26	9.00	19.86

Source: Same as Table 3.2

the input prices were lower. Lower tariffs in both subperiods permitted industries to have a higher import content of raw material inputs and a faster growth of capital intensity over time. Whenever they wanted to increase production to meet the strong domestic demand resulting from higher tariffs on imported products, they simply increased raw material and capital inputs, mostly imports. With the protection resulting in higher domestic prices and lower imported raw material and capital input prices, they did not have to make an effort to modify, adapt or manage the inputs to reduce total costs in order to be competitive in the market.[9] In fact, the protection not only provided a shelter for these industries to exist even when their TFPG was declining over time, but it also squeezed out the TFPG as a source of their real output growth.

For exporting industries, when comparing the two subperiods, the TFPG was higher in the second period of the 1970s than in the earlier one. It increased from 0.65 percent which accounted for about four percent of real output growth in the first period to about 1.72 percent which accounted for about 15 percent of real output growth in the second period. In fact, the second period was also noted for the expansion of exports in response to the policies favoring export promotion started in early 1970s. In the 1960s export grew at 9.86 percent a year. In the 1970s the rate of export growth was Increased to 14.56 percent a year. This suggests a positive relation between TFPG and the growth of exports in the two decades. The growth of the TFPG which reflected the increase in savings of all real inputs per unit of output over time enables the industries to compete in the world market. On the other hand, the increases in exports allowed domestic production to grow fast enough to exploit some abundant raw materials, to better utilize capital stock, and to employ better skilled workers. All of these factors together with the advantage of extending production to the most efficient scale foster increases in the TFPG. This positive effect of export growth on the TFPG of industries was in contrast with the low TFPG observed in the import-competing industries discussed earlier. The growth of import-competing industries entailed the faster growth of raw materials and capital goods, mostly imported, than their real output growth over time. Meanwhile, as will be seen in the next section, their labor productivity growth was also hindered by the distorted production technology in light of available unskilled labor. All these factors, together with the possible inefficiency in the use of plant size due to the small domestic market, explain the low TFPG of the import-substituting industries.[10]

3.4 Sources of Labor Productivity Growth and TFPG

This section concerns two questions regarding to the source of labor productivity growth and the source of TFPG of the manufacturing industries in Thailand during 1963 - 1979. First, how important was it that increases in capital intensity contributed to the improvement of labor productivity? Second, how important was it that increases in physical inputs contributed to the advancement of total factor productivity?

For the first question, the analysis is done by considering the following equation which states that labor productivity growth can be categorized to be from three sources, namely, the growth of raw material inputs per worker, the growth of capital input per worker, and the TFPG.

(46)

$$\left[\frac{\hat{Q}_i(t)}{Q_i(t)} - \frac{\hat{L}_i(t)}{L_i(t)}\right] = \beta(t)\left[\frac{\hat{M}_i(t)}{M_i(t)} - \frac{\hat{L}_i(t)}{L_i(t)}\right] + \left[1 - \alpha(t) - \beta(t)\right]\left\{\frac{\hat{K}_i(t)}{K_i(t)} - \frac{\hat{L}_i(t)}{L_i(t)}\right\} + TFPG$$

where the notation was described in Section 1.

The estimation of the rates of labor productivity growth, increases in real raw material and capital inputs per worker, and the TFPG by equation (46) for the aggregated industries during the entire period of 1963 - 1979 and the two subperiods of 1963 - 1970 and 1970 - 1979 are presented in Table 3.4. According to the table, during the whole period of 1963 - 1979, labor productivity growth of manufacturing industries in Thailand grew at the rate of about 4.6 percent per year. Of this, about 68 percent was accounted for by the increase in raw material input per worker, 22 percent by TFPG, and the lowest 10 percent by the growth of capital per worker. When comparing the contribution of each source of labor productivity growth in two subperiods, it is found that TFPG became a much more important source in the second subperiod of 1970 - 1979 than in the first subperiod of 1963 - 1970, while the contribution of both the growth of raw material input per worker and that of the growth of capital intensity declined. The contribution of TFPG to labor productivity growth increased from 9 percent in the 1960s to 36

Table 3.4: GROWTH RATES OF LABOR PRODUCTIVITY, INTERMEDIATE AND CAPITAL INPUTS PER WORKER, AND TOTAL FACTOR PRODUCTIVITY, 1960 - 1979

Continuous Annual Growth Rates in Percent of:

Year	Output per Worker	Input per Worker		Weighted Input per Worker			TFP
		Intermediate	Capital	Intermediate	Capital	Total Input	
1963 - 70	4.43 (100.00)	5.45	2.35	3.30 (74.50)	0.74 (16.70)	4.04 (91.20)	0.39 (8.80)
1970 - 79	4.84 (100.00)	4.61	0.24	3.01 (62.19)	0.07 (1.45)	3.08 (63.64)	1.76 (36.36)
1963 - 79	4.6 (100.0)	4.89	1.56	3.14 (68.26)	0.44 (9.57)	3.58 (77.83)	1.02 (22.17)

Source: Same as Table 3.1

Note: Figures in parentheses are ratios of growth rates of inputs per worker and TFPG to growth rate of real output per worker in percentages.

percent in the 1970s. On the other hand, that of real raw materials per worker declined from 75 percent to 62 percent; that of capital per worker from 17 to less than 2 percent in the two successive subperiods.

It is interesting to note the small contribution of increases in capital per worker as contrasted with the increasingly larger contribution to the TFPG to labor productivity growth over the two subperiods. In the 1960s, LPG was 4.43% and capital-labor ratio increased at 2.35 percent a year. In the 1970s, labor productivity growth accelerated to 4.84 percent despite the smaller increase in capital intensity. In fact it was the acceleration of TFPG that led to the increase in labor productivity. This can possible be explained by the following reasons. In the 1960s when capital input could be obtained at both lower prices and tariffs, capital intensity increased faster than the later period of the 1970s. Lower skilled workers in the 1960s had to work with imported machinery and equipment which were not quite suitable for local labor skills, management and markets. The result was that increases in capital intensity was accompanied by low TFPG and it did not account for much of the increase in labor productivity. In the second period of the 1970s, the capital-labor ratio increased at a lower rate than the previous decade due to the increases in the relative prices of imported capital goods and the increases in capacity utilization. Entrepreneurs were inclined to adapt existing machinery and equipment to fit the available raw materials, labor skills and market size instead of having newly imported capital equipment. This enabled the accumulation of capital together with increasing TFPG to be the source of improvement in labor productivity. Thus, the effectiveness of policies to improve labor productivity by simply subsidizing and lowering tariffs on any capital input purchases cannot be supported, at least by our study.

Regarding the source of TFPG, did the increase in TFPG result from improvement embodied in raw material, capital and labor inputs? If that were the case, we would expect a positive association between TFPG and the growth of real inputs. In other words, industries with a higher growth of real inputs should also have a higher TFPG.

The above hypothesis was tested by estimating the following simple regression:

(47) $$TFPG = b_o + b_1 \, GIP + u$$

Where TFPG denotes total factor productivity growth and GIP denotes the growth of all real inputs. If TFPG is led by increases in real inputs, b_1 should have a positive value. The estimated regressions for the entire period of 1963 - 1979 and two subperiods of 1963 - 1970 and 1970 - 1979 are presented below.

