Empirical Tests of New Growth Theory: Openness and Growth

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Abstract

New growth theory has stressed the role of export externality and increasing returns to scale in promoting sustained growth. This paper discusses these sources of economic growth in Asian NICs (newly industrializing countries) in recent times by applying some modern econometric tests based on cointegration and other methods. Countries such as Japan, Korea and Taiwan are considered as examples for empirical applications of the broad tenets of the new growth theory.

I. Introduction

New growth theory developed over the last six years or so (see *e.g.*, Grossman-Helpman [1990], Romer [1986, 1990] and Lucas [1988]) has emphasized the role of openness in trade and export externality as a positive factor in promoting long run growth. Two mechanisms in the growth process appear to be important here. One is the dynamic productivity effect of the growth of the export sector, which acts as a catalytic agent in the diffusion of modern technology and know-how across other sectors. The sec-

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ond is the persistence of increasing returns to scale (IRS) in the production of technology-intensive products which play an increasing role in the export trade of the newly industrializing countries (NICs) of East Asian countries such as Japan, Korea, Hong Kong, Singapore and Taiwan. Thus the new growth theory reminds us that when investment takes place under conditions of increasing returns to scale, the marginal product of capital need not decline over time to the level of the discount rate and hence the incentive to accumulate capital may persist indefinitely thus sustaining a steady growth of output. Furthermore the externality effects of exports on growth have helped other sectors to grow and take advantage of increasing returns to scale in technology-intensive products. From an empirical standpoint one could examine the persistence of these two growth-sustaining forces from the recent experiences of the so-called newly industrializing countries (NICs) of the East Asian Pacific Rim such as Hong Kong, Korea (South), Singapore and Taiwan, which achieved in the last decade a very high rate of economic success. It is believed that openness in trade and outward-looking policy measures in these countries have contributed greatly to their success rates. Some recent econometric estimates by Quah and Rauch [1990] have found over the data set of 81 developing and less developed countries (LDCs) that openness in trade strongly causes income growth, when the causality is measured in the sense of Granger [1969].

This paper attempts to provide some empirical tests of the new growth theory with regard to the impact of openness on growth. Openness is measured by the externality effect of exports, where increasing returns to scale provide the mechanism through which new technology diffusion occurs. We model the export sector as the initiator of economy-wide structural changes in the form of technical innovations and diffusion of skill-intensive externality of human capital and test if it contributes to a higher level of aggregate productivity. We investigate if the dynamic expansion of the export sector, largely based on the increased specialization in manufacturing exports has been the driving force behind the modernization of the economy. A set of three countries, *e.g.*, Japan, Korea and Taiwan is selected here for our empirical applications, though other countries such as Philippines and Thailand are also mentioned in the background for comparative purposes. Three reasons for selecting the above three countries may be

mentioned. One is that these countries have been most successful in their growth performance over the period covered here. Secondly, the detailed empirical study of Asian NICs exports by Kellman and Chow [1989] showed that traditional export items were very dissimilar in pattern across the four countries: Korea, Hong Kong, Taiwan and Singapore but similar and homogeneous patterns were found for exports of certain sophisticated R&D intensive products such as electrical machinery and computer equipment *etc.* Thirdly, these countries have consistently followed deliberate government policies promoting optimal growth trajectories where exports were used as the major instrument variable. Our objective was to provide empirical tests for the persistence of long run growth and to examine the contributions of labor, capital and export externality. The econometric method used to test these impacts is based on the specification and estimation of the error correction models (ECM) used in modern cointegration theory, which distinguish between the short run and the long run behavior in the growth process in these countries.

II. Openness and Growth

Openness in trade has been empirically measured in three different ways. One is in terms of uniform tariff barriers and the associated policy measures. Quah and Rauch [1990] have found a positive relationship between this type of openness and economic growth over 81 less developed countries 1961-85. The other two measures of openness are given by the ratio of exports to GDP and that of imports to GDP. Of these two, the export ratio is a more convenient measure, since it can specify more directly the externality impact of the export sector over the other sectors. Using this measure the linkage between exports and economic growth in LDC has been traditionally analyzed by two groups of methods. One group of methods uses export growth to measure openness in trade and correlates it with per capita income. Thus Feder [1982], Chow [1987] and Edwards [1989] have used regression methods to explain income growth rates in terms of export growth for the developing countries. For a sample of 8 NICs Chow [1987] carried out causality tests in the sense of Sims [1972] linking exports of manufactures and the manufacturing output and found a strong causal relationship from exports to

income growth. The second group of methods attempted by Balassa [1983], Bradford [1987] and others looks at the composition of export products and uses its diversification to represent outward development or openness in world trade. Thus Bradford [1987] used empirical data for more than 12 countries either NICs, or next-tier NICs in the world over 1965-80 and found that high rates of income growth and rapid structural change are strongly positively correlated for those countries which are successful NICs. Here the index of structural change is derived from the share in GDP of the 16 manufacturing branches that are technology-intensive.

