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CUMULATIVE TRADE AND ECONOMIC GROWTH IN THE EAST ASIAN COUNTRIES*

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There have been many empirical researches to find out the role of trade on economic growth. However, no attempt has been made to unravel the role of cumulative trade on economic growth. It could be presumed that the beneficial effects of trade will accumulate to affect the operation of economies to the future. We used cumulative trade augmented time index in our cost function framework to test whether cumulative trade contributed to the economic growth of the East Asian countries. We found that cumulative trade enhanced technical progress and played an important role in the economic growth of the East Asian countries. Cumulative trade also contributed to the East Asian countries' catching up the superior technologies of developed countries.

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I. INTRODUCTION

The contribution of openness to economic growth has been explained in various ways. Trade promotes international competition which enhances production efficiency. Greater capacity utilization and economies of scale are the benefits of exports. Openness also allows greater specialization which generates higher productivity growth and openness to trade provides access to superior foreign technology embodied in imported inputs. Knowledge spillovers take place as commodity traders serve as a conduit for information flows. Grossman and Helpman (1991a) present a model which shows that cumulative volume of trade can cause technical progress to accelerate and the economy to grow faster.

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The favorable effects of trade are more relevant in less developed countries. Less developed countries can learn more than developed countries to catch up the technology gap.

There have been empirical researches to support those points. Among them: Feder (1983), Tyler (1981), and Kavousi (1984) showed that exports contribute to economic growth. Miller and Upadhyay (2000) report that openness and human capital contribute to TFP growth; the export-to-GDP ratio has a significant positive effect at the 1% level in the study of 83 countries for 1960-1989 period. Balassa (1985) found that exports accelerate growth from the study of 43 developing countries in the 1973-78 period. While those studies provided positive correlations between export expansion and output growth the study on the semi-industrialized countries by Esfahani (1991) attributes the positive export-GDP association to the contribution of exports to the reduction of import shortages. The study points out that exports in semi-industrialized countries are the main source of foreign exchange for the much needed imports of intermediate and capital goods. Weinhold and Rauch (1999) presented the evidence that specialization in manufacturing sector increases the rate of growth of manufacturing productivity in less developed countries. Anne Harrison (1995) provided a good survey and tested various openness measures to find that greater openness is associated with higher economic growth. Frankel et al. (1996) used gravity equation to find that openness (the share of trade to GDP) explains much of the growth of the East Asian countries, especially, in Singapore, Hong Kong, and Malaysia. Lawrence and Weinstein (1999) report that imports are more contributing than exports to the TFP growth of Japan and Korea.

However, those empirical researches are only on current trade not on cumulative trade.[1] The contributing effects of trade to economic growth will not vanish after contributing current economic growth but will continue to affect future economic growth. Those effects of trade will be accumulating; i.e., past levels of trade affect current growth. Learning will accumulate, enhanced competitiveness will affect future production, and acquired knowledge will be used next periods also. Catch-up effect might be present in doing so. Less developed countries will benefit more from trade. In this paper we used cumulative trade to test its role in technological progress and output growth in the seven East Asian countries (Korea, Japan, Taiwan, Singapore, Malaysia, Thailand, and Hong Kong). Those countries have been selected because they are trade-oriented fast-growing countries of the East Asian miracle, and thus, it is presumed that the spill-over and catch-up effects from trade are more noticeable than other countries. During 1968-1995 preiod they recorded 5.0% to 9.5% average annual output growth rate of non-agricultural sector as reported in Table 1. The high growth rate of output accompanied huge factor accumulation. The

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[1] Grossman and Helpman presented theoretical framework using the cumulative trade as a variable in the function of the knowledge capital (Grossman and Helpman (1991a)).

growth rates of capital ranged from 7.5% to 13.1%. The growth rates of labor ranged from 4% to 6% except Japan and Hong Kong. In most of the countries trade grew more rapidly than the factors of production and output. All the countries except Japan recorded a trade growth rate of higher than 10%. The economic growth of the East Asian countries is also sustaining. The growth rates of output have not changed much, except Japan, in 1986-1995 period compared to previous periods as can be seen in Table 2. The growth rates of Korea, Taiwan, and Singapore in 1986-1995 are a little lower than in 1968-1975 by about 2%; however, the growth rates of Malaysia and Thailand are higher in 1986-1995 than in 1968-1975. The growth rates of total factor productivity (TFP) show improving or stable trends except Japan as can be seen in Table 3. The TFP growth rate of Japan has decreased recording 3.16% in 1968-1975 period, 1.46% in 1976-1985, and 1.0% in 1986-1995. The TFP growth rates of Malaysia and Hong Kong have not changed much but the controversial TFP growth rate of Singapore has improved much in the 1986-1995 period compared to the previous periods. The TFP growth rate of Singapore in the 1968-1975 period was -1.37%, -0.19% in 1976-1985, but shows huge surge of 3.74% in 1986-1995. Korea, Taiwan, and Thailand also show improving trends in TFP growth.[2]