(48) $$TFPG\ (1963 - 70) = 1.14 - \underset{(0.03)}{0.20}\ GIP \qquad R^2 = 0.02$$

(49) $$TFPG\ (1970 - 79) = 2.64 - \underset{(0.09)}{0.15}\ GIP \qquad R^2 = 0.12$$

(50) $$TFPG\ (1963 - 79) = 2.01 - \underset{(0.05)}{0.08}\ GIP \qquad R^2 = 0.08$$

According to the above estimated regressions, b_1 is not significantly different from zero in any period. There simply is no evidence to conclude that increases in real inputs brought about any increases in total factor productivity.

Footnotes to Section 3

1 The low TFPG estimate may also attribute to the downward bias caused by the overestimation of the growth rate of raw materials and labor and factor shares described in Section 2, although the biases are not expected to be significant.

2 See A.O. Krueger and B. Tuncer, "Estimating Total Factor Productivity growth in a Developing Country."

3 See Y. Tsao, "The Growth of Productivity of the Manufacturing Industries in Singapore, 1970-79," a memio, National University of Singapore, 1983.

4 See M. Bruno, "Raw Materials, Profits, and Productivity Slowdown," Quarterly Journal of Economics, February 1984, pp. 1 - 29.

5 See the price data and discussion in Division of Price Index, the Ministy of Commerce, The Wholesale Price Index of Thailand, 1978, and the Bank of Thailand, Annual Reports, Bangkok, 1973 - 1976.

6 The figures are computed from the National Statistical Office of Thailand, Report of Industrial Census: Whole Kingdom, Bangkok, various years.

7 See Bank of Thailand, Annual Report, Bangkok, 1973 - 1975.

8 This hypothesis was tested and found invalid in the case of Turkey in A.O. Krueger and B. Tuncer, "An Empirical Test of the Infant Industry Argument," The American Economic Review, Vol. 72, December 1982, pp. 1142 - 1152.

9 An example for the argument can be found in Paitoon Wiboonchutikula, "Productivity Growth of Agricultural Machinery Industry in Thailand, 1960-1979," in Consequences of Small Farm Mechanization, International Rice Research Institute and Agricultural Development Council, Philippines, 1983.

10 For further discussion on other possible reasons for the superior performance of the export promotion policy over the import-substitution policy, see A.O. Krueger, "Export-Led Industrial Growth Reconsidered," in Wontack Hong and Lawrence B. Krause, eds., Trade and Growth of Advanced Developing Countries in the Pacific Basin, Korea Development Institute, Seoul, Korea, 198[illegible].

IV. THE MEASUREMENT OF EFFICIENCY AT INDIVIDUAL FIRM LEVEL

Productivity can be compared within a firm over the passage of time, or it can be compared among firms in a given period of time. For the former case, productivity of a firm changes because of the changes in technology and the level of efficiency of production over time. For the latter case when time and the state of technology are given, productivity may be different among firms in the same industry because of their differences in the efficiency levels. Some firms may be more technically efficient than others. The technically efficient firms will produce maximum output with given inputs under the available state of technology at that time. The technically inefficient firms will produce less than the maximum output given the same amount of inputs as the efficient one. This section measures and analyses the levels of technical efficiency of firms in selected industries in Thailand in 1974, 1977 and 1979, the years in which the firm data are available. It also decomposes TFPG into two sources namely, changes in technical efficiency and other residuals such as the technological progress.

4.1 The Method of Measurement of Efficiency of the Firms

The production function is defined as the relationship that shows the maximum possible output which can be produced from given quantities of inputs. Any firm which produces below the maximum on the production function is said to be technically inefficient.

If production function of an output y is defined as

(51) $$y = f(x)$$

where $x = (x_1 x_2, \ldots\ldots\ldots, x_n)$ is the vector of real inputs for the product - ion of y, then the production of the j-th firm can be specified as

(52) $$y_j = f_j\ (x) + u_j \quad , \quad u_j \leq 0$$

where u_j is the difference between the output obtained by the j-th firm using input x and the output on the frontier of the production function in Equation (51).

A most technically efficient firm will adopt the "best practice techniques" to maximize output for a given bundle of inputs. It will produce on the production possibility frontier and have $u_j = o$ If the firm does not use the best practice technique, it will be less efficient. The production of the firm will be below the production possibility frontier and u_j will be negative. In general, The magnitude of u in an industry will vary across firms, depending on the level of technical efficiency or the firms.

Aigner and Chu[1] specify a homogeneous Cobb -Douglas production frontier and show how the parameter u can be estimated using mathematical programming., The problem is formulated to minimize the sum of absolute differences (a linear programming problem) or the sum of squared differences (a quadratic programming problem), under the constraint that all differences are negative or zero. The estimated frontier is supported by a set of sampled data and is therefore extremely sensitive to outliners.

Timmer[2] follows Aigner and Chu's suggestion and solves the above problem by discarding a few extreme observations. The justification is that these observations lying above the frontier are due to random errors. However both of Aigner and Chu's and Timmer's estimated production frontier have no statistical properties because no assumptions are made about the distribution of u_j. Thus, the efficiency measurement of each firm from this method is the efficiency level relative to the best practice frontier of the samples rather than the population.

To amend Aigner and Chu's model to statistical analysis, some assumptions on u_j have to be made and the production frontier is estimated by either the maximum likelihood method[3] or the "corrected" ordinary least square method [4,5]. The maximum likelihood estimates of the parameters of the frontier depend on the distribution of u and it is difficult to provide a good prior arguments for any particular distribution. Richmond's corrected least square method is simpler and can provide consistent estimates of the parameters. Richmond assumes that the production function is specified as

(53) $$\log y_j = \log A + \sum_{i=1}^{n} a_i \log x_{ij} - Z_j$$

where $Z_j = -\log u_j$ and Z_j has a gamma distribution with parameter n. Thus, Z is in fact the efficiency parameter with mean n and variance n. If $n < 1$, most firms are fairly efficient. If $n = 1$, all firms have a uniform distribution, If $n > 1$, most firms are relatively inefficient.

It is possible to transform Equation (3) into

(54) $$\log y_j = a_o + \sum_{i=1}^{n} a_i \log x_{ij} + v_j$$

where $a_o = \log A - n$, $v_j = n - Z_j$, $E(v_j) = 0$, $Var(v_j) = n$, and $E(v_i v_j) = o, i \neq j$.

In addition, if it is assumed that $E(v_j / x_{ij}) = 0$, Equation (4) can be estimated by the ordinary least squares method where $E(\hat{a}_o) = \log A - n$, $E(\hat{a}_i) = a_i$, and $E(\hat{n}) = n$; $i = 1, 2, ---n$.

The firm specific efficiency measurement can then be estimated by $u_j = y_j/\hat{y}_j$, and the average efficiency level of the industry is $E(u) = 2^{-n}$.

4.2 Estimates of the Efficiency Levels of Manufacturing Firms

Following Richmond's[6] approach for measuring efficiency at the firm level, the production function of the j - th manufacturing firm is defined as

$$(55) \qquad \log Y_j = \log A + \alpha \log M_j + \beta \log L_j + \gamma \log K_j + V_j$$

where M_j, L_j and K_j are three inputs used in the production of Y_j. The inputs are intermediate inputs, labor input, and capital input respectively.