For the set of countries in our selected samples we may consider this empirical evidence linking openness and economic growth, where openness is measured by export growth and the overall economic performance is measured by an index of structural change, *e.g.*, the average annual gain in percentage terms in the share of manufactures in total exports and in total GDP (gross domestic product). Tables A and B show a very high degree of positive correlation between export growth and structural change in all the successful NICs in Asia, with Korea and Taiwan taking the lead. Japan, as a mature exporter, experienced less structural change in exports during this period, and it is conceivable that the role of exports in such a mature econo-

Table A
Structural Change and Economic Growth in East Asia

	(1) Growth Rate of Exports (%)	(2) X_{mfg}/X Initial (%)	(3) X_{mfg}/X Final (%)	(4) Total Gain (2)-(1)	(5) Degree of Structural Change	(6) Growth Rate of Output (%)
Korea	30.0	12.7	92.3	79.6	3.1	8.7
Taiwan	23.0	36.6	92.2	55.6	2.1	9.1
Thailand	14.1	1.4	52.3	50.9	1.9	6.8
Philippines	9.0	3.2	36.3	33.1	1.2	4.3
Japan	14.3	88.9	98.1	9.2	0.3	7.3

Notes: X_{mfg}/X = Share of Manufactures in Total Exports, in per cent. The periods covered are: Korea 1960-86, Taiwan 1961-87, Japan 1960-85, Thailand and The Philippines 1960-87. The growth rate of real output is computed using constant prices; the growth rate of exports is computed using the current value of exports.

Sources: (1) World Development Reports of World Bank, (2) Statistical Yearbook of S. Korea, Taiwan, Thailand, Philippines and Japan.

Table B
Specialization in High-Technology Exports (HTX) in East Asia

	(1) Initial and End Value of (HTX/X)	(2) Total Gain End – Initial Value of (1)	(3) Average Annual Gain in (HTX/X)
Korea	0.0 – 33.7	33.7	1.30
Taiwan	1.3 – 32.3	31.0	1.20
Thailand	0.0 – 11.9	11.9	0.44
Philippines	0.0 – 10.5	10.5	0.39
Japan	22.9 – 62.3	39.4	1.60

Notes: HTX = High-technology Exports, represented by exports of machines and transport equipment, Section 7 of SITC.

(HTX/X) = Share of High-technology exports in total exports, both measured in current value terms.

Periods covered: Korea, Thailand, Philippines 1960-87; Taiwan 1961-87; Japan 1960-85.

Source: (1) World Bank Tables, (2) Statistical Yearbooks of Korea, Taiwan and Japan and (3) IMF World Economic Reports.

my is less than it is in the exports-oriented NICs.

Besides the increased concentration in the export of manufactures, further specialization is taking place in the three more developed countries in the sample as the share of high-technology in total exports is constantly increasing. This process is especially pronounced in the case of Japan (see Table B) and virtually non-existent in the cases of Thailand and the Philippines. Again, the concentration of high-technology exports (HTX) seems to have been a correct strategical decision by Korea, given that the annual compounded growth rate of world demand for HTX of 13.3% has been higher than the growth rates of world demand for either manufactured or total exports of 12.3% and 7.9% respectively. Experiences for Japan and Taiwan are similar.

These empirical methods have however some basic limitations from an economic viewpoint. First of all, the correlation between exports and output growth may not have any structural long run significance, when the two variables are nonstationary over time. The modern theory of cointegration in dynamic economic modelling has emphasized this point very clearly. Thus consider a pair (y_t, x_t) of variables, where y_t is the dependent variable

and it is assumed that both series are nonstationary. Let us assume that their first differences *i.e.* $\Delta y_t = y_t - y_{t-1}$, $\Delta x_t = x_t - x_{t-1}$ are stationary. Then the ordinary regression of y_t (*e.g.*, output growth) on x_t (*e.g.*, export growth) would frequently have high R^2 statistics typically displaying highly autocorrelated residuals (*i.e.*, low Durbin-Watson statistics), which produces a strong bias towards accepting the spurious relationships. As Phillips and Durlauf [1986] have shown that such regressions have the disturbing feature that the conventional t and F tests for the regression coefficients do not converge and there are no asymptotically correct critical values for the conventional significance tests.