[Table 1] Average Annual Growth Rates of Non-agricultural Output*, Labor, Capital, Trade, and TFP in Percentage for 1968-1995.

Growth Rates of	Countries						
	Korea	Japan	Taiwan	Singapore	Malaysia	Thailand	Hong Kong
Output	9.5	5.0	9.0	8.8	8.2	8.4	7.1
Labor	5.1	1.1	4.2	4.0	5.1	6.1	1.7
Capital	13.1	8.0	10.9	12.2	9.0	8.8	7.5
Trade	14.5	6.7	12.4	10.7	10.0	10.1	10.1
TFP	1.99	1.78	3.14	0.88	1.23	1.08	2.87

* In Singapore and Hong Kong output is GDP including agricultural sector.

[Table 2] Average Annual Growth rates of Non-agricultural Output for Three Subperiods.

Subperiods	Countries						
	Korea	Japan	Taiwan	Singapore	Malaysia	Thailand	Hong Kong
1968-1975	11.7	8.3	9.9	10.8	6.7	7.3	6.7
1976-1985	8.3	4.3	9.5	7.0	9.1	7.7	8.2
1986-1995	9.0	3.0	7.9	8.9	8.5	10.0	6.3

[2] For other measures of TFP growth rates refer to Young(1995), Collins(1996), Sarel(1997), Hsieh(1999), and Iwata *et al.*(2003) among others. The authors except Young report that TFP growth played more important role in the output growth of East Asian countries than Young's result.

[Table 3] Average Annual Growth rates of TFP for Three Subperiods for Non-agricultural Sector

Subperiods	Countries						
	Korea	Japan	Taiwan	Singapore	Malaysia	Thailand	Hong Kong
1968-1975	2.65	3.16	1.04	-1.37	1.24	-0.04	3.13
1976-1985	0.06	1.46	3.84	-0.19	1.24	0.79	2.85
1986-1995	3.40	1.00	4.11	3.74	1.20	2.24	2.67

To find out the effect of cumulative trade to economic growth we use a translog cost function for those economies. We will test whether cumulative trade contributes to technological progress by estimating the cost function. The estimated cost function will also give the elasticities of labor, capital, output, and cumulative trade to let us know the relative contribution of the factors to the growth of the economies.

Ⅱ. THE MODEL

As mentioned above current trade will affect future economic growth for some time. However, it could be presumed that the effect of trade to the future would diminish as time goes by. Thus we use perpetual inventory method to measure the cumulative trade by applying depreciation rates. Thus,

$$Q(t) = (1-\delta)Q(t-1) + T_r(t-1) \tag{1}$$

where $Q(t)$ is cumulative trade at time t, δ is its depreciation rate, and T_r is the volume of trade which is exports plus imports. Various depreciation rates have been applied to derive the stocks for this study. When the depreciation rate is 1.0 the cumulative trade is just the one period lag of trade. The cumulative trade has been divided by GDP. We assume that cumulative trade contributes to technological progress,[3] and thus the index of technological progress is augmented by cumulative trade such that:

$$T = A\exp(\gamma_Q Q^*)\exp(t),^4 \tag{2}$$

where T is the index of technological progress augmented by technical progress, A is a constant, Q^* is the cumulative trade divided by GDP, t is the index of exogenous technical change represented by a time trend. We employed a translog cost function to analyze the economies such that:

[3] Grossman and Helpman specified that knowledge capital is a function of cumulative trade and cumulative amount of domestic research.