The measurement of the efficiency levels of firms is done for selected industries and years in which the firm data are available. The selecled industries will be shown in the tables below and the years under study are 1974, 1977, and 1979. The source of the data is the industrial census conducted by the National Statistical Office of Thailand (NSOT). The NSOT census is as mentioned earlier, a sample that is drawn from all firms with ten or more workers, the response rate of the NSOT census sample is on the average about 75 percent. The rate varies from year to year and industry to industry.

The data of output of each firm is the value of production. Intermediate inputs include the values of raw materials, energy, and other expenses. Labor input is the number of workers. Capital inputs are the aggregation of the gross book values of three types of assets namely building and structures, machinery and equipment, and vehiches. All variable except the number of workers are in nominal terms without deflation because the production frontiers are estimated by using cross sectional data.

A note should be made on the estimates of capital inputs. The gross book values of assets from the census are based on the historic costs rather than the replacement costs. Since the data on the years of purchases of different types of capital goods in each firm are not available, it is not possible to adjust the values for inflation. As such, for the new firms the capital inputs may be overstated and the efficiency levels understated. For the old firms the biases may be in the opposite directions. In fact, if additional data on the age of firms were available, we would at least be able to identify firms with such biases.

An alternative procedure of measuring capital inputs other than the one using the book values of fixed assets would be the perpetual inventory method described in Section 2.3 . The method requires panal data of firms which are unfortunately not available. Although there are data of each industry by firms on a yearly basis, the firms are not identifiable. Otherwise we would have been able to trace data of the same firm in successive years to obtain the panal data. Thus, the capital inputs estimates may be susceptible to the most errors of measurement.

4.2.1 Estimates of Average Efficiency of Selected Industries

The estimates of the average efficiency of selected industries in Thailand for the years 1974, 1977 and 1979 are shown in Tables 4.1, 4.2 and 4.3 respectively. In 1974 data are available for a smaller number of industries compared to other years. The sample firms of each industry is also fewer. Most industries in 1974 however, showed high levels of efficiency. The ones with the highest efficiency levels of greater than 90 percent were cotton ginning, rubber sheet and block rubber, and motorcycles and bicycles. The rest except builders' woodwork had the efficiency levels in the range of 80-90 percent. The efficiency of rubber tires and tubes was about 89 percent. Pulp paper, and paperboard, and other rubber product industries had the efficiency of 81 percent. Builders' woodwork showed the lowest efficiency level of 75 percent.

In 1977 data are available for more industries. The sample size is also larger so that the better estimates of efficiency can be obtained. Almost all industries with data available for comparison with those in 1974 showed that efficiency was improved in 1977. The top most efficient industries in 1974 showed even higher levels of efficiency. Builders' woodwork's efficiency increased to [illegible]7 percent and the pulp paper and paperboard, rubber tires and tubes, and other rubber product industries showed some improvement of efficiency in 1977 but their levels were still below 90 percent. The additional selected industries in 1977 with efficiency greater that 90 percent were other paper and paper product, and transport equipment industries. The ones with the lowest efficiency of less than 80 percent were textile printing, and radio, T.V., and communication equipment.

Table 4.1: ESTIMATES OF AVERAGE EFFICIENCY OF SELECTED MANUFACTURING INDUSTRIES IN THAILAND, 1974

ISIC	Industries	No.of firms	Efficiency Levels
32112	Cotton ginning	6	.957
32113	Builders' woodwork	11	.747
34111	Pulp, paper, and paperboard	5	.807
35510	Rubber tires and tubes	10	.885
35591	Rubber sheets and block rubber	9	.996
35599	Other rubber products	10	.809
38440	Motorcycles, tricycles and bicycles	6	.948

Source: National Statistical Office of Thailand

Table 4.2: ESTIMATES OF AVERAGE EFFICIENCY OF SELECTED MANUFACTURING INDUSTRIES IN THAILAND, 1977

ISIC	Industries	No. of Firms	Efficiency level
32112	Cotton ginning	[illegible]	.968
32113	Builders' woodwork	19	.867
32117	Textile printing	9	.758
34111	Pulp paper, and paperboard	8	.848
34120	Paper containers and paperboard	5	.703
34190	Paper and paper products, nce.	8	.915
35510	Rubber tires and tubes	14	.867
35591	Rubber sheets and block rubber	23	.952
35599	Other rubber products	23	.831
38320	Radio T.V. and Commumication equipment	7	.798
38431	Automobile assembly	7	.914
38432	Motor vehicle bodies	12	.948
38439	Other motor vehicles	7	.957

Source: National Statistical Office of Thailand

Table 4.3: ESTIMATES OF AVERAGE EFFICIENCY OF SELECTED MANUFACTURING INDUSTRIES IN THAILAND, 1979

ISIC	Industries	No.of Firms	Efficiency Levels
32112	Cotton ginning	19	.942
32113	Builders' woodwork	10	.955
32117	Textile printing	18	.701
34111	Pulp paper, and paperboard	7	.801
34120	Paper containers and paperboard	12	.740
35510	Rubber tires and tubes	23	.923
35591	Rubber sheets and block rubber	22	.883
35599	Other rubber products	20	.595
38320	Radio,T.V.and Communication equipment	9	.582
38431	Automobile assembly	11	.165
38432	Motor vehicle bodies	14	.863
38439	Other motor vehicles	23	.815
38440	Motorcycles, tricycles and bicycles	11	.928

Source: National Statistical Office of Thailand

In 1979 all industries except for rubber tires and tubes showed a decline in technical efficiency. The industries which showed the smaller declines in efficiency and were able to maintain or have the over 90 percent levels of efficiency were cotton ginning, builders' woodwork, and motorcycles and bicycles. The rest showed larger and varying degrees of efficiency declines. The ones with the larger declines than the rest were industries in the group of paper and paper products and transport equipment.

For all the three years the industries which showed consistently high levels of efficiency were cotton ginning, rubber sheet and block rubber, and motorcycles and bicycles. The ones which showed more declines in efficiency in the late 1970s were paper and paper product, and transport equipment industries. Most of the industries in the former group of high average efficiency levels were exporting industries which were exposed to competition in the world market. The latter group of lower efficiency had higher capital intensity and the industries produced import - substituting products.

4.2.2 Estimates of Efficiency Levels of Individual Firms

The estimates of the firm specific efficiency levels of the selected industries for the years 1974, 1977, and 1979 are presented in Table 4.4. The discussion of the measured efficiency of the firms will be done below by industry.

4.2.2.1 Textile and Textile Product Firms

Data are available for three industries producing textiles and textile products. They are cotton ginning, builders' woodwork, and textile printing. The cotton ginning industry showed the highest level of average technical efficiency. Firms in this industry had low capital-labor ratio and were mostly of medium size in terms of employment. They employed less than 100 workers. In 1974 and 1977 all firms showed the efficiency levels greater than 90 percent. In 1979 there were data from more sample firms available. The additional firms were mostly of smaller size and the average efficiency of the industry showed a decline somewhat. This implies that the additional smaller firms had below average efficiency of the industry. In fact, the more efficient firms in each year were medium ones employing 30 - 50 workers.

