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EXPORTS AND GROWTH: AN ECONOMETRIC ANALYSIS FOR KOREA

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Abstract

This paper dicusses the sources of rapid economic growth in Korea in recent times and their economic implications by means of three types of econometric tests based on the modern theory of cointegration, the dominant role of demand over supply and the significant degree of economies of scale due to the spillover effects of human capital and of technological diffusion. The empirical growth profile of Korea in recent times seems to vindicate some of the major tenets of the new growth theory.

Key words:
Exports, economic growth, cointegration, demand dominance, increasing returns to scale.

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INTRODUCTION

Recent times have seen a very high rate of economic success by the so-called newly industrializing countries (NICs) of the Asian Pacific Rim such as Hong Kong, Singapore, Korea (South) and Taiwan. Japan which is of course a mature exporting country has also evidenced a steady process of growth. This successful growth record of outward-oriented economies in East Asia in the last decades has revived the debate on optimal growth strategies for LDCs (less developed countries) on two major fronts: one is the emergence of 'new growth theory' [26][30][32] which emphasizes the role of increasing returns to scale and the dynamic spillover effects of the export sector's growth, and the second is the externality impact of exports as a leading sector in the diffusion of modern technology across other sectors and industries. Seemingly it appears that the rapid economic growth in these successful NICs in Asia lends support to the basic premises of the new growth theory. For example Korea's export growth rate of 22.9 percent accompanied the average annual growth rate of per capita real income of 6.4 percent over the 1965-87 period. Experiences of the other successful NICs in Asia are very similar, i.e., export growth rates are very high and far above that of per capita income. Some recent econometric estimates by Quah and Rauch [28] have found over a larger data set of 81 LDCs that openness in trade strongly causes income growth, where causality is defined in the sense of Granger [19].

The empirical evidence also seems to suggest that structural change provided a major link between exports and economic growth in the outward-oriented LDCs. The exports sector is the initiator of economy-wide structural changes in the form of technical innovations and diffusion of skill-intensive externality of human capital and thus it contributes to a higher level of aggregate productivity. 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. The expansion of the exports sector itself has been promoted by continuously changing the exports base in response to changing world demand.

In Korea, the pace of change in the structure of the economy has been vary rapid since the early 1960's when the export-oriented growth strategy was adopted. For the period 1961-86, the compounded growth rate of the volume of exports was 21.1%, which is almost three times the 8.5% rate of growth of output. Manufacturing output grew at a rate of 16.1%, more than twice the 7.3% growth rate of non-manufacturing. Over the period, manufacturing's share of GDP steadily climbed from 5.6% to 29.8%. The structural change implied by a larger share of manufacturing in aggregate output raised the overall efficiency of the economy as aggregate productivity moved closer to the higher productivity levels prevailing in manufacturing. The increase in overall productivity was the result of two effects: first, the direct effect on total productivity of a relatively larger manufacturing sector; the second, the indirect effect resulting from the linkages existing between manufacturing and the rest of the economy.

In this paper we attempt a contribution to this issue of exports and rapid economic growth by providing some empirical tests of the new growth theory with regard to the following aspects: openness and growth and the role of increasing returns to scale. Furthermore we discuss the econometric basis of structural change and productivity growth, where the export sector plays a key dynamic role. The economy of South Korea (hereafter called Korea) is used as a benchmark for our analysis of the empirical and econometric tests of structural change and the new growth theory. Korea is selected among the successful NICs in Asia, since its growth performance has been phenomenal, well studied and documented [2][8] and its national policies have followed openness in trade much more strongly than Japan for example.

Openness and growth

Empirical evidence suggests a clear relation between openness and economic growth, when 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 1 and 2 show a very high degree of positive correlation between export growth and structural change in all the successful NICs in Asia, with Korea nd 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 economy is less essential than it is in the exports-oriented NICs.

Table 1. 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
PHILIPP.	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

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.

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 2) 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.

In Korea, growth of HTX was especially rapid, with a compounded annual growth rate, in terms of current value, of 45.5% for the period 1961-86. This may be seen in the background of a high degree of specialization in high-technology exports in different East Asian countries in Table 2.