[4] This specification is applied from the specification of the commodity augmentation factors. See Boskin and Lau(1992)

$$\begin{aligned}\ln C = {} & \alpha_0 + \alpha_L \ln W_L + \alpha_K \ln W_K + \alpha_Y \ln Y + \alpha_T \ln T + 0.5\alpha_{LL}(\ln W_L)^2 \\ & + \alpha_{LK} \ln W_L \ln W_K + \alpha_{LY} \ln W_L \ln Y + \alpha_{LT}(\ln W_L)\ln T \\ & + 0.5\alpha_{KK}(\ln W_K)^2 + \alpha_{KY} \ln W_K \ln Y + \alpha_{KT}(\ln W_K)\ln T \\ & + 0.5\alpha_{YY}(\ln Y)^2 + \alpha_{YT}(\ln Y)(\ln T) + 0.5\alpha_{TT}(\ln T)^2\end{aligned} \tag{3}$$

where C is the total cost of labor and capital for non-agricultural sector, W_L is the wage rate, W_K is the rental rate of capital, Y is the output of non-agricultural sector, and $\ln T = \ln A + \gamma_Q Q^* + t$, where Q^* is cumulative trade divided by non-agricultural output. $\ln T$ is the cumulative trade augmented index of technological progress, which means that cumulative trade contributes to technological progress when γ_Q is positive. After substituting $\ln T = \ln A + \gamma_Q Q^* + t$ and normalizing by the price of capital under the assumption of linear homogeneity in prices,[5] Equation (3) becomes

$$\begin{aligned}\ln(C/W_K) = {} & \alpha_0^* + \alpha_L^* \ln(W_L/W_K) + \alpha_Y^* \ln Y + \alpha_T^* \gamma_Q Q^* + \alpha_T^* t \\ & + 0.5\alpha_{LL}^* \ln(W_L/W_K))^2 + \alpha_{LY}^* \ln(W_L/W_K)\ln Y \\ & + \alpha_{LT}^* \gamma_Q \ln(W_L/W_K) Q^* + \alpha_{LT}^* \ln(W_L/W_K) t \\ & + 0.5\alpha_{YY}^*(\ln Y)^2 + \alpha_{YT}^* \gamma_Q (\ln Y) Q^* + \alpha_{YT}^*(\ln Y) t \\ & + 0.5\alpha_{TT}^* \gamma_Q^2 Q^{*2} + \alpha_{TT}^* \gamma_Q Q^* t + 0.5\alpha_{TT}^* t^2\end{aligned} \tag{4}$$

This is a variable cost function with the variable inputs of capital and labor and a fixed input of cumulative trade. From Equation (4) a labor share equation from Shepard's Lemma and a revenue share equation under the assumption of perfectly competitive output markets can be obtained as follows.

$$S_L = \alpha_L^* + \alpha_{LL}^* \ln(W_L/W_K) + \alpha_{LY}^* \ln Y + \alpha_{LT}^* \gamma_Q Q^* + \alpha_{LT}^* t \tag{5}$$

$$S_Y = \alpha_Y^* + \alpha_{LY}^* \ln(W_L/W_K) + \alpha_{YY}^* \ln Y + \alpha_{YT}^* \gamma_Q Q^* + \alpha_{YT}^* t \tag{6}$$

where S_L and S_Y are the cost shares of labor and output, respectively. Capital share can be obtained as $1 - S_L$. Our specification does not impose a priori constant returns to scale; thus, the cost elasticity of output needs not be one. The cost function should be concave in factor prices, accordingly, the Hessian matrix of second partial derivatives with respect to factor prices should be

[5] This assumption amounts to restricting the parameters such that: $\alpha_K = 1 - \alpha_L$, $\alpha_{KK} = -\alpha_{LK}$, $\alpha_{LK} = -\alpha_{LL}$, $\alpha_{KY} = -\alpha_{LY}$, $\alpha_{KT} = -\alpha_{LT}$

negative semi-definite. If the cumulative trade is contributing to technical progress γ_Q will have plus sign and the elasticity $\partial \ln C / \partial \ln Q^*$ will be negative in the variable cost function.