Firms in the builders' woodwork industry were on the average larger than the ones in the cotton ginnings industry. A large number of sample firms employed over 300 workers. The capital-labor ratio was also much higher. The efficiency levels of most firms in 1974 were low, but they were tremendously increased after the mid-1970s. The more efficient firms in 1977 and 1979 all employed 300 - 400 workers, but the capital intensity of the firms were on the average of the industry.

Firms in the textile printing industry were all small, employing less than 60 workers. However, the average capital intensity of the industry was higher than that of the cotton ginning industry. No data are available for 1974. In 1977 about 40 percent of total number of firms had efficiency below 70 percent. In 1979 the number of less efficient firms increased to over 70 percent. The most efficient firm in each year was shown to have below average size and capital intensity.

Table 4.4: ESTIMATES OF EFFICIENCY LEVELS OF MANUFACTURING FIRMS IN THAILAND, 1974, 1977 and 1979

Firm	32112: Cotton ginning			32113: Builder' woodwork			32117: Textile printing		34111: Pulp paper and paper board		
	1974	1977	1979	1974	1977	1979	1977	1979	1974	1977	1979
1.	80.9	90.2	71.6	100.0	81.5	64.7	83.5	72.7	100.0	55.2	90.0
2.	90.3	78.2	80.7	63.1	68.6	93.4	71.3	72.8	58.8	64.1	100.0
3.	100.0	82.4	82.6	57.5	73.5	100.0	100.0	59.1	84.7	74.8	73.8
4.	95.8	100.0	92.8	43.3	100.0	84.0	64.7	29.9	53.7	100.0	91.6
5.	99.7	92.7	68.7	60.4	89.4	86.8	70.0	65.3	89.3	78.2	92.3
6.	76.6	86.2	81.2	63.6	59.9	82.7	41.6	59.2		70.5	76.8
7.			72.7	59.3	63.7	78.3	76.6	43.6		74.9	96.2
8.			82.7	51.5	43.5	89.9	47.2	100.0		83.3	
9.			86.0	66.8	77.6	92.6		51.1			
10.			69.4	44.2	66.8	91.3		96.2			
11.			100.0	68.7	79.5			48.9			
12.			89.7		89.4			31.5			
13.			70.7		73.4			70.6			
14.			82.7		63.6			50.5			
15.			77.5		62.8			50.3			
16.			68.0		60.5			59.9			
17.			66.6		70.3			56.9			
18.			96.0		66.6			66.9			
19.			78.4		59.2						

Table 4.4 (continued)

Firm	34120: Paper containers and paperboard		34190: Paper and Paper products,nec.	35510: Rubber tires and tubes		
	1977	1979	1977	1974	1977	1979
1.	15.2	73.7	64.0	65.6	75.3	73.1
2.	19.0	52.6	89.3	95.9	100.0	97.0
3.	10.7	100.0	92.9	71.8	40.7	64.8
4.	100.0	59.0	54.0	100.0	58.3	49.2
5.	16.4	67.5	92.5	51.2	65.3	70.3
6.		54.9	97.0	96.7	65.6	64.7
7.		72.8	100.0	62.8	99.7	69.6
8.		58.4	90.8	68.7	80.9	75.4
9.		59.7		71.2	74.1	56.0
10.		52.9		90.9	95.5	73.7
11.		54.6			83.8	79.7
12.		42.0			92.3	96.4
13.					56.4	75.2
14.					85.3	83.6
15.						52.3
16.						84.8
17.						100.0
18.						82.3
19.						99.1

Table 4.4 (continued)

Firm	35591: Rubber sheets and block rubber			35599: Other rubber products			38320: Radio, TV. and communication	
	1974	1977	1979	1974	1977	1979	1977	1979
1.	96.8	81.5	86.0	63.6	62.0	58.4	58.6	82.3
2.	96.2	87.9	50.4	56.2	50.4	58.3	74.6	91.2
3.	96.7	81.2	60.1	100.0	73.8	100.0	91.8	81.0
4.	100.0	78.4	67.1	85.8	67.3	35.5	80.4	74.6
5.	94.3	59.4	77.4	64.5	76.2	67.9	59.4	100.0
6.	92.4	78.2	59.9	60.3	65.6	55.8	100.0	71.4
7.	94.0	94.6	62.1	78.1	62.6	36.1	58.8	66.5
8.	92.8	81.4	79.7	61.3	56.3	73.1		61.2
9.	92.1	82.7	62.5	55.6	68.5	40.9		74.8
10.		94.2	79.8	65.9	52.2	57.3		
11.		86.1	57.9		56.1	52.9		
12.		73.1	100.0		55.0	53.6		
13.		74.8	67.1		87.1	47.1		
14.		90.9	81.9		70.3	11.7		
15.		85.1	61.9		67.2	84.1		
16.		76.8	80.4		50.8	40.7		
17.		76.0	78.2		54.1	55.1		
18.		68.5	77.6		100.0	64.3		
19.		81.7	75.3		76.8	77.0		
20.		75.3	68.8		71.7	64.0		
21.		82.9	22.8		65.4			
22.		100.0	73.9		57.0			
23.		74.6			54.6			

Table 4.4 (continued)

Firm	38431: Automobile assembly			38432: Motor vehicle bodies		38439: Other motor vehicles		38440: Motor cycles, tricycles and bicycles		
	1974	1977	1979	1977	1979	1977	1979	1974	1977	1979
1.	89.0	89.0	23.0	99.3	100.0	76.1	45.6	100.0		100.0
2.	86.2	86.2	16.5	82.3	82.9	74.7	37.3	82.9		77.7
3.	95.6	95.6	24.8	77.3	46.4	92.0	36.2	98.9		72.0
4.	88.1	88.1	32.4	100.0	58.4	100.0	39.9	78.7		82.1
5.	59.8	59.8	28.9	83.0	74.7	89.8	33.4	79.6		74.4
6.	100.0	100.0	47.5	84.4	61.8	89.0	18.1	97.5		64.7
7.	76.4	76.4	100.0	72.2	62.7	99.1	40.9			86.5
8.			25.6	79.8	61.1		61.1			83.6
9.			18.1	69.1	68.3		39.3			77.7
10.			38.1	81.9	86.2		45.6			73.8
11.				77.5	60.6		49.6			78.0
12.				80.2	89.8		50.6			
13.					68.6		36.6			
14.					66.8		31.3			
15.							39.6			
16.							100.0			
17.							50.3			
18.							53.6			
19.							41.1			
20.							42.5			
21.							27.5			
22.							26.9			
23.							34.5			

Resource: National Statistical Office of Thailand

4.2.2.2 Paper and Paper Product Firms

In the group of paper and paper product industries there are industries producing pulp ,paper,paper containers and paperboard, and other paper and paper products. The numbers of sample firms of these industries were small for all years. Firms in the pulp paper, and paper-board industry were large. The employment of an average-sized firm was 300-500 workers. The capital-labor ratios of most firms were among the highest. However, the efficiency levels were below the average of all industries in all years. They were in the range of 80-85 percent. The most efficient firms in this industry were shown to have a large size and high capital intensity.