Secondly, the researchers emphasizing a positive correlation between exports and output growth have usually employed a linear regression equation relating income growth rates Δy_t , openness x and other variables z :

$$E(\Delta y_t | x, z) = X\beta + Z\gamma \quad (1)$$

and they applied this formulation to the steady state versions of these variables. Therefore they frequently use sample time averages of Δy_t , x and z in estimating the regression equation (1). However due to nonstationarity, the time averaging process fails to reveal the dynamic relationships between growth and openness in cross-section samples. Thus Levine and Renelt [1990] found no robust relationship between the growth of the export-GDP ratio and the growth of GDP per capita. Recently Levin and Raut [1992] have shown that this lack of robustness may be due to neglecting significant nonlinearities in the relationship. Furthermore, if we let e_t as the additive error in the specification (1):

$$E(\Delta y_t | x, z) = f(X, Z) + e_t \quad (2)$$

where $f(\cdot)$ may be a nonlinear function, one could test if the residuals e_t satisfy the condition of stationarity. For this purpose the modern theory of cointegration performs an augmented Dickey-Fuller (ADF) test by running an empirical regression of a generalized form:

$$\Delta e_t = \delta e_{t-1} + b_1 \Delta e_{t-1} + \dots + b_p \Delta e_{t-p} + u_t \quad (3)$$

and performing a t -test to determine if δ is significantly less than zero or not. Clearly if the output variable y_t is not stationary to the first order, the

ADF test would reveal the inappropriateness of the regression model (2) as a long run structural specification. It would also explain in part the lack of robustness obtained by the empirical studies of Levine and Renett [1992], who performed a sensitivity analysis of cross-country growth regressions in respect of heterogeneity in data structures.

Finally, the sources of economic growth due to exports are not specifically captured in the regression models of the type (2), since the export sector's contribution to productivity growth through increasing returns or other types of complementarity between trade policies and human capital investment is not incorporated. For economies like Korea previous econometric studies by Sengupta [1991, 1993] showed such externalities to be very strong and significant. Hence there is a need to apply the modern theory of cointegration in this framework of export externalities.

Two types of specifications are attempted here to explore the link of exports and output growth or the three Asian NICs *e.g.*, Japan, Korea and Taiwan which have proved most successful in world competition over the last two decades. These specifications involve export externality and the export elasticities. We apply here the theory of cointegration to develop tests for structural relationships between openness and growth. This theory essentially proposes two steps. In the first step we determine the order of integration of all the variables in a regression model which make them stationary. In the second step suitable error correction models (ECM) are formulated by using the cointegrating vectors from the first-stage.

On statistical grounds the issue may be raised here that the method of cointegration is less appropriate here, since we do not have large samples, *e.g.*, each country has less than 30 observations. Two justifications may be mentioned however. By including longer periods the sample size could have been easily increased, but in an economic sense this would be less meaningful, since the structural changes in the earlier period were almost negligible with no rapid rise in exports. Secondly, our purpose was to identify persistence in long run growth if any and to distinguish it from the short run phenomena. This is done mainly through estimating the dynamic production frontiers. Although the least squares results based on regression methods are reported here, we have discussed elsewhere (*e.g.*, see Sengupta and España [1993]) some nonparametric methods of estimating the ECM mod-

els of the long run production frontiers. Since the results of these alternative methods are very similar to the least squares results we report the latter here. Now a time series y_t is said to be integrated of order d , denoted $I(d)$ if it must be differenced d times before it becomes stationary. Thus a time series y_t is $I(0)$ if it is stationary, whereas if it is $I(1)$, its first difference Δy_t is stationary. The concepts of cointegration provides an important link between the interrelationships of integrated processes and the concept of steady state equilibrium. It was originally introduced by Granger [1969] and later extended by Engle and Granger [1987] and many others. Suppose a steady state relation holds as

$$y_t = \alpha' x_t = \sum_{i=1}^m \alpha_i x_{it}$$

or,

$$z_t = y_t - \alpha' x_t = 0$$

where the time series z_t measures the extent to which the system is out of equilibrium and can therefore be termed the *equilibrium error*. Hence if y_t and $\hat{x}_t = \alpha' x_t$ are both $I(1)$, then the equilibrium error will be $I(0)$ and z_t will rarely drift far from zero. In this case y_t and $\hat{x}_t$ must have long run components that virtually cancel out to produce equilibrium errors z_t . In such circumstances $\hat{x}_t$ and y_t are said to be cointegrated and in this case only meaningful statistical inferences can be drawn by using the error correction models (ECM) to transform the original regression problem in nonstationary variables. Engle and Granger [1987] have shown that if y_t and x_t are both $I(d)$, then there exists an error correction representation

$$A(L)(1-L)^d y_t = -\gamma z_{t-1} + \theta(L)\varepsilon_t \quad (4)$$

where the error ε_t is white noise, $A(L)$, $\theta(L)$ are polynomial lag functions and $z_t = y_t - \alpha' x_t$ is the residual from the cointegrating regression. A special case of this representation occurs when $d = 1$ and $\theta(L) = 1$, i.e., the error term ε_t has no moving average part. The ECM then appears as:

$$\Delta y_t = b_0 + b' \Delta x_t - \gamma(y_{t-1} - \alpha' x_{t-1}) + \varepsilon_t \quad (5)$$