Ⅲ. DATA AND ESTIMATION METHOD

Estimation is implemented for the group of seven East Asian economies (Korea, Japan, Taiwan, Singapore, Malaysia, Thailand, and Hong Kong). Except Singapore and Hong Kong,[6] only non-agricultural sectors are considered. The output(Y) is obtained by excluding agriculture from total GDP categorized by kind of activity. Non-agricultural indirect taxes are subtracted from and subsidies are added to output(Y). Non-agricultural indirect taxes are obtained by multiplying total indirect taxes to the share of non-agricultural GDP to total GDP. Non-residential and non-agricultural capital stock is used for the capital (K). We generate four categories of capital stock separately (non-residential buildings, other construction, transportation equipment, machinery and other equipment)[7] and add them up to form capital (K). The perpetual inventory method is used to derive each categorized capital stock. Base year capital is calculated using the formula $K_{i0} = I_{i0} / (m_i + \delta_i)$, $i = 1,2,3,4$ where K_{i0} is the base year stock of the ith categorized capital, I_{i0} is the gross fixed capital formation of the ith category excluding agriculture, m_i is the growth rate of I_{i0} for the first ten years, δ_i is the depreciation rate of each category. The depreciation rates for non-residential buildings, other construction, transportation equipment, machinery and other equipment are 0.0304, 0.03024, 0.2079, and 0.1376, respectively. These values are derived by taking unweighted average of the depreciation rates of asset types from the table of Jorgenson and Yun (1990). The depreciation rate of total capital stock is the weighted average of the depreciation rates of categorized capital stocks. Rental price of capital(W_K) is $P_I(r - inf + \delta)$ where P_I is the price of non-agricultural fixed capital formation, r is the nominal interest rate, and inf is the inflation rate of P_I. We average the real interest rates of the sample period. Labor is total man hours worked in the non-agricultural sector. Total man-hours are calculated by multiplying total non-agricultural employment and average weekly hours and 50. Total labor cost is compensation of employees in non-agricultural sector times TM_N / EMP_N where TM_N is total non-agricultural employment and EMP_N is employees in the non-agricultural sector. Unit cost of labor (W_L) is obtained by dividing the compensation of employees by total man-hours worked in non-agricultural sector and normalizing it to the base year 1985. PPP values for

[6] GDP including agricultural sector is considered for Singapore and Hong Kong.

[7] This classification is in accordance with the definitions and classifications in the United Nations Systems of National Accounts (SNA).

1985 from Summers and Heston (1991) are used to convert data to US dollars. The sources of the data can be found in the Data Appendix.

For estimation purposes stochastic disturbance terms are added to Equation (4) through (6). We assume that the disturbances ε_{ti}'s are first order autoregressive such that: $\varepsilon_{ti} = \rho\varepsilon_{ti-1} + \mu_t$ and μ_t is distributed i.i.d. over time. We apply $\rho = 0.85$ for all the three estimation equations. α_0, α_L, α_K, α_Y, and α_t are estimated individually for each country applying dummy variables, and the other parameters are estimated jointly using the 3SLS estimation procedure. The instrumental variables for the estimation are country dummies, all exogenous variables and their squares lagged one and two periods, and time and its square. Heteroscedacity is taken care of using White's method. The sample period of the data for estimation is 1968-1995.

Ⅳ. ESTIMATION RESULTS

The cost function and the share equations of (4)-(6) are estimated by using cumulative trade derived under different depreciation rates. The results are summarized in Table 4. The estimated coefficient of cumulative trade is significant under the depreciation rates of 0.3-1.0. Especially, the estimated coefficient of cumulative trade under the depreciation rates of 0.5-0.9 is significant at 1% level. From the experiments it can be seen that cumulative trade is contributing to technical progress. The estimated cost functions for the seven East Asian Countries met curvature conditions at all data points for all the models.

[Table 4] Estimates of γ_Q under various Depreciation Rates. The Standard Errors are in the Parentheses.

	Depreciation Rate									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
γ_Q	-0.144	0.714	1.211*	1.704*	2.138**	2.464**	2.657**	2.708**	2.616**	2.401*
	(0.270)	(0.402)	(0.542)	(0.678)	(0.799)	(0.898)	(0.970)	(1.012)	(1.020)	(0.994)

* Significant at 5 % level
** Significant at 1 % level

We present estimation results for the model of the cumulative trade under depreciation rate of 0.5.[8] R^2's for the cost function, the labor share equation, and the revenue share equation are .99, .98, and .94, and the Durbin-Watson statistics are 1.71, 1.83, and 1.88, respectively. Estimated parameters and standard errors are reported in Table 5. Country dummy numbers from 1 to 7 represent

[8] Estimation results for the models of depreciation rates of 0.6 and 0.7 are robust except that some t-values for the elasticities deteriorate a little.

Korea, Japan, Taiwan, Singapore, Malaysia, Thailand, and Hong Kong respectively.

