

The Effects of Export, Technical change and Markup on Total Factor Productivity Growth: Evidence from Singapore's Electronics Industry

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and

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Abstract:

This paper illustrates a new technique to measure the effect of export demand on the conventional TFP growth index at the industry level. We apply the technique to Singapore's electronics industry and find that rapid growth in exports accounts for most of the TFP growth in this industry.

Keywords: TFP growth; Exports; Singapore's electronics industry

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I. Introduction

Total factor productivity (TFP) growth is traditionally defined as a residual of the rate of output growth and the rate of growth of all inputs. Given this definition, the conventional TFP growth index can be decomposed into its three major components: direct technical change, markup and scale effects. In this paper, we further decompose scale effects into four sub-components: (1) export demand, (2) exogenous domestic demand, (3) changes in factor prices, and (4) indirect embodied technical change. This technique is similar to the decomposition by Nadiri and Nandi (1999). Our contribution is to include in the model export demand, which has been argued in the literature as an important factor in affecting TFP growth for export-oriented industries in emerging economies. The current technique allows us to assess the relative importance of exports in enhancing TFP growth at the industry level.

We apply the technique to Singapore's electronics industry and find that Singapore's electronics industry experiences roughly a rate of TFP growth of 0.02 percent per annum from 1972 to 1997. This result is consistent with our expectations and findings of other studies that the TFP growth performance for one of the most important industries in Singapore has been minimal (See, for example, Bloch and Tang, 2000; Leung, 1997; Rao and Lee, 1995). The decomposition shows that TFP growth in this industry is mainly the result of export-led increasing returns to scale and embodiment of new technology in improved capital equipment. Both direct disembodied technical change and markup have a negative effect on the industry's TFP growth, possibly reflecting the low level of technology and increasing price competition facing the industry during the last twenty-five years.

II. Measurement of TFP Growth and Its Decomposition

It is shown by Nadiri and Prucha (1990) that the traditional TFP growth can be decomposed as:

$$(1) \quad T\dot{F}P = -(\dot{b}/q) + [\dot{Y}_P - \dot{Y}_C] + [1 - \rho^{-1}] \dot{Y}_C$$

where $b = \partial \ln VC_t / \partial T$ and $q = (1 - \eta_k)$. VC_t is variable cost at time $t = 1, 2, 3, \dots, n$, T is a trend indicating the level of disembodied technology, and $\eta_k = \partial \ln VC_t / \partial \ln K_{t-1}$. K_{t-1} is the quasi-fixed capital stock at the beginning of time t . The term (\dot{b}/q) on the right-hand-side of (1) measures the direct effect of technical change. A dot above a variable denotes the rate of growth of that particular variable.

\dot{Y}_p and \dot{Y}_c are the rates of growth of output weighted by the revenue share and cost elasticity, respectively. $[\dot{Y}_p - \dot{Y}_c]$ measures the direct effects of non-marginal cost pricing, while $[1 - \rho^{-1}]\dot{Y}_c$ measures the effects of scale economies with $\rho = (1 - \eta_k)/\eta_y$ and $\eta_y = \partial \ln VC_t / \partial \ln Y_t$.

Scale effects can be further decomposed into its major components. We can rewrite $[1 - \rho^{-1}]\dot{Y}_c$ as:

$$(2) \quad [1 - \rho^{-1}] * \eta_y * \dot{Y}$$

Assume that prices of outputs are related to variable marginal cost according to the relation:

$$(3) \quad P = (1 + \theta) * \frac{\partial VC}{\partial Y} = (1 + \theta) * \eta_y * \frac{VC}{Y}$$

where P denotes the price of output and θ is the markup of the price over its marginal cost. Taking logarithmic of both sides in (3) and differentiating it with respect to time yields,

$$(4) \quad \frac{d \ln P}{dt} = \frac{d \ln(1 + \theta)}{dt} + \frac{d \ln \eta_y}{dt} + \frac{d \ln VC}{dt} - \frac{d \ln Y}{dt}$$