All terms here are $I(0)$, hence no difficulties of statistical inference arise. In

the steady state we have the long run equilibrium production behavior

$$y_t = \alpha'x_t + (b_0/\gamma)$$

III. Empirical Applications of ECM Models

The tests of export externality and other specifications are primarily dependent on the order of integration of the variables used in the regression models. The order of integration of the variables was largely determined through the use of the *DF* statistic as mentioned in (3) before. For the export externality models the following variables were found to be integrated of order two at the 5% level of the *DF* test: *GNPR* (real gross national product), *INV* (gross investment), *N* (volume of employment) and *X* (total exports). Table 1 summarizes the ECM model. The order of integration of the other variables was as follows:

Order of Integration

	Export Demand Variables		
	Japan (1962-87)	Korea (1967-87)	Taiwan (1962-87)
<i>XGSR</i>	2	3	2
<i>PRW</i>	2	3	2
<i>YW</i>	2	3	2

Here the variables are: *XGSR* (real exports of goods and services), *PRW* (domestic price level relative to the world price level) and *YW* (level of real world income). For the production function models discussed in the next section the variables selected are: *LGDP* (log of gross domestic product in real terms), *LKR* (log of real capital stock), *LN* (log of employment) and *CRES* (the cointegrating regression residuals). For each variable we add the term D_i to indicate that it is integrated of order $i = 1, 2, 3$. The sources of data are: Yearbook of Labor Statistics (ILO), International Financial Statistics Yearbook (IMF), IMF Supplement on World Trade Statistics, World Development Review (IBRD) and Taiwan Statistical Handbook. Since the capital stock series is not available from the data sources above we have

Table 1
Error Correction Models of Export Externality
 Dependent Variable: *GNPRD2*

	Japan		Korea		Taiwan	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Intercept	-6.401	-1.61	-181.1	-1.95	6.541	1.24
<i>INVD2</i>	0.579	2.13	0.192	2.09	0.124	2.15
<i>ND2</i>	0.102	1.98	0.063	1.99	0.130	2.18
<i>XD2</i>	0.101	2.10	0.439	3.02	0.482	1.98
<i>GNPRD2</i> (-1)	0.102	1.64	0.194	0.71	0.145	1.89
<i>XD2</i> (-1)	0.092	1.98	0.101	0.62	0.211	1.08
<i>XD2</i> (-2)	-0.008	1.02	-0.054	1.02	0.013	0.78
<i>INVD2</i> (-1)	-0.031	1.89	-	-	-	-
Adj. R^2	0.702		0.692		0.714	
DW Statistic	1.961		2.013		1.970	
Sample Period	1967-86		1967-86		1967-86	
<i>DF</i>			-4.8; -7.14			

- Notes: 1. D_i denotes the order of integration of the variables.
 2. Adj. R^2 denotes R^2 adjusted for degrees of freedom.
 3. *DF* denotes the value of Dickey-Fuller statistics.

used the Dadkhah-Zahedi [1986] formulation where gross capital stock K_t is defined as

$$K_t = \log 2 + 0.5 \log \sum_{i=0}^{t-1} (1-\delta)^i I_{t-i} + \frac{t}{2} \log(1-\delta) + \frac{1}{2} \log K_0 \quad (6)$$

where K_0 is the capital stock for the initial year. This method has been widely adopted in the empirical development literature. The details of the statistical data are described in earlier papers by Sengupta [1991, 1993]. (The complete set of data is available from the author on request).

Tables 2 and 3 provide the estimates of the error correction models for the impact of exports. As it is clear from Table 1, the export variable (X) has a significant statistical impact on the real national income for all the three countries, though in absolute magnitude it is more important for Korea and Taiwan. One reason for this may be that the export share of *GDP* is on the average about 12.9% over the period 1967-86 for Japan, whereas it is 30.6% for Korea and 56.7% for Taiwan. In terms of proportional growth rates of

Table 2
Error Corrections Models of Export Demand

Dependent Variable	Japan		Korea		Taiwan	
	<i>XGSRD2</i>		<i>XGSRD3</i>		<i>XGSRD2</i>	
	Coefficient	<i>t</i> -value	Coefficient	<i>t</i> -value	Coefficient	<i>t</i> -value
Intercept	-54.55	-0.19	3.81	0.01	4478.24	0.28
<i>PRWD2</i>	-100.01	-1.83	-	-	-3708.58	-1.86
<i>PRWD3</i>	-	-	-261.49	-2.96	-	-
<i>PRWD3</i> (-1)	-	-	-102.75	-1.34	-	-
<i>YWD2</i>	668.12	2.73	-	-	18464.47	1.32
<i>YWD3</i>	-	-	782.39	3.82	-	-
<i>YWD3</i> (-1)	-	-	-1091.77	-3.00	-	-
<i>XGSRD3</i> (-1)	-	-	0.92	2.17	-	-
<i>CRES</i> (-1)	-1.25	-6.06	-2.38	-4.81	-0.62	-2.70
<i>CRES</i> (-2)	0.52	2.43	3.92	3.84	0.41	2.03
<i>CRES</i> (-3)	-	-	-1.71	-2.74	-	-
Adj. R^2	0.623		0.752		0.259	
DW Statistics	1.728		1.900		2.175	
Sample Period	1962-1987		1967-1987		1962-1987	
DF Statistic for residuals	-4.3; -6.1		-4.5; -7.4		-5.3; -9.0	