Table 2. 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
PHILIPP.	0.0 – 10.5	10.5	0.39
JAPAN	22.9 – 62.3	39.4	1.60

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.

It appears that export expansion in Korea was based on specialization in export areas experiencing higher than average growth rates, notably specialization in manufacturing exports. At the same time, further specialization was taking place as exports displayed an increasingly larger high-technology component. The end result was a rapidly expanding exports sector increasingly specialized in the export of high-technology goods, implying a rapid pace of structural change in the whole economy. Also we have to note that as a result of the increased production of manufactures for exports, the share of manufacturing to GDP in Korea almost tripled during the period 1960-87 from 12.1 to 30.3. Other NICs also had similar experiences. This empirical evidence of export growth and structural change has been traditionally analyzed by two groups of econometric methods. One group uses export growth to measure openness in trade and correlates this measure with per capita income growth rates. In some variants of this approach [16][7][29] regression methods are used to explain income growth rates in terms of export growth. Thus Chow [7] carried out Sim's type causality tests [33] linking exports of manufactures and manufacturing output using a sample of 8 NICs, where he found a strong causal relationship from exports to income growth. The second group of methods [4][6] looks at the composition of export products and uses a measure of diversification in its composition to represent outward development. Thus Bradford [6] examined empirical data for more than twelve countries either NICs or, next-tier NICs in the world over 1965-80 and tested for the correlation between structural change and economic growth, where the index of structural change is derived from the share of GDP of the 16 manufacturing branches which are technology-intensive. He concluded that high rates of income growth and rapid structural change are strongly positively correlated for those countries which are successful NICs.

These methods however have some basic limitations from an economic viewpoint. One is that they do not refer to the structural forces like resource reallocation between sectors and the productivity improvements that must accompany the dynamic process of income growth. Second, they fail to capture the dynamic characteristics of the disequilibrium process [5] underlying rapid economic growth. Thus one needs to show how in the course of one or two decades a successful NIC like Korea shifted from a low level demand supply equilibrium to a high level equilibrium. If D and S denote aggregate demand and supply of national output, which of the two disequilibriating pressures: excess demand (ΔD-ΔS), or excess supply (ΔS-ΔD) has played a prominent role in the dynamic process? This question is closely related to the theory underlying the two-gap model [17][3] which emphasize inadequate savings and insufficient foreign exchange as the limiting constraints on augmenting the LDC growth rate to a substantially higher rate. Finally, there is the fundamental problem of spurious correlation between exports and output growth, when the two variables are all growing over time. The modern theory of cointegration in dynamic modelling of economic time series has emphasized this point very clearly. For one thing if output, capital, labor and exports are all growing over time as in growing economies such as Korea, the time series data are most likely to be nonstationary. In such cases the usual static production functions with exports as a proxy for technical change, estimated by ordinary least squares (OLS) will have a very high value of R^2 but it may not imply a structural or longrun equilibrium relationship between the output and the vector of inputs. Hence even from an econometric standpoint the standard causality tests [18] hypothesizing exports as the leading cause of income growth are not very meaningful when all variables are nonstationary. This is because the standard statistical tests based on significant R^2 values and significant t-statistics for the regression coëfficients are not valid anymore. Thus consider a pair (y_t, x_t) of variables in terms of the levels of economic time series, where y_t is output and x_t is a vector of inputs and each is nonstationary. Assume that the nonstationarity is such that the first differences (i.e., $\Delta y_t, \Delta x_t$) are nearly stationary. Then the ordinary regression of y_t on the input vector x_t would frequently have high R^2 statistics typically displaying highly autocorrelated residuals (i.e., low

Durbin-Watson (DW) statistics), which produce a strong bias towards acceptance of a spurious relationship when the series are generated as random walks. As Phillips and Durlauf [27] have shown that such regressions have the disturbing feature that the distributions of the conventional test statistics (e.g., t,F) are not all like those derived under the assumption of stationarity, e.g., the regress coefficients do not converge in probability as the sample size increases and the distributions of both the t and F tests diverge, so that there are no asymptotically correct critical values for these conventional significant tests.