The paper containers and paperboard industry consisted of medium sized firms with low capital labor ratios. The average efficiency was 88 percent in 1977 and declined to 74 percent in 1979. Furthermore, over 75 percent of firms showed the efficiency levels below 70 percent. The more efficient firms in this industry had a smaller size and a moderate capital intensity.

The size of firms in the other paper and paper product industry were similar to the paper containers and paperboard industry, but the capital-labor ratios were about the average of those of the above two paper and paper product industries. The data which are available only for 1977 showed that the efficiency levels of most firms were quite high. The most efficient firm had the average size and capital intensity.

4.2.2.3 Rubber and Rubber Product Firms

Industries in the group of rubber and rubber products had the largest sample size in all years. The average firms in both rubber tires and tubes, and rubber sheets and block rubber industries employed 150 - 200 workers whereas that of other rubber products employed 50 - 100 workers. The capital-labor ratio was very high in the rubber tires and tube industry, but they were very low in the rubber sheet and block rubber and other rubber product industries. On the average of all firms, those in the rubber sheet and block rubber industry had the highest level of efficiency followed by those in rubber tires and tubes, and other rubber products industries. The most efficient firms in each industry had medium size and average capital intensity. About 40 percent of firms in rubber tires and tubes had efficiency below 70 percent in 1974, but most firms showed an improvement after the mid 1970s. Most firms in rubber sheets and block rubbers showed a decline in efficiency in 1979 but they could still maintain the above average levels of efficiency. The firms in other rubber product industry showed the largest decline in efficiency in the late 1970s. In 1979 there were over 80 percent of firms operating less than the 70 percent efficiency level.

4.2.2.4 Radio, T.V. and Communication Equipment Firms

An average firm in the radio, T.V., and communication equipment employed 100 - 120 workers, and the capital-labor ratio was below the average of firms in the selected industries. The available data in 1977 and 1979 showed that the average efficiency of firms deteriorated from 80 percent in 1977 to 57 percent in 1979. Besides, over one half of firms in the industry still had efficiency below 70 percent. The group of the more efficient firms had the size slightly larger than medium, employing over 100 workers.

4.2.2.5 Transport Equipment Firms

There are four industries producing transport equipment namely automobile assembly, motor vehicle bodies, other motor vehiches, and motorcycles and bicycles. For the first three industries data are available for 1977 and 1979. For the last industry they are for 1974 and 1979. Firms in the automobile industry are of the largest size. An averaged firm employed 400 - 500 workers and had the capital - labor ratio following those of the pulp paper and paperboard, and the rubber tires and tube industries. Firms in the motorcycles and bicycles, and the other motor vehicles industries employed 100 - 200 workers with lower capital - labor ratio than the automobile assembling firms. Firms in the motor vehicle bodies industry had the smallest size in the group. They employed less than 100 workers and had the lowest capital intensity.

The average efficiency levels of all transport equipment industries were quite high in 1974 and 1977. However, in 1979 the levels dropped significantly and over 60 percent of firms in all industries except for motorcycles and bicycles had efficiency less than 70 percent. For the motorcycles and bicycle industry, the efficiency levels of most firms were still above 75 percent despite the overall decline in the levels. The more efficient firms in automobile assumbly were large, employing over 300 workers. For the rest of the industries the efficient ones were the medium sized firms. All the transport equipment industries however had special feature in common. There were a few firms in each industry with very high levels of efficiency coexisting with a large number of the rest of the firms with lower but similar levels of efficiency competing with each other.

On the whole the average efficiency of most industries were high in all years. It seems to satisfy the competitive conditions which would drive in inefficiency firms out of the industries. However, in 1979 the efficiency of most industries and firms dropped significantly. The industry with majority of firms having high levels of efficiency for all years were cotton spinning, rubber sheet and block rubber, and motor-cycles and bicycles. The ones with the most deterioration in efficiency in 1979 were the paper and paper product and some transport equipment industries. By and large, the more efficient firms in most industries had medium scales of employment and capital intensity compared to others in the same industries. In the more capital intensive pulp paper and paper product, and the automobile assemble industries however, the more efficient firms had a larger size than the average. The gain in the efficiency may be from the economies of scale of production of these capital intensive industries. The inefficient firms in each industry might have employed nonoptimal capital-labor ratios, or operated by inputs of lower quality and incompetent managerial ability.

4.3 <u>Changes in Efficiency and Productivity of Selected Industries</u>

As discussed earlier in Sections 1 to 3, TFPG measures the sources of real output growth which cannot be accounted for by the increases in measurable real inputs. These sources include the improvement in efficiency, the increase in capacity utilization, the improvement in the quality of inputs (such as the upgrading of labor quality and the adoption of new vintage of capital), the advancement of technology, and finally, the possible measurement errors. This section intends to group these sources of TFPG to be from two main sources namely, the changes in efficiency and the rest called the residuals. The decomposition of the TFPG can also show more clearly the relationship between TFPG and the changes in efficiency and technological knowledge of the five selected industries shown in Table 4.5.

According to the table, in the textile and textile product industry the annual rate of growth of TFP during 1974-1979 was 8.55 percent. Of this figure 4.61 percent was due to the increases in technical efficiency over the period, leaving the rest of 3.94 percent which accounted for about 46 percent of the TFPG, to be from the residuals or the technological change. The decomposition of the TFPG rates did show that the improvement in efficiency dominates the technical change as a source of TFPG in this industry.

When the whole period of 1974-79 in separated into two subperiods of 1974-77 and 1977-79, there was an increase in efficiency at the rate of 8.45 percent a year in the earlier subperiod and a decline at 1.15 percent in the latter subperiod. Since the annual rate of TFPG was 14.18 percent in 1974-77 and 0.20 percent in 1977-79, the measured technical

Table 4.5: CHANGES IN EFFICIENCY AND PRODUCTIVITY OF SELECTED INDUSTRIES IN THAILAND, 1974 - 1979

Industry	1974 - 79 Annual percentage rate of change of TFP	Efficiency	Residuals
Textile and textile products	8.55	4.61	3.94
Paper and paper products	8.92	-0.45	9.37
Rubber and rubber products	6.09	-1.41	7.50
T.V., radio, and communication equipment	-1.40	-15.22	13.82
Transport equipment	-3.71	-4.66	0.95

Industry	1974 - 77 Annual percentage rate of change of TFP	Efficiency	Residuals
Textile and textile products	14.18	8.45	5.73
Paper and paper products	12.00	1.81	10.19
Rubber and rubber products	7.98	-0.84	8.82
T.V., radio, and communication equipment	n.a.	n.a.	n.a.
Transport equipment	-2.04	-1.11	-0.93

Industry	1977 - 79 Annual percentage rate of change of TFP	Efficiency	Residuals
Textile and textile products	0.20	-1.15	1.35
Paper and paper products	3.49	-3.84	7.33
Rubber and rubber products	2.99	-0.72	3.71
T.V., radio, and communication equipment	-1.40	-15.22	13.82
Transport equipment	-6.43	-9.99	3.56

Source: National Statistical Office of Thailand, Report of Industrial Census: Whole Kingdom, 1974, 1977, and 1979.

change was 5.73 percent in the first subperiod and 1.35 percent in the second. It again showed that the high TFPG in the first subperiod was about 60 percent accounted for by the increases in efficiency and 40 percent in the technical change. In the second subperiod of the late 1970s, the deterioration in efficiency and the slowdown in the rate of technical advancement explained the low TFPG.