[Table 5] Estimated Parameters and Standard Errors for the seven East Asian Countries. The depreciation rate of the cumulative trade is 0.5.

Parameter	Estimate	Standard Error
γ_Q	2.13819	.799885
α_{01}^*	2.02449	.813861
α_{02}^*	1.59392	.849134
α_{03}^*	.068665	.459833
α_{04}^*	-1.38509	.754963
α_{05}^*	-1.19119	.585695
α_{06}^*	-.517029	.455448
α_{07}^*	-2.10642	.725986
α_{L1}^*	.660337	.086585
α_{L2}^*	-.055752	.049493
α_{L3}^*	.043470	.017832
α_{L4}^*	-.212176E-02	.059292
α_{L5}^*	-.052238	.032959
α_{L6}^*	-.121283	.021043
α_{L7}^*	.074373	.031666
α_{Y1}^*	.410479	.354078
α_{Y2}^*	-.470172	.192474
α_{Y3}^*	.041003	.092242
α_{Y4}^*	.724043	.242299
α_{Y5}^*	.534667	.146724
α_{Y6}^*	.098765	.092916
α_{Y7}^*	.606710	.162378
α_{T1}^*	.681652E-02	.026717
α_{T2}^*	.058384	.017178
α_{T3}^*	-.640857E-02	.989511E-02
α_{T4}^*	-.034398	.016284
α_{T5}^*	-.030876	.013678
α_{T6}^*	.980053E-02	.011092
α_{T7}^*	-.021940	.014069
α_{LL}^*	.074003	.020874
α_{YY}^*	.190973	.090660
α_{TT}^*	.130918E-02	.588474E-03
α_{LY}^*	.014259	.022896
α_{LT}^*	-.491640E-02	.137607E-02
α_{YT}^*	-.013183	.600403E-02
Equation	R2	DW
Cost	0.999	1.718
Labor Share	0.985	1.835
Revenue Share	0.943	1.886

The elasticities of output, labor, cumulative trade, and technical progress calculated from the estimated model of depreciation rate 0.5 are reported in Table 6. Those elasticities are from the calculation of $\partial \ln C/\partial \ln Y$, $\partial \ln C/\partial \ln W_L$, $\partial \ln C/\partial \ln Q^*$, and $\partial \ln C/\partial t$. The elasticity of capital can be obtained as $1-\partial \ln C/\partial \ln W_L$ due to the assumption of linear homogeneity in prices. Since the estimated elasticities are the functions of the estimated parameters we also present an estimate for the standard errors of the elasticities at the sample means of the inputs. All of the elasticities for all the countries are statistically significant except the elasticity of cumulative trade in Japan, which is significant at 10% level. The elasticity of cumulative trade is highest in Singapore, Hong Kong, and Malaysia while it is lowest in Japan. Table 7 also reports relative contributions of labor, capital, cumulative trade, and technical progress.[9] The relative contribution of cumulative trade to output growth is

[Table 6] Elasticity of Output, Labor, Cumulative Trade, and Technical Progress in Percentage, Annual Average of 1968-1995 when the Depreciation Rate of the Cumulative Trade is 0.5. (Figures in the parentheses are standard errors calculated at respective sample means of the inputs)

	Elasticity of			
	Output	Labor	Cumulative Trade	Technical Progress
Korea	1.069 (0.070)	0.768 (0.011)	-0.107 (0.044)	-0.0382 (0.0064)
Japan	1.074 (0.039)	0.774 (0.005)	-0.014 (0.009)	-0.0143 (0.0050)
Taiwan	0.998 (0.032)	0.782 (0.007)	-0.144 (0.055)	-0.0355 (0.0063)
Singapore	1.308 (0.037)	0.687 (0.011)	-0.418 (0.134)	-0.0351 (0.0066)
Malaysia	1.365 (0.049)	0.699 (0.014)	-0.303 (0.117)	-0.0520 (0.0102)
Thailand	1.108 (0.066)	0.636 (0.021)	-0.068 (0.033)	-0.0239 (0.0090)
Hong Kong	1.459 (0.066)	0.813 (0.007)	-0.328 (0.117)	-0.0436 (0.0097)

[9] Relative contributions of labor, capital, cumulative trade, and technical progress are calculated such as:

$RC_L=(1/\sigma)(1/(1-(1/\partial \ln C/\partial \ln Q_M^*))(\partial \ln C/\partial \ln W_L)\Delta L\times 100,$