Notes: Comments below Table 1 apply here also.

exports also, the figures are 8.7%, 16.1% and 13.4% on the average for Japan, Korea and Taiwan respectively. One could interpret the significant impact of the export variable on income growth in three different ways: One is to drop exports (*XD2*) as a regressor and the value of adjusted R^2 declines by more than 0.25; also the signs of the other regressor (*INVD2*) become either negative or statistically insignificant. Secondly, if we decompose the income variable (*Y*) into a two-sector version with exports (*X*) and non exports (*M*) as follows:

$$X = G(G_X, L_X, M)$$

$$M = F(K_M, L_M, X)$$

$$Y = X + M, K = K_M + K_X, L = L_M + L_X$$

Table 3
Error Corrections Models of Output

Dependent Variable	Japan		Korea		Taiwan	
	<i>XGSRD2</i>		<i>XGSRD3</i>		<i>XGSRD2</i>	
	Coefficient	<i>t</i> -value	Coefficient	<i>t</i> -value	Coefficient	<i>t</i> -value
Intercept	-0.005	-1.49	-0.0012	-0.42	-0.003	-0.85
<i>LKRD3</i>	1.38	3.80	0.93	2.25	-	-
<i>LKRD3</i> (-1)	1.01	2.06	1.28	3.05	1.18	3.02
<i>LKRD3</i> (-2)	1.23	2.64	-1.17	-2.12	-1.15	-2.26
<i>LND2</i>	0.07	0.13	1.78	6.31	1.75	6.81
<i>LND2</i> (-1)	-0.037	-0.60	-0.86	-2.42	-0.88	-2.69
<i>LND2</i> (-2)	0.27	0.47	-0.65	-1.99	-0.65	-2.17
<i>LGDPD2</i> (-1)	-0.41	2.03	0.35	1.42	0.36	1.62
<i>LGDPD2</i> (-2)	-0.58	-2.90	0.24	1.29	0.23	1.30
<i>CRES</i> (-1)	-	-	-1.04	-2.97	-1.08	-3.36
Adj. R^2	0.712		0.799		0.834	
DW Statistics	2.602		1.795		2.10	
Sample Period	1963-1987		1960-1988		1963-1987	
DF Statistic for residuals	-5.1; -6.4		-5.2; -6.3		-4.8; -5.9	

Notes: Comments below Table 1 apply here also.

with outputs X and M produced by the two sectors by using the two inputs capital (K) and labor (L), we could formulate a system of growth equations

$$\Delta M = F_K I_M + F_L \Delta L_M + F_X \Delta X$$

$$\Delta X = G_K I_X + G_L \Delta L_X + G_M \Delta N$$

where the subscripts on F and G denote the marginal productivities of the respective inputs in the two sectors. Note that if the two sectoral output X and M are integrated of order one, their first differences are integrated of order zero and the standard least squares regressions are valid. However in our case the orders of integration turned out to be two for the two sectoral outputs for each of the three countries and the estimates of the coefficients F_X and G_M by the *ECM* models turned out to be as follows:

1967-87	Japan	Korea	Taiwan
F_X	0.29	0.99	0.82
G_M	0.16	0.32	0.20
F_X/G_M	1.8	3.1	9.1

If we use the ratio F_X/G_M of marginal productivities of the two sectors as a measure of export externality, clearly Korea and Taiwan have a far greater degree of export externality than Japan. Note that in an econometric sense this result has a structural and long run significance, which is absent in the ad hoc regression models of Feder [1982] and Bradford [1987].

Some comments may be made here about using the ratio F_X/G_M of marginal productivities of the two sectors as a measure of export externality. First of all, the simultaneous equation system (7) may be viewed as a two sector model of interdependence, where sectoral growth in output is partly determined by the growth of demand arising in the other sector. A disequilibrium model is more appropriate in such situations where it is not known whether demand or the supply forces have played a dominant role. Sengupta and España [1993] have found however that in our empirical framework sectoral growth has been largely demand determined. Hence we have estimated the econometric model formulation (7). Secondly, Bacha [1984] used this type of model to distinguish between a programming view and a structural view of export growth and its impact on national income growth. In the programming view the net export ratio is viewed as a government instrument in a Keynesian open economy multiplier model chosen optimally.