For the paper and paper product industry, during 1974-79 the TFPG was at a high of 8.92 percent a year or about 25 percent of real output growth. Table 4.5 shows that the TFPG was high despite the decline in technical efficiency at 0.45 percent a year. In fact the residual term which measures increases in capacity utilization, technical change and others, was estimated to be 9.37 percent a year. Considering the two subperiods, in the first one the rate of TFPG was 12 percent. Of which 1.81 percent was due to the increases in efficiency, and the rest of 10.19 percent was the technical change. In the second subperiod, the TFPG rate declined to 3.49 percent because of the decline in efficiency at 3.84 percent a year. In fact, the technical progress was at the rate of 7.33 percent a year. This is an example of the industry in which the high TFPG does not necessarily imply an increase in efficiency over time.

In the rubber and rubber product industry the TFPG was high but there was a slight deterioration of efficiency over the period of 1974 - 79. It is the industry with very high level of efficiency (93 percent) in the initial year of 1974, but the level declined somewhat over the period. The TFPG rate of the period was 6.09 percent and the change in efficiency was -1.41 percent, leaving 7.50 percent to be from technical progress and others. In the first subperiod the TFPG rate was as high as 7.98 percent a year, but the efficiency declined at 0.84 percent. This leads to the estimate of technical progress to be 8.82 percent a year. In the second subperiod there was a further decline in the efficiency measure and a slowdown in technical change to 3.71 percent a year. When combining the both measurements, the annual rate of TFPG of 2.99 percent was at a much lower rate compared to the first subperiod.

For the radio, T.V., and communication equipment industry, data are available only for the period of 1977 to 1979. During this period the efficiency level declined at the annual rate of 15.22 percent despite the improvement in technology at 13.82 percent a year. The resultant TFPG rate was -1.40 percent. The deterioration in the efficiency of the industry in the late 1970s clearly dominated the rapid technical change of the industry.

Another industry where the technological advancement failed to offset the deterioration of efficiency to gain position TFPG in the industry was the transport equipment industry. During 1974-79, the efficiency of the industry declined at 4.66 percent a year whereas the annual rate of technical progress was 0.95 percent. The combined rates of changes resulted in the TFP declining at 3.71 percent a year. In the first subperiod both the annual change in efficiency and the residual terms were negative. They were -1.11 and -0.93 percent respectively, and the TFPG rate was -2.04 percent. In the second subperiod, the efficiency deteriorated much more rapidly at 9.99 percent a year. It domonated the progress in technology of 3.56 percent a year such that the TFPG rate was as low as -6.43 percent a year.

Of all the selected industries except for the paper and paper products and the rubber and rubber products industries, changes in efficiency dominated technical change as a source of TFPG. In the textile and textile products industry the TFPG during 1974-79 was high and it was mainly due to the increases in efficiency over time. The efficiency could increase in this exporting industry because of the keen competition in the world market and the improvement in the managerial ability. For the radio, T.V. and communication equipment, and the transport equipment industries the deterioration of efficiency especially in the late 1970s, dominated the technical progress such that the TFPG rate was negative. These industries were under high protection for the import substitution purpose.

In both the paper and paper product and the rubber and rubber product industries the technical progress dominated the slight deterioration in technical efficiency and the TFPG rates were thus high in both industries. They were the cases where high TFPG did not coincide with rapid increases in efficiency. While the efficiency of the paper and paper product industry was lower than the average of all selected industries and showed some decline over time, that of the rubber and rubber product industry was as high as 93 percent in 1974 but could not quite maintain that high level in the later years.

For all industries there were both the deterioration of efficiency and the smaller measurement of the residual term which led to the decline in the TFPG rate in the late 1970s. In fact, the year 1979 was noted for another high increase in energy prices, some increases in tariff rates, the decline in capacity utilization and also the slowdown in the technical improvement.

Footnotes to Section 4:

1 See D.J. Aigner and S.F. Chu, "On Estimating the Industry Production Function," American Economic Review, Vol. 58, No. 4, 1968, pp. 826-839.

2 See C.P. Timmer, "Using a Probabilistic Frontier Production Function to Measure Technical Efficiency," Journal of Political Economy, Vol. 79, No.4, pp. 776-794.

3 See S.N. Afriat, "Efficiency Estimation of Production Function," International Economic Review, Vol. 13, No.3, pp. 568-598.

4 See J. Richmond, "Estimating the Efficiency of Production." International Economic Review, Vol. 15, No.2, pp. 515-521.

5 Although the level of technical efficiency of an industry can also be estimated by specifying a stochastic production function, cost, or profit frontiers, these methods cannot be used to measure efficiency at the firm level.

6 See J. Richmond, "Estimating the Efficiency of Production."

5. Summary, Conclusions, and Recommendations

This paper can be separated into two related parts. The first part estimated and analysed the source of growth of real output of each three-digit ISIC industry in Thailand during 1963-1979 using aggregated industrial census data. The sources were categorized to be from the accumulation of real inputs and the increase in their productivity (TFPG). In additional to the study on the productivity growth of the industries, the second part measured efficiency at the firm level. It presented the efficiency level of each firm and the average efficiency of some selected industries. For these industries we were able to decompose the productivity changes into changes in efficiency levels and the changes in other factors such as technological changes. The findings of the first part can be summarized as follows:

1. Among all sources of growth of real output of total manufacturing industries in Thailand during the entire period of 1963-1979, the TFPG was rather low despite the high rate of increase of real output. It accounted for about seven percent of the rate of growth of real output, leaving the remaining 93 percent to be accounted for by the growth of real inputs. However, over time the TFPG was increasing and it accounted for a higher percentage of the real output growth. It increased from 0.39 percent or accounted for 2.08 percent of real output growth for the first subperiod of 1960-1970 to 1.76 percent or accounted for 15.33 percent for the second subperiod of 1970-1979.

2. TFPG of most industries declined during the middle and late 1970s when there were high increases in energy and raw material prices. However, after some periods for inputs and output to adjust, the TFPG rose again in the midst of the high prices.

3. Evidence does not support that TFPG of protected import-substituting industries increased over time. In fact, TFPG of import-substituting industries was lower than the average of all industries. The protection of these industries not only provided a shelter for them to exist even when their TFPG was declining over time, but it also squeezed out TFPG as a source of their real output growth.

4. Exporting industries had TFPG above the average of all industries. Moreover, their total factor productivity seemed to grow with export growth.

5. Evidence does not support the effectiveness of policies to improve labor productivity simply by subsidizing purchases of capital inputs of industries, nor does it show increases in physical inputs to be a source of the advancement of total factor productivity.

The findings of the second part are presented below:

1. The average efficiency of the selected industries were high during 1974 - 79. It seems to satisfy the competitive conditions which would drive the inefficient firms out of the industry.

2. In 1979, the year of another steep increase in energy prices, there was a decline in average efficiency levels of most industries and firms. Firms in the paper and paper product and the transport equipment industries, which were more capital intensive, experienced more declines than the rest of the industries.