Clearly one alternative is to transform the series by first, second or higher order differences in time till they are stationary and then run regressions on the basis of the transformed series. As a matter of fact Granger and Newbold [20] in their initial studies suggested that regressions should be run on the first differences of the variables, thus implying that all series in the regression are integrated processes of order one. A vector process x_t is defined to be integrated of order d denoted as I(d), if it requires for its each component (x_{it}) to be differenced d times to achieve stationarity. Thus if a time series x_t is I(0) then it is stationary, whereas if it is I(1) its change Δ_t is stationary. The method of running regressions in the form $\Delta y_t = f(\Delta x_{1t}, \Delta d_{2t}, \ldots, \Delta x_{mt})$ where y_t and x_t are both I(1) is obviously the time series analysts's solution to the nonstationarity problem. However it has one basic limitation that the steady state characteristics of long run equilibrium are completely ignored by this specification, since Δy_t and Δx_t are both zero in the steady state.

The concepts of cointegration provides an important link between the interrelationships of of integrated processes and the concept of steady state equilibrium. It was originally introduced by Granger [21] and extended in Engle and Granger [13]. Suppose the steady state input output relation holds and it is defined by

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

or

$$z_t = y_t - \alpha' x_t = 0 \tag{1}$$

Thus z_t given by (1) 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 [13] have shown that if y_t and x_t are both I(d), then there exists an error correction representation

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

where the error ϵ_t is white noise, A(L), θ(K) are polynomial lag functions and $z_t = z_t - \alpha' x_t$ 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:

$$\Delta y_t = b_0 + b' \Delta x_t - \gamma(y_{t-1} - \alpha' x_{t-1}) + \epsilon_t \tag{2}$$

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

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

In case the inputs and outputs grow at a constant positive rate in the steady state, i.e., $\Delta y_t = gy_t$, $\Delta x_t = gx_t$, then the steady state expansion path takes the simple form

$$y_t = \alpha' x_t + f(t) \tag{3}$$

where f(t) depending on time t is a function of other parameters b_0, γ, b and g. Models of this simple dynamic form (3) have been shown to be capable of being generated by economic mechanisms based on minimizing adjustment costs in a partial manner as in distributed lag models.

Tests of cointegration

In our analysis of the Korean growth process we apply the cointegration theory and the ECM approach to two types of models. One is an aggregate model consisting of a production function that has been extended to include exports as an additional argument; the other is a two-sector model comprising exports and non-exports. The aggregate model permits an estimation of the aggregate effects of exports on growth. It is applied to Korea and five other selected economies in order to compare the exports coefficient across different countries. The two-sector model is applied only to Korea. It is used to empirically determine in which sector primary factors are more productive, i.e., to determine the actual magnitudes of the marginal productivity coefficients. The two-sector model also allows for the determination of direction and magnitudes of externality effects across sectors.

Consider in the aggregate model, an extended production function with output (Y) depending on capital (K), labor (L) and exports (X):

$$Y = H(K,L,X) \tag{4}$$

Clearly if output and input variables are all nonstationary and integrated of order one, i.e., they are I(1), then their first differences are all I(0). Therefore by taking time derivatives of both sides of equation (4) one could derive:

$$\dot{Y} = H_K I + H_L \dot{L} + H_X \dot{X} \tag{5}$$

where the dot over the variable denotes its time derivative and H_K, H_L, H_X are the marginal productivities of capital, labor and exports with $I = \dot{K}$ denoting investment. This equation (5) has two flexible features. One is that this dynamic specification does not suffer from the econometric objection of spurious correlation or regression, since all the variables $\dot{Y}, I, \dot{L}$ and $\dot{X}$ are stationary and hence the standard OLS results with t-statistics retain their validity. This is quite different from the specification of Feder [16] and his followers [29] who estimate the dynamic model in a growth rate form as

$$\dot{Y}/Y = \alpha_0 + \alpha_1(I/Y) + \alpha_2(\dot{L}/L) + \alpha_3(X/Y)(\dot{X}/X)$$