Equivalently,

$$(5) \quad \dot{P} = (1 + \theta) + \dot{\eta}_y + \dot{VC} - \dot{Y}$$

Taking total derivative with respect to time of a double-log output demand function, we obtain,

$$(6) \quad \dot{Y} = \alpha_1 \dot{P} + \alpha_2 \dot{GDP} + (1 - \alpha_2) \dot{POP} + \alpha_3 \dot{EXP}$$

where GDP is the level of gross domestic product, POP is the total population and EXP is the level of direct export. We substitute (5) into (6) and manipulate to yield,

$$(7) \quad \dot{Y} = \frac{\alpha_1 \{(1 + \theta) + \dot{\eta} + VC\} + \alpha_2 \dot{GDP} + (1 - \alpha_2) \dot{POP} + \alpha_3 \dot{EXP}}{(1 + \alpha_1)}$$

Given (7), scale effects in (2) can be alternatively written as:

$$(8) \quad [1 - \rho^{-1}] * \frac{\eta_Y}{(1 + \alpha_1)} * \left(\alpha_1 \{(1 + \theta) + \dot{\eta} + VC\} + \alpha_2 \dot{GDP} + (1 - \alpha_2) \dot{POP} + \alpha_3 \dot{EXP} \right)$$

Also, given $VC = \sum_i w_i X_i$, we can decompose scale effects into its various components

by rewriting (8) as:

$$(9) \quad A * \left(\alpha_1 \left[(1 + \theta) + \dot{\eta}_Y + \left(\sum_i \lambda_i \dot{w}_i + \sum_i \lambda_i \dot{X}_i \right) \right] + \alpha_2 \dot{GDP} + (1 - \alpha_2) \dot{POP} + \alpha_3 \dot{EXP} \right)$$

where $A = [1 - \rho^{-1}] * \frac{\eta_Y}{(1 + \alpha_1)}$ and $S_i = \frac{w_i X_i}{\sum_j w_j X_j}$ for $i, j = labor, material \text{ and } energy$.

From (9), we can immediately obtain the sub-components of scale effects such that scale effects = $D_1 + D_2 + D_3 + D_4$.

The effect of export demand is:

$$(10) \quad D_1 = A * (\alpha_3 E \dot{X}P)$$

The effect of exogenous domestic demand is:

$$(11) \quad D_2 = A * (\alpha_2 \dot{G}DP + (1 - \alpha_2) \dot{P}OP)$$

The effect of changes in factor price is:

$$(12) \quad D_3 = A * \left(\alpha_1 \sum_i \lambda_i \dot{w}_i \right)$$

The effect of indirect embodied technical change:

$$(13) \quad D_4 = A * \left(\alpha_1 \sum_i \lambda_i \dot{X}_i \right)$$

where $A = [1 - \rho^{-1}] * \frac{\eta_y}{(1 + \alpha_1)}$, θ is the markup of the price over its marginal cost and

$$\lambda_i = \frac{w_i X_i}{\sum_j w_j X_j} \text{ for } i, j = \text{labor, material and energy} .$$

The effect of export demand on scale economies and TFP growth is measured by D_1 . The extent of this effect depends on the elasticity of demand with respect to export, α_3 , which measures how output changes in response to changes in export. The effect of exogenous domestic demand on TFP growth is given by D_2 , which depends on the elasticity of demand with respect to income, α_2 . The effects on TFP growth of changes in factor prices (D_3) and indirect embodied technical change (D_4) depend on the price elasticity of demand, α_1 . When output is perfectly price inelastic, $\alpha_1 = 0$, changes in

factor prices and indirect embodied technical change have no effect on output and TFP growth.