3. The more efficient firms in each industry except for the paper and paper product and the transport equipment industries had medium size in terms of employment. For the paper and paper product and transport equipment industries, the more efficient firms had much larger size and higher capital-labor ratios. This suggests that in industries in which it is more likely to have economies of scale, larger firms are more efficient than the smaller ones.

4. The study of dispersion of efficiency levels of all firms in the same industry shows that in some industries such as the transport equipment industry, there was coexistence of a few firms with high levels of efficiency and a large number of firms with similar but much lower levels of efficiency.

5. When the TFPG was separated to be from changes in the level of technical efficiency and other factors such as increases in capacity utilization and pure technological change, most industries showed that the changes in efficiency dominated other factors as a source of TFPG. In the paper and paper product and the rubber and rubber product industries the technical progress dominated the slight deterioration in efficiency so that TFPG remained high throughout 1974 - 79. They were the cases where the high TFPG did not necessarily imply a rapid improvement in technical efficiency.

In conclusion, the TFPG of manufacturing industries in Thailand was still small compared to that of developed countries and some newly industrialized countries. However, similar to many industrialized countries, as industrial development progresses, the TFPG of Thailand became an increasingly important source of growth of industrial production. At the early stage of development in the 1960s, increases in raw materials and capital goods were the most important source of growth. In the 1970s when the Industrial sector became more developed, the TFPG as a source of growth of production increased. The increases in TFPG were from the increases in efficiency, capacity utilization, and the technological knowledge.

Our study also shows that the period of increases in the TFPG coincided with that of changes in industrialization and trade policies from import substitution to export promotion. The import substitution policies protect industries which are less likely to have market demand potential outside the domestic market and prospects for cost-saving or productivity-increasing over time. On the other hand, export promotion policies encourage industries in which the country has a comparative advantage, and hence the potential for demand expansion in the world market. The growth in demand and competition in the world markets can enhance the TFPG and then enables the exporting industries to grow faster. Meanwhile, TFPG also helps the industries to be more competitive in the world markets and increases the exports even further. Thus, any industrialization or trade policies should also be considered in terms of the impact of the policies on TFPG. A policy which emphasizes increases in TFPG will contribute toward a more rapid industrial growth in the long run.

In increasing TFPG at the firm level, firms should both improve the efficiency level and adopt new technological knowledge. In other words, firms should be flexible in adjusting the employment of factor inputs in response to changes in the prices of inputs, and be innovative in diversifying the products in response to changes in output prices in order to increase efficiency and competitiveness. In addition, firms should adopt a program including training to upgrade skills of workers and the managerial ability of manager, improving knowledge on resource-saving at the plant level, and increasing investments to adapt or adopt new technologies.

In order to obtain high TFPG both at the industry and the firm levels stated above, both the private sector and the government should work together. On the part of the government, the following is what the government can do to lead the private sector to achieve the objective of high TFPG:

1. The government should be aware of the importance of TFPG on industrial growth and have a policy to promote TFPG in both the private and the public sectors. In doing so, the government has to know the productivity performance of industries in each year and the possible impact of various government policies on the annual changes in productivity. To obtain such knowledge there must be a government agency to measure and analyse TFPG. The agency can be a division of any government offices such as National Economic and Social Development Board (NESDB), National Statistical Office (NSO), Thailand Management Development and Productivity Center (TMDPC), or any other research institutions. Presently NSO has conducted an annual industrial census which provides minimal data for the measurement of TFPG. NSO can revise and extend the questionnaires for a better measurement of TFPG and do the measurement itself. Alternatively, NESDB, TMDPC, or other research institutions can co-operate with NSO in designing the questionnaires to obtain the data base appropriate for the best TFPG measurement and analysis. To obtain the most accurate and reliable measurement of TFPG, the government agency should include personnel competent with technical capability. For example, it should consist of policy makers, representatives of NESDB, NSO, TMDPC, BOI, IFCT, other main users from the private sector, and some independent technical experts.

2. Policy makers should consider the impact of various policies for industrialization on TFPG. Any policy whcih hinders TFPG will not be likely to promote a rapid industrial growth in the long run. Besides, the government should cultivate widespread awareness of the importance and ways and means of prod[illegible]vity improvement.

3. The government should initiate or support programs on research, development, and education. This can be in the form of grants for research in the public sector, or any financial incentives for research in the private firms.

4. TMDPC should provide a package program to facilitate technical assistance on the production floor, training of labour and management, modernization of the plants, and information on new investments in fixed assets.

5. The government should recommend the financial institutions to evaluate new investment projects based on potential productivity performance, in addition to the existing criteria such as profitability and financial stability. The institutions should mobilize funds to firms and industries with additional potential for higher TFPG and efficiency improvement. The total factor productivity or efficiency of the firm can be compared with the average of other firms or the best practice firms in the same industry suggested in the study.

Bibligraphy

Literature Bibliography

Akrasanee, N.: "Import Substitution and Sources of Industrial Growth in Thailand, 1960-69," Thai Economic Review, January, 1974.

: "The structure of Industrial Protection in Thailand during the 1960's, "Economic Bulletin for Asia and the Far East 24, No. 213, 1973, 35-56.

: "The Structure of Effective Protection in Thailand: A Study of Industrial and Trade Policies in the Early 1970's" report prepared for the World Bank, World Bank, Washington, D.C., 1975.

: et al., eds.: Trade and Employment in Asia and the Pacific, University of Hawaii Press, Honolulu, 1977.

Afriat, S.N. : "Efficiency Estimation of Production Function," International Economic Review, Vol 13, No. 3, 568-598

Aigner, D.S. and Chu S.F.: "On Estimation the Industry Production Function," American Economic Review, Vol.58, No.4, 1968, 826-839.

Baldwin, R. : "The Case Against Infant Industry Protection," Journal of Political Economy 77, No. 3, May/June 1969, 295-305.

Berndt, E.R. : "Aggregate Energy, Efficiency, and Productivity Measurement," Annual Review of Energy, 1978, 225-73

Binswanger, H.P. and V.W. Ruttan: Induced Innovation, The Johns Hopkins University Press, Baltimore, 1978.

Bruno, M. : "Raw Materials, Profits, and the Productivity-Slowdown," Quarterly Journal of Economics, February 1984, 1-29.

Caves, D.W., L.R. Christensen, and M.W. Tretheway: "Flexible Cost Functions for Multiproduct Firms," Review of Economics and Statistics, Vol.62, 1980, 477-481

Chen, E.K.Y.: "Factor Inputs, Total Factor Productivity and Economic Growth: The Asian Case, "The Developing Economies, Vol. XV, June 3, 1977.

Christensen, L.R. and D.W. Jorgenson: "U.S. Real Output and Factor Input, 1927-1967, "Review of Income and Wealth 16, 1970, 19-50.

Denison, E.F.: "The Source of Economic Growth in the United States and the Alternative Before Us," Supplementary Paper No. 13, Committee for Economic Development, New York, 1962.

: Why Growth Rates Differ, The Brookings Institution, Washington, D.C., 1967.