$RC_K=(1/\sigma)(1/(1-(1/\partial \ln C/\partial \ln Q_M^*))(\partial \ln C/\partial \ln W_K)\Delta K\times 100,$

$RC_{Q*}=(1/\sigma)(1/(1-(1/\partial \ln C/\partial \ln Q^*))(-\partial \ln C/\partial \ln Q^*)\Delta Q^*\times 100,$

$RC_t=(1/\sigma)(1/(1-(1/\partial \ln C/\partial \ln Q^*))(\partial \ln C/\partial t)\times 100,$

where RC_L, RC_K, RC_{Q*}, and RC_t are relative contribution of labor, capital, cumulative trade, and technical progress in percentage, respectively. σ is the returns to scale which is calculated as $(1-(1/\partial \ln C/\partial \ln Q^*))/(\partial \ln C/\partial \ln Y)$, and ΔL, ΔK^*, and ΔQ^* are the annual growth rates of labor, capital, and cumulative trade, respectively. See Prucha and Nadiri (1991) for the detail.

[Table 7] Relative Contribution of Labor, Cumulative trade, Technical Progress in Percentage, Average of 1969-1995. The depreciation rate of the cumulative trade is 0.5.

	Relative Contribution of			
	Labor	Capital	Cumulative Trade	Technical Progress
Korea	35	27	4	34
Japan	21	43	1	35
Taiwan	34	25	5	36
Singapore	25	34	8	32
Malaysia	30	23	3	44
Thailand	40	33	2	25
Hong Kong	17	17	13	53

highest in Hong Kong and Singapore recording 13% and 8%, respectively. In Taiwan and Korea cumulative trade contributes 5% and 4% to output growth, respectively. The relative contribution of cumulative trade is very small in Japan and Thailand recording only 1% and 2% respectively. The contribution of cumulative trade is much lower than the other sources of output growth in most of the countries. Technical progress is a very important source of output growth in the East Asian countries. It is the most important source of growth in Hong Kong, Malaysia, and Taiwan and the second most important source of growth in Korea, Japan, and Singapore.

Ⅴ. THE CATCH-UP MODEL

If cumulative trade helps a country, which is technologically lagged behind, catch up the leader the following form of technology index can be considered.

$$T^* = \gamma_Q Q^* + \gamma_C((Y_{Jt} - Y_{it})/Y_{it})Q^* + t \tag{7}$$

where Y_{Jt} is the per capita non-agricultural GDP of Japan at time t and Y_{it} is the per capita non-agricultural GDP of country i at time t. $\gamma_Q Q^*$ represents the contribution of cumulative trade to technical progress and $\gamma_C((Y_{Jt} - Yit)/Y_{it})Q^*$ represents the catch-up factor. Equation (7) can be written as

$$T^* = (\gamma_Q - \gamma_C)Q^* + \gamma_C((Y_{Jt}/Y_{it})Q^* + t \qquad (8)^{10}$$

Equation (8) is substituted to Equations (4), (5), and (6) for catch-up model and they are estimated using 3SLS estimation procedure. We applied $\rho = 0.8$ for all the three equations. The instrument variables are same as the non-catch-up model except that the log of population lagged one period is added

[10] Equation (7) and (8) are due to Benhabib and Spiegel (1994).

for the catch-up model. Table 8 reports the estimates and standard errors of γ_Q and γ_C for different depreciation rates for the catch-up model. Both of the coefficients γ_Q and γ_C of cumulative trade are statistically significant at 1% level under the depreciation rates of 0.2, 0.3. We report the estimation results for the catch-up model under the depreciation rate of 0.2.[11] R^2's for cost function, labor share equation, and revenue share equation are .998, .984, and .945, and the Durbin-Watson statistics are 1.486, 1.741, and 1.706, respectively. The estimated parameters and standard errors are reported in Table 9. Country dummy numbers from 1 to 7 represent Korea, Japan, Taiwan, Singapore, Malaysia, Thailand, and Hong Kong respectively.

[Table 8] Estimates of γ_Q and γ_C for Different Depreciation Rates for Catch-up Model. The standard errors are in the parentheses.