III. Econometric Model Specification

For implementation of the technique, we adopt a structural approach that relaxes the usual assumptions of constant returns to scale, perfect competition and constant factor utilization. The estimation model captures the dynamic interaction between the demand and supply sides of the industry and its impact on profit margin, productivity change and scale economies.¹ Labor, raw materials and energy are treated as variable inputs, while capital stock is assumed to be a quasi-fixed factor. We further assume that given the capacity and the level of output, each firm is to minimize variable costs and that variable costs can be modeled by a restricted normalized translog variable cost function, VC_t , as follows:

$$\begin{aligned}
 \ln(VC_t/w_{Et}) = & \beta_0 + \beta_Y \ln Y_t + \beta_T T + \beta_K \ln K_{t-1} + \beta_L \ln W_{Lt} \\
 & + \beta_M \ln W_{Mt} + 0.5(\beta_{YY} (\ln Y_t)^2 + \beta_{TT} T^2 + \beta_{KK} (\ln K_{t-1})^2 \\
 (14) \quad & + \beta_{LL} (\ln W_{Lt})^2 + \beta_{MM} (\ln W_{Mt})^2) + \beta_{YT} \ln Y_t T + \beta_{YK} \ln Y_t \ln K_{t-1} \\
 & + \beta_{YL} \ln Y_t \ln W_{Lt} + \beta_{YM} \ln Y_t \ln W_{Mt} + \beta_{TK} T \ln K_{t-1} \\
 & + \beta_{TL} T \ln W_{Lt} + \beta_{TM} T \ln W_{Mt} + \beta_{KL} \ln K_{t-1} \ln W_{Lt} \\
 & + \beta_{KM} \ln K_{t-1} \ln W_{Mt} + \beta_{LM} \ln W_{Lt} \ln W_{Mt}
 \end{aligned}$$

where subscripts t , Y , L , M and K denote time period, output, labor, material and capital input. The price of labor, W_{Lt} , the price of material, W_{Mt} , and the variable production cost are normalized by the price of energy input, w_{Et} . The homogeneity restriction is imposed on the cost function by the normalization.

The cost-share equations are derived by using Shephard's Lemma as follows:

$$(15) \quad S_{it} = \beta_i + \beta_{ii} \ln W_{it} + \beta_{Yi} \ln Y_t + \beta_{iT} T + \beta_{Ki} \ln K_{t-1} + \beta_{ij} \ln W_{jt}$$

¹ See, for example, Nadiri and Nandi (1999), Park and Kwon (1995) and Appelbaum (1982) for discussion of the structural approach.

where the cost-share for i input is given by $S_{it} = w_{it}X_{it}/VC_t$ and X_{it} denotes the quantity of i input ($i = L, M$). Given profit maximization, the revenue share equation is:

$$(16) \quad R_t = (\beta_Y + \beta_{YY} \ln Y_t + \beta_{YT} + \beta_{YK} \ln K_{t-1} + \beta_{YL} \ln W_{Lt} + \beta_{YM} \ln W_{Mt}) (1 + Y_t / \alpha_1 P_t)^{-1}$$

where $R_t = P_t Y_t / VC_t$ is the revenue-cost ratio and P_t is the price of output. α_1 is the price elasticity of demand. Equation (16) characterizes the equilibrium conditions for optimal choice of output and input mix.

Same as (6), the output demand function is assumed to be double-log and takes the form of:

$$(17) \quad \ln Y_t = \alpha_0 + \alpha_1 \ln P_t + \alpha_2 \ln GDP_t + (1 - \alpha_2) \ln POP_t + \alpha_3 \ln EXP_t$$

GDP_t and POP_t are the sources of domestic demand, while EXP_t represents demand from abroad.

Using annual data from 1972 to 1997, we jointly estimate the system of equations that includes (14) to (17) for the electronics industry. We use a nonlinear three-stage least squares method with a set of instrumental variables. All data in current dollars are deflated to 1985 constant dollars. Time-series data at the 3-digit Singapore Standard Industrial Classification (384) are taken from *Census of Industrial Production* and *Yearbook of Statistics of Singapore*.

IV. Estimation Results

The estimation results shown in Table 1 indicate that the model appears to be well estimated for the electronics industry. The second-order conditions of the maximization problem are satisfied at each point of the sample for all industries, implying the cost function is concave with respect to input prices and increasing in output. The standard errors of the estimated parameters in general are small relative to the estimates and the system R^2 shows that the model fits the data reasonably well.