: "Some Major Issues in Productivity Analysis: An Examination of Estimates by Jorgenson and Grilliches," Survey of Current Business 49, 1969, 1-28.

: Accounting for United States Economic Growth, 1929-1969 The Brookings Institution, Washington, D.C., 1974.

Diewert, W.E.: "Exact and superlative indix Number," Journal of Econometries, Vol.4, 1976, 115-145.

Elias, V.J.: "Sources of Economic Growth in Latin American Countries," The Review of Economics and Statistics, August 1978, 362-70.

Ezaki, M.: "Growth Accounting of the Philippines: A Comparative Study of the 1965 and 1969 Input-Output Tables," The Philippines Economic Journal, No. 29, 1975, 399-435.

: "Growth Accounting of Postwar Japan: The Input Side," The Economic Studies Quarterly, Japan, December 1978, 193-215.

Fisher, P.M.: "The Existence of Aggregate Production Function," Econometrica, October 1969, 553-77.

Gollop, F.M. and D.W. Jorgenson, "U.S. Productivity Growth by Industry, 1947-73", in New Developments in Productivity Measurement and Analysis, J.W. Kendrick and B.N. Vaccara, eds., University of Chicago Press, Chicago, 1980.

Harberger, A.C.: "Perspectives on Capital and Technology in Less-Developed Countries," mimeograph, University of Chicago, 1978.

Hayami, Y. and V.W. Ruttan: Agricultural Development, An International Perspective, The John Hopkins University Press, Baltimore, 1971.

__________ and H.M. Southworth: Agricultural Growth in Japan, Taiwan, Korea and the Philippines, The University Press of Hawaii, Honolulu, 1979.

Kendrick, J.W.: Productivity Trends in the United States, Princeton University Press for the National Bureau of Economic Research, Princeton, 1961.

Hicks, J.C.: "The Mainspring of Economic Growth," American Economic Review.

Jorgenson, D.W. and M. Ezaki: "The Measurement of Macroeconomic Performance in Japan, 1951-1968," in K. Ohkawa and Y. Hayami, eds., Economic Growth: The Japanese Experience Since the Meiji Era, Vol. 1, No. 19, The Japanese Economic Research Center, Tokyo, 197[illegible].

Jorgenson, D.W. and Z. Grilliches: "The Explanation of Productivity Change," Review of Economic Studies 34, 1967, 249-83.

Kendrick, J.W. Productivity Trends in the United States, Princeton University Press, Princeton, 1961.

: Postwar Productivity Trends in the United States NBER, New York, 1973.

: Productivity in the United States, Trend and [illegible] The John Hopkins Unviersity Press, 1980.

Krueger, A.O.: Liberalization Attempts and Consequences, Ballinger Publishing Company, Cambridge, Massachusetts, 1978.

and B. Tuncer: "Estimating Total Factor Productivity Growth in a Developing Country," World Bank Staff Working Paper, No. 422 Washington, D.C., 1981.

: "An Empirical Test of the Infant Industry Argument," The American Economic Review, Vol. 72, December 1982, 1142-1152.

Krueger, A.O., H.B. Lary, T. Monson and N. Akrasanee, eds.: Trade and Employment in Developing Countries, 1: Individual Studies, The University of Chicago Press, Chicago, 1981.

Krueger, A.O.: Trade and Employment in Developing Countries, 3: Synthesis and Conclusion, The University of Chicago Press, Chicago, Forthcoming.

: "Export-Led Industrial Growth Reconsidered," in W. Hong and L.B. Krause, eds., Trade and Growth of Advanced Developing Countries in the Pacific Basin, Korea Development Institute, Seoul, Korea, 1981.

Massell, B.F. "A Disaggregated View of Technical Change," The Journal of Political Economy, December 1961, 547-57.

Nishimizu, M. and C.R. Hulten: "The Sources of Japanese Economic Growth, 1955-1971," The Review of Economics and Statistics, August 1978, 351-61.

Park, W.R.: Cost Engineering Analysis, John Wiley and Sons, New York, 1973.

Richmond, J.: "Estimating the Efficiency of Production," International Economic Review, Vol. 15, No. 2, 515-521.

Robinson, S.: "Sources of Growth in Less Developed Countries: A Cross Section Study," Quarterly Journal of Economics, August 1971, 391-408.

Solow, R.M.: "Technical Change and the Aggregate Production Function," Review of Economics and Statistics, 1957, 312-20.

Star, S. and R.E. Hall: "An Approximate Divisia Index of Total Factor Productivity," Econometrica, March 1976, 257-63.

Timmer, C.P. : "Using a Probabilistic Frontier Production Function to Measure Technical Efficiency," Journal of Political Economy, Vo. 79 No. 4, 776-794.

Usher. D., ed.: The Measurement of Capital, The University of Chicago Press, Chicago 1980.

Wiboonchutikula, P.: "Protection and Resource Allocation: A Study of Employment Effects of Differential Incentives in Thailand," unpublished M.A. thesis, Thammasat University, June 1975.

: "The Total Factor Productivity Growth of the Agricultural Machinery Industry in Thailand, 1960-1979," Consequences of Small Farm Mechanization in Asia, International Rice Research Institute and Agricultural Development Council, Philippines, 1983, 51-59.

: "The Growth of Thailand in a Changing World Economy: Past Performance and Current Outlook," Southeast Asian Affairs, 1984. Institute of Southeast Asian Studies, Singapore, 1984, 326 - 339

Statistical Bibliography

Bank of Thailand: Annual Report, Bangkok, various years.

Board of Investment: Investors Manual, Bangkok, 1971.

Department of Customs: Annual Reports, Bangkok, various years.

Division of Commodity and Marketing Research, Department of Business Economics, Ministry of Commerce: Report on Industrial Research, Bangkok, various reports.

Division of Price Index, Department of Business Economics, Ministry of Commerce: Wholesale Price Index for Thailand, Bangkok, 1984.

Industrial Economic and Planning Division, Ministry of Industry: Industrial Statistics, Bangkok, 1982.

International Labor Office: Labor Statistics, various issues.

International Monetary Fund: International Financial Statistics, various issues.

National Economic Council, Central Statistical Office: Statistical Yearbook of Thailand, Bangkok, 1952.

National Economic and Social Development Board: Industrial Development Planning of Thailand, 1977-1981, Bangkok, various publications.

______ : National Income Account of Thailand, Bangkok, various issues.

National Statistical Office of Thailand: Labor Force Survey: Round 1 and Labor Force Survey: Round 2, Bangkok, annual publications.

______ : Report of the Industrial Census: Whole Kingdom, Bangkok, 1964, 1969, 1971, 1977, 1979.

______ : Industrial Census: Whole Kingdom, Computer Files, Bangkok, 1972, 1975, 1976.

Statistical Office of United Nations, Department of Economic and Social Affairs, United Nations: Indexes to the Industrial Standard Classification of All Economic Activities, New York, 1971.

Thailand Input-Output Joint Project, National Economic and Social Development Board, Institute of Developing Economies (Tokyo), and National Statistical Office of Thailand: Basic Input-Output Table of Thailand, 1975, Bangkok, 1980.

United Nations Industrial Development Office, United Nations: The Growth of Industry, 1938-1961, National Tables, New York, 1963.