Finally, the estimates of ECM models of export demand in Table 2 show the long run impact of world income to be highly significant for both Japan and Korea, though much less for Taiwan. This result is significant for two reasons. One is that it contradicts the hypothesis of Kellman and Chow [1989] who found export to be rather insensitive to changes in relative prices (e.g., real exchange rates) and incomes. Secondly, the ECM models show the long run behavior of export demand to be significantly different from the short run. Denoting the export demand time series by x_t , one could decompose it into its conditional mean and conditional variance as

$$x_t = E_{t-1}(x_t | z) + \varepsilon_t$$

$$\sigma_t^2 = E_{t-1}(\varepsilon_t^2)$$

where $E_{t-1}(x_t | z)$ is the conditional mean depending on information available up to the period $t-1$ and z is the set of regressors such as the relative price ratio (*PRW*) and world income (*YW*). Based on the estimated values of the residual ε_t one could test if the shocks to the export demand equation is persistent or not. Thus we set up the model known as the *ARCH* (autoregressive conditional heteroscedasticity)

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^p \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^p \beta_i \sigma_{t-i}^2$$

for testing the time-varying nature of variance. For $p = 1$ one obtains the time-varying model for variance as

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2$$

Clearly if the condition $\hat{\alpha}_1 + \hat{\beta}_1 = 1$ holds for the estimated parameters then the impact of exogenous shocks is persistent *i.e.*, of a permanent nature. This implies that the hypothesis of cointegration cannot be rejected. When we performed such tests on the export demand function (Table 2) and the real output equation (Table 3) we could not reject the hypothesis of cointegration. These results seem to support two broad propositions. One is that the estimated parameters in the aggregate output and export demand equations do indeed reflect a long run equilibrium relationship between the variables involved. Secondly, the conditional variance tests imply that any exogenous shocks to the system due to technical innovation or world income changes would have persistent effects on output growth and export demand growth. These results are likely to be reinforced if we consider only manufacturing exports rather than total exports. Some detailed empirical tests of cointegration for manufacturing exports for Korea and Taiwan reported by Sengupta and España [1993] confirm this conjecture, which is consistent with the recent findings by the trade economists such as Bhagwati [1988] that the export promotion strategies of the NICs help the growth of intra industry trade in manufactures among developing and developed countries to a significant extent.

IV. Tests of Increasing Returns to Scale

Increasing returns to scale (*IRS*) has played a prominent role in the new growth theory. Two dimensions of scale economies are important for rapid economic growth. One is the presence of significant *IRS* in modern production, especially in the export sector which involves nonrival inputs to use a term due to Romer [1990]. Nonrival input is one for which subsequent units have a significantly lower unit costs of production than the first. In the extreme case a nonrival input has a high cost of producing the first unit and a zero cost for subsequent units, *e.g.*, a new design for a microprocessor which can be replicated at a negligible cost. The increasing use of such nonrival inputs has given a new dimension to commercial and non-basic R&D research thus intensifying the competitiveness in international trade. As Romer has pointed out that as a fraction of *GDP* Japan now spends considerably more on commercial nonbasic R&D than does the U.S.

The second dimension of *IRS* focuses on the knowledge spillover effects which improves labor productivity across the board. As Lucas [1988] pointed out this may be the most significant factor explaining the large difference in marginal productivity of capital between an *LDC* and a developed economy, when the concept of capital is broadened to include human capital. However we do not have separate data on human capital or the skill levels of the workforce. Hence we could not empirically test this hypothesis.

A direct empirical test of the existence of *IRS* can be obtained by estimating an aggregate production function with real *GDP* as the output variable (*Y*) and capital stock (*K*) and employment (*L*) as the two aggregate input variables. Two major difficulties of this approach are that the aggregate function may involve variable which are nonstationary. In this case the regression model may not have any structural significance. Secondly, data on capital stock are not generally available in a reliable form from the official statistics. For this reason we restrict ourselves to the manufacturing sector alone, which is more relevant in the export performance and then we construct a series of capital stocks (K_t) based on investment streams (I_{t-i}) and depreciation rate (δ) by following the method proposed by Dadkhah-Zahedi [1986] as mentioned before in (6).

For testing the nonstationarity of the input and output data we applied the

cointegration method to determine the following order of integration.