Table 2 shows the results of decomposition of TFP growth for the electronics industry. The results show that the industry experiences a rate of TFP growth of 0.02 percent per annum during the period 1972-97. This small, but positive rate of TFP growth is due to large positive scale effects, which are, in turns, caused primarily by strong export demand. The effect of direct (disembodied) technical change and markup are both negative on TFP growth. The negative effect of direct (disembodied) technical change appears to reflect the low level of technology employed, while the negative markup effect is possibly resulted from increasingly competitive forces that erode output price and markup for the industry.

Table 1: Parametric Estimates of the Cost and Demand Equations

Coefficients	Estimates	Coefficients	Estimates
B	-1471.1 (820.27)	BYL	-0.0452 (0.0106)
BY	16.012 (6.6086)	BYM	0.0449 (0.0115)
BT	-104.42 (58.197)	BTK	21.426 (12.149)
BK	602.84 (341.06)	BTL	0.0034 (0.0035)
BL	0.3002 (0.1061)	BTM	-0.0014 (0.0044)
BM	0.6959 (0.1196)	BKL	0.0273 (0.0144)
BYY	-1.3390 (0.6133)	BKM	-0.0318 (0.0164)
BTT	-3.6458 (2.0546)	BLM	-0.0113 (0.0143)
BKK	-127.90 (72.681)	B0	0.2815 (0.1441)
BLL	N/A	B1	-1.9770 (2.1734)
BMM	0.0244 (0.0232)	B2	0.0843 (0.3028)
BYT	0.3951 (0.1725)	B3	1.0490 (0.1044)
BYK	-0.4292 (0.3342)	System R^2	0.9862

Notes:

1. Standard errors are in the parentheses.
2. N/A denotes those parameters that have been set to zero for the second-order conditions of the maximization problem to be satisfied

As expected, export demand is the most important contributor of TFP growth for the electronics industry in Singapore, as shown in column 5 of Table 2. Export demand contributes a per annum rate of 0.47 percent to the industry's TFP growth rate, the largest source of contribution to the industry's TFP growth rate compared to any other sources. Exogenous domestic demand does not appear to have a major positive effect on TFP growth, as shown in column 6. Consumer electronic products such as VCR and TV sets, which are mainly for domestic consumption, account for roughly 0.03 percent increase in TFP growth rate. In column 7, the effect of changes in factor prices is minimal. The

positive effect reflects that factor prices for the industry have been decreasing, in particular for material inputs. Another important source of TFP growth is the effect of indirect embodied technical change, which is shown in column 8. Embodiment of technical change in capital produces factor augmentation technical change, which accounts for roughly 0.26 percent of per annum TFP growth.

Table 2: Decomposition of TFP Growth For Singapore's Electronic Industry 72-97

Average Annual TFP Growth	Effect of Direct Technical Change	Markup Effect	Scale Effect	Source of Scale Effect				
				Export Demand	Domestic Demand	Factor Price	Indirect Technical Change	Residual Scale Effect
0.0203	-0.0986	-0.4522	0.5710	0.4705	0.0312	0.0062	0.2596	-0.1965

V. Conclusion

We formulate an approach that incorporates the effect of export demand in a structural model that allows dynamic interaction between supply and demand. Using the parametric estimates of the model, we decompose the conventional TFP growth index in Singapore's electronics industry into its major components: the effect of direct (disembodied) technical change, the effect of non-marginal cost pricing, export demand, exogenous domestic demand, changes in factor prices, and indirect embodied technical change.

Our results show that Singapore's electronics industry experiences a rate of TFP growth of 0.02 percent per annum during 1972-97. Scale effects are the major contributor of TFP growth, while direct (disembodied) technical change and markup exert negative effects on the estimate of TFP growth for this industry. We further decompose scale effects and find that TFP growth mainly comes from two sources. One is the export-led increasing returns to scale and the other is the embodiment of new technology in improved capital equipment. They contribute, respectively, roughly 0.47 and 0.26 percent to the TFP growth for the industry during 1972-97.

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