	Depreciation Rate				
	0.1	0.2	0.3	0.4	0.5
γ_Q	-7.002(8.789)	1.397(0.500)**	1.737(0.618)**	1.462(0.606)**	1.771(0.731)*
γ_C	-16.221(23.295)	1.412(0.465)**	1.992(0.641)**	0.503(0.486)	0.641(0.564)

	Depreciation Rate				
	0.6	0.7	0.8	0.9	1.0
γ_Q	2.021(0.858)*	2.191(0.976)*	2.269(1.076)*	2.256(1.148)*	2.181(1.888)
γ_C	0.737(0.648)	0.798(0.743)	0.805(0.849)	0.725(0.960)	0.514(1.065)

* significant at 5 % level
** significant at 1 % level

Table 10 and Table 11 show the elasticities and relative contributions for the catch-up model when the depreciation rate is 0.2. Most of the elasticities are statistically significant at 5% level; however, the elasticities of cumulative trade for Malaysia, Thailand, and Japan are significant at 11.5%, 13.4%, and 16.7% levels, respectively and the rate of technical change for Japan is significant at 12.7% level. The elasticities of cumulative trade and technical change are highest in Singapore recording -.93 followed by Malaysia with -.76. The elasticity of cumulative trade for Japan is close to zero. The estimates for the rate of technical progress range from 0.86 percent per annum in Japan to 4.03 percent in Singapore.[12] The average rate of technical change for Malaysia, Thailand, and Hong Kong is high at 3.49, 3.23, and 2.98 percent, respectively. The relative

[11] The model of depreciation rate of 0.3 gives more insignificant elasitisities than the model of depreciation rate of 0.2.

[12] The rates for Singapore, Malaysia, and Thailand are relatively high compared to previous researches; however, Iwata *et al.*(2003) also reported high rates. Their TFP growth estimates for Singapore, Malaysia, and Thailand are 3.9, 3.4, and 3.4 percent, respectively.

[Table 9] Estimated Parameters and Standard Errors of Catch-Up model for the seven East Asian Countries. The depreciation rate of the cumulative trade is 0.2.

Parameter	Estimate	Standard Error
γ_Q	1.39706	.500939
γ_C	1.41236	.465972
α_{01}^*	-.282929	.757932
α_{02}^*	2.95544	.693613
α_{03}^*	.177701	.363483
α_{04}^*	-1.25601	.694338
α_{05}^*	-1.87362	.760474
α_{06}^*	-.458728	.582623
α_{07}^*	-1.63225	.504286
α_{L1}^*	.748441	.073201
α_{L2}^*	-.102728	.037697
α_{L3}^*	.049157	.012589
α_{L4}^*	.031016	.049201
α_{L5}^*	.013774	.027822
α_{L6}^*	-.066876	.018454
α_{L7}^*	.047438	.028002
α_{Y1}^*	.595091	.260514
α_{Y2}^*	-.696055	.151791
α_{Y3}^*	.065032	.058391
α_{Y4}^*	.883935	.171922
α_{Y5}^*	.719701	.108282
α_{Y6}^*	.237001	.069486
α_{Y7}^*	.541784	.102025
α_{T1}^*	.121998	.025527
α_{T2}^*	.048660	.016202
α_{T3}^*	-.012011	.011856
α_{T4}^*	-.042336	.021564
α_{T5}^*	-.019382	.020837
α_{T6}^*	-.010392	.017138
α_{T7}^*	-.024878	.014951
α_{LL}^*	.099168	.018856
α_{YY}^*	.222061	.063354
α_{TT}^*	-.129362E-02	.798493E-03
α_{LY}^*	.841299E-02	.018920
α_{LT}^*	-.726389E-02	.118244E-02
α_{YT}^*	-.020133	.487104E-02
Equation	R2	DW
Cost	0.998	1.486
Labor Share	0.984	1.741
Revenue Share	0.945	1.706

contribution of cumulative trade is highest in Hong Kong contributing 23% of GDP growth and Singapore is the next at 17% followed by Malaysia at 11%. It is only 1% in Japan, and 4% and 5% in Korea and Taiwan, respectively. Cumulative trade is contributing more than labor or capital to GDP growth of Hong Kong. Comparing Table 11 with Table 7 we can see that the relative contributions of cumulative trade for the catch-up model and the non-catch-up model are the same in Korea, Japan, and Taiwan but much higher for the catch-up model in other countries. However, much is left for technical progress. The technical progress is an important source of economic growth for all the countries contributing more than 20% to output growth. The technical progress is the most important source of economic growth for Hong Kong and Singapore contributing 40% of output growth in Hong Kong and 32% in Singapore. In Japan, Malaysia, and Thailand technical progress is the second most important source of economic growth. Labor is the most important source of economic growth in Korea and Taiwan while capital is the most important source of economic growth in Japan. Capital is the second most important source of economic growth in Korea, Singapore, and Taiwan.[13]