Table C
Order of Integration: Production Function Variables

	Japan	Korea	Taiwan
<i>LGDP</i> (output)	2	3	3
<i>LKR</i> (capital)	2	3	3
<i>LN</i> (labor)	2	3	3

The Dickey-Fuller statistics were as follows:

		Δ^0	Δ^1	Δ^2	Δ^3
Output	Japan	9.3	-1.0	-6.3	-7.4
	Korea	11.3	-0.4	-7.4	-10.6
	Taiwan	13.9	0.4	-1.2	-9.5
Capital	Japan	13.8	1.	-0.6	-1.3
	Korea	12.3	2.8	-0.4	-4.5
	Taiwan	17.2	2.0	-0.4	-5.6
Labor	Japan	8.4	-1.8	-1.4	-1.6
	Korea	6.9	-1.3	-8.3	-11.8
	Taiwan	12.3	-0.9	-6.0	-7.3

We have to emphasize here two methodological problems. First, Engle and Granger [1987] developed the error correction models only for the case where the vector of dependent variables are all cointegrated of order (1, 1), *i.e.*, for the case of residuals from the cointegration regression being $I(0)$. In our production frontier case the vector of variables are cointegrated of order (2, 1) or (3, 1). Although the theory for higher levels of cointegration has been developed, its empirical application involves two major problems. One is that we have to take second and third difference of the data set and this *fine tuning* does not always produce meaningful economic results. Secondly, the cointegration theory is developed for the linear case, its nonlinear transformation raises additional problems for the noise components of the residual terms. Due to these reasons we have adopted a different method so as to filter out the noise components from the input output data before estimating the production functions. This method has two advantages. It eliminates

the polynomial trend in the deterministic component of the data and also produces more meaningful coefficients for the production function estimates. This method is based on the variate difference method developed by Tintner [1969]. This method decomposes a time series into two parts, one permanent and the other transitory and then builds a regression model based on the permanent components only. Thus let us write the permanent component hypothesis as

$$\begin{aligned} Y_t &= Y_t^p + u_t; \quad K_t = K_t^p + v_t; \quad L_t = L_t^p + w_t \\ Y_t^p &= F(K_t^p, L_t^p) \end{aligned} \quad (8)$$

where the superscript p denotes the permanent component of each variable and u_t, v_t, w_t are the transitory components which are assumed to be statistically independent of the respective permanent components. An empirical test of the permanent component hypothesis consists in finding the functional form $F(\cdot)$ of the relation between the permanent output and the permanent components of capital and labor. To determine the permanent components of the time series we proceed as follows: Let x_t be the time series which is integrated of order d , then we know that the d -th difference of the series is enough to eliminate the trend in the variable x_t . Hence the permanent part x_t^p of x_t is given by the polynomial

$$x_t^p = a_0 + a_1 t + a_2 t^2 + \dots + a_d t^d \quad (9)$$

The transitory component is given by the difference between x_t and x_t^p . Following this method and assuming a Cobb-Douglas form of the production function in (8) above we obtain the following estimates:

1961-87	Intercept	$\log K_t^p$	$\log L_t^p$	$Adj R^2$	DW
Japan	0.069	0.426* (2.89)	1.601* (2.69)	0.995	2.01
Korea	2.432*	0.359* (8.75)	1.462* (16.91)	0.989	1.95
Taiwan	5.211	0.625* (2.91)	1.725* (6.89)	0.991	1.89

Note: t -values in parentheses, asterisk for 1% significance.

It is clear that the evidence of *IRS* is overwhelming. Moreover what is most striking is that the labor coefficient is about 3 to 4 times larger than the capital coefficient. This is definitely suggestive of the effect of *learning by doing* or what has been called by Lucas [1990] the spillover effect of human capital. These effects multiply the productivity of a worker at any given skill level by a positive multiple depending on the technology used. We may also mention the point that if each of the three variables output, capital and labor are detrended first and then the production functions reestimated, the persistent of *IRS* is upheld. This suggests that scale economies are structural and not transitory and the high values of adjusted R^2 are more indicative of the relative success of Cobb-Douglas production functions in capturing the process of overall output growth.

A direct estimate of the productivity of human capital in the form of externality effects due to knowledge spillover mentioned by Lucas [1988] is possible only when detailed data on the skill-intensity of the labor force in the exports and the manufacturing sector are available. Short of that the partial measures of the contribution of R&D and the intensity of new technical know-how may be used as proxy variables. Recently Enos and Park [1988] have studied the pattern of adoption and diffusion of imported technology in four major industries in Korea, *e.g.*, petrochemical, synthetic fibers, machinery and iron and steel and compared this experience with Japan. On an overall basis they summarized the sources of growth of GNP due to labor, capital, economies of scale and technological advance as follows:

Sources of growth	USA 1948-69 (%)	Korea 1963-82 (%)	Japan 1953-72 (%)
Labor	22.0	35.8	17.1
Capital	19.8	21.4	23.8
Scale economies	10.5	18.0	22.0
Technological advance	29.8	11.8	22.4
Miscellaneous	17.7	13.0	14.7
Total	100.00	100.0	100.0

It is clear that Korea's growth has stemmed proportionally more from increases in labor supply and the associated augmentation of the skill factor and proportionally less from advances in technology. Furthermore if one analyzes the role of the major agents responsible for the adoption of foreign technologies, one basic difference emerges between Japan and Korea. In Korea at least until 1980, the government has been the primary agent; in Japan it seems to have been since 1946 the large private firms. Also the number of foreign suppliers of technology scrutinized by the agents seems to have been greater in the case of Korea than in Japan. This explains the element of comparative advantage of the technology-intensive export sector in Korea.

A comparison of Korea and Taiwan in terms of their growth performance discussed in some detail by Cho [1990] shows a broad pattern of similarity except in the degree of economic concentration. While Korea's economic growth has been based on an expansion of the size of firms yielding significant scale economies, Taiwan's growth has been largely in the form of increase in the total number of manufacturing establishments rather than the average size. For example the average annual number of manufacturing establishments rose at an annual rate of 0.9 percent in Korea, whereas it rose at the rate of 9.6% in Taiwan during the period 1966-81. According to Cho [1990] the two countries, different approaches to financial policy may have played a significant role. For instance in Korea, 100 of the largest firms borrowed about 35% of total financial institutions' loans whereas the top 97 firms in Taiwan got only 11.6% of such loans. Also Korea's example is very close to Japan's where scale economies fostered by financial policies have played a big role in the growth of productivity. Furthermore in some countries like Korea the deliberate policy of promoting the HCI (Heavy and Chemical Industries Promotion Plan: 1973-79) plan yielded improved performance from 1986 onwards leading to rapid overall economic growth. As Lee [1991] has shown that the HCI sectors in Korea comprising such heavy industry projects as iron and steel, nonferrous metal, machinery, shipbuilding and capital were widely accepted as the leading sectors in self-sustained growth. The persistence of significant scale economies played a major role in this long run process.

V. Concluding Remarks

The high growth economies of the Asian Pacific Rim *e.g.*, Japan, Korea and Taiwan provide a good testing ground for the new growth theory that has emerged over the last six years. Two major tenets of the new growth theory are empirically tested here against the growth experiences of these three countries. The first is the externality effect of exports and its productivity growth, which played the role of a catalyst for other sectors, growth. The econometric tests based on the modern theory of cointegration are applied so as to identify the structural aspects of export externality. One notes that the role of increasing returns to scale emphasized in new growth theory has been very prominent in these successful NICs and more so in the export-oriented sectors. For Korea this has helped the process of building capacity ahead of demand and planning for a steady long run growth. Diversification of the export-nix, low interest policies and active state policies have helped both Korea and Taiwan to attain steady rates of growth upsurge over the period 1967-86. This growth process has been helped greatly for Korea and Taiwan by the growth in the national saving rate. Thus for Korea for example it is clear from Table 4 that the savings ratio to GDP rose from 11.7% to 44.1% and the investment ratio rose from 20.2% to 37.5%. This growth of the savings rate has roughly paralleled the ratio of exports to GDP which rose from 8.5% to 48% during the same period. By using the neoclassical model of optimal growth Sengupta [1993] has shown elsewhere that this growth in saving rates helped maintain the growth rate of per capita capital and output.

Table 4
Evolution of Exports (X/Y), Savings (S/Y) and
Investment (I/Y) Shares of GDP

	Initial	Final	$\Delta(X/Y)$	Initial	Final	$\Delta(S/Y)$	Initial	Final	$\Delta(I/Y)$	g_Y
Japan (1967-86)	7.6	17.2	9.6	35.7	42.0	6.3	32.1	33.6	1.5	5.4
Korea (1967-86)	8.5	48.1	39.6	11.7	44.1	32.4	20.2	37.5	17.3	8.0
Taiwan (1967-86)	24.4	84.0	59.6	18.2	47.0	28.8	23.3	25.1	1.8	8.1
Philippines(1967-6)	24.9	30.4	5.5	22.3	21.9	-0.4	21.5	12.9	-8.6	3.6

Note: Average annual growth rate of output is denoted by g_Y .

Finally, the growth of human capital has played a much more important role than the physical capital for these three NICs. Not only has it made the scale economies more persistent in the manufacturing sector, it has also generated a dynamic resource reallocation process from the nonexports to the exports sector thereby augmenting the overall productivity of labor. Although the marginal productivity effect of the skill level and education could not be analyzed here due to lack of data, some recent estimates by Tallman and Wang [1990] for Taiwan suggest that the contribution of the skill factor may far outweigh that of labor. Thus using annual data over 1965-86 and an unrestricted Cobb-Douglas production function they found for Taiwan the following results:

	Constant	Employment	Labor Skill	Capital	Adj. R ²
Coefficient	0.227	0.687	0.516	0.313	0.995
t-value	1.90	8.76	8.02	3.99	

Clearly there is a strong case for more research along these lines for Korea and Japan and also the other countries of the Asian Pacific Rim. For Japan and Korea we have obtained some preliminary estimates over the period (1962-87) of the coefficients of two types of labor, one skilled and other unskilled by taking the skilled workers as those who have college degrees, *i.e.*, above the high school diploma and the coefficient of skilled labor turns out to be significant and higher than that of the unskilled labor. However this line of research requires more investigation before any final conclusions can be drawn.

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