[Table 10] Cost Elasticities. Annual Average of 1968-1995 for Catch-up Model with Depreciation rate of 0.2. (Figures in the parentheses are standard errors calculated at respective sample means of the inputs)

	Elasticity of			
	Output	Labor	Cumulative Trade	Technical Progress
Korea	1.120 (0.046)	0.782 (0.007)	-0.216 (0.080)	-0.0184 (0.0060)
Japan	1.107 (0.030)	0.784 (0.004)	-0.018 (0.009)	-0.0086 (0.0056)
Taiwan	1.038 (0.022)	0.792 (0.005)	-0.258 (0.009)	-0.0215 (0.0079)
Singapore	1.302 (0.030)	0.687 (0.009)	-0.926 (0.326)	-0.0403 (0.0092)
Malaysia	1.342 (0.042)	0.709 (0.012)	-0.756 (0.478)	-0.0349 (0.0154)
Thailand	1.132 (0.043)	0.648 (0.014)	-0.530 (0.331)	-0.0323 (0.0151)
Hong Kong	1.455 (0.046)	0.820 (0.007)	-0.332 (0.128)	-0.0298 (0.0108)

[13] Iwata *et al.*(2003) also reports small contribution of capital to ouput growth. They attribute 44-47% of ouputput growth to TFP growth, which is higher than our estimation of the contribution of technical progress but they do not consider cumulative trade.

[Table 11] Relative Contribution of Labor, Capital, Cumulative trade, Technical Progress of Catch-up Model in Percentage, Average of 1969-1995. The depreciation rate of the cumulative trade is 0.2.

Countries	Relative Contribution of			
	Labor	Capital	Cumulative Trade	Technical Progress
Korea	44	31	4	21
Japan	24	46	1	29
Taiwan	40	28	5	27
Singapore	22	29	17	32
Malaysia	33	24	11	32
Thailand	36	27	8	29
Hong Kong	19	18	23	40

Ⅵ. CONCLUSION

We estimate the cost functions of seven East Asian countries using cumulative trade-augmented time index to find out whether cumulative trade enhances technical progress. Our estimation results show that cumulative trade played an important role in the economic growth of the East Asian countries by augmenting technical progress. This implies that the East Asian countries benefited from trade through learning-by-doing, emulating advanced technologies, competition in the large world market, etc., confirming our assumption that the effects of trade are accumulated. Our estimation shows that the rate of technical progress is higher in the non-catch-up model than in the catch-up model. When catch-up factor is considered the relative contribution of technical progress diminishes, which means that less developed countries absorb more foreign knowledge through trade enabling themselves a faster technical progress than developed countries. The cumulative trade played a noticeably bigger role in the economic growth of Hong Kong, Singapore, and Malaysia than other countries in the catch-up model. On the other hand technical progress also played an important role in the output growth in the East Asian countries, and in some cases, a more important role than factor accumulation. This result is in line with the recent researches, which report that TFP growth is an important source of the economic growth of East Asian countries.[14]

[14] Refer to Iwata *et al.*(2003), Sarel(1997), Hsieh(1999), and Collins(1996) among others.

DATA APPENDIX

The variables of GDP by economic activity, Gross Fixed Capital Formation and its categories, and Compensation of Employees are taken largely from the Yearbook of National Account Statistics of UN (YNAS) because the YNAS carries all three variables together and provides well-organized and standardized data. Some data for recent years are obtained from the statistical yearbooks of each country and Statistical Yearbooks of Asia and Pacific. Data for Taiwan are collected from National Income in Taiwan Area, and the data for Hong Kong are collected from Estimate of GDP, Hong Kong. Data for compensation of Employees of total economy and agriculture are only partly available in some countries. Thus, they are interpolated. Lending rate is used for the interest rate in calculating the rental rate of capital. Lending rate is collected from International Financial Statistics. The prices of GDP and Gross Fixed Capital Formation are obtained by dividing current values by constant values and normalizing them with the base year 1985. Total employment, classified into status and economic activity, and average weekly hours worked in non-agricultural sectors, are taken mostly from the Yearbook of Labor Statistics. Some unavailable data for some countries are interpolated.

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