Since the variables Y, L and X are nonstationary, the standard OLS regressions have implications of doubtful validity. Secondly, the dynamic model (5) can be decomposed into a two-sector version, where the externality impact of the export sector on the non-export sector can be assessed both quantitatively and qualitatively. Thus we consider a simple two-sector model as

$$N = F(K_N, L_N, X)$$
$$X = G(G_X, L_X, N)$$
$$Y = N + X,\ K = K_N + K_X,\ L = L_N + L_X$$

with outputs X and N produced by the export sector and the rest of the economy (i.e., the non-export sector) by using the two inputs K and L for the respective sectors. By taking time derivatives one can then easily derive the dynamic specification as:

$$\dot{N} = F_K I_N + F_L \dot{L}_N + F_X \dot{X}$$
$$\dot{X} = G_K I_X + G_L \dot{L}_X + G_N \dot{N} \qquad (6)$$

where the subscripts on F and G denote the marginal productivities of the respective inputs in the two sectors. Note that if all the sectoral variables are integrated of order one, their first differences are integrated of order zero and hence the standard OLS regressions are valid along with the t-statistics and R^2 values, i.e., the regression equations have a structural or equilibrium interpretation in the following sense: any deviations from the equilibrium relationship would tend to zero on the average and this would happen very frequently, since the regression variables are all stationary.

For the aggregate model (5) the OLS results for Korea are compared with those obtained when the export variables ($\dot{X}$) is left out. Thus we obtain

$$\dot{Y} = C + \hat{\alpha} I + \hat{\beta} \dot{L}$$
$$= -314.6 + 0.206I + 0.029\dot{L} \qquad R^2 = 0.568$$
$$(-0.529) \quad (4.553) \quad (2.245) \qquad DW = 2.033,\ \hat{\rho} = -0.037$$

$$\dot{Y} = C + \hat{\alpha} I + \hat{\beta} \dot{L} + \hat{\gamma} \dot{X}$$
$$= -208.9 + 0.151I + 0.024\dot{L} + 0.401\dot{X} \qquad R^2 = 0.641$$
$$(-0.372) \quad (2.875) \quad (1.921) \quad (1.805) \qquad DW = 1.965,\ \hat{\rho} = 0.016$$

On the basis of these estimates the percentage contributions to output growth due to different inputs appear as follows:

I : 56
$\dot{L}$: 22
$\dot{X}$: 22
(Here $\dot{Y}$ = 100)

Clearly the impact of the export sector's role is very important, as much as the contribution of human capital in the form of $\dot{L}$. This suggests the existence of spillover effects of labor productivity due to export externality which has been strongly emphasized in the new growth theory [26][30] in recent times. Note that if we assume the externality effect of exports is embodied as Harrod-neutral technical progress associated with labor productivity, then the aggregate production function (4) can be expressed as

$$Y = H(K,AL), \; A = A(X)$$

where AL is augmented labor with A depending on exports, which permit learning by doing effects of technical innovation.

To put the Korean estimation results in perspective the dynamic model

$$\dot{Y} = C + \alpha I + \beta\dot{L} + \gamma\dot{X}$$

of the externality effect of exports is also estimated for a group of selected developing and industrial countries in Table 3.

Here we have two export-oriented NICs in Asia, three mature industrial exporters and one LDC represented by the Philippines. Clearly the externality effect of exports is positive and statistically significant in all cases except Japan, where the export share of national output is much lower compared to the others. The Korean case is unique in this perspective in that both export growth and the export share of GDP are very high and exports grow at double the rate for output growth.

Table 3. Externality Effect of Exports on Growth
1967-86

	Intercept	I	I^2	$\dot{L}$	$\dot{X}$	R^2	DW	X/Y	g_X	g_Y
Korea	-208.9	0.151*	–	0.024*	0.401*	0.641	1.96	30.6	16.1	8.0
Taiwan	6.8*	0.094*	–	0.050	0.438*	0.933	1.56	56.7	13.4	8.1
Japan	-7.7*	0.615*	-0.384*	0.119*	0.116	0.690	1.98	12.9	8.7	5.4
Belgium	-314.8*	1.148	-0.001	0.631*	0.333*	0.419	1.95	59.0	6.1	3.0
Germany (FRG)	-190.0*	1.651	-0.003	0.028*	0.610*	0.447	2.44	28.3	5.3	2.7
Philippines	-0.7*	0.336*	–	0.001	0.389*	0.407	1.52	21.6	4.2	3.6

Notes: 1. In case of the industrial countries in the sample an additional term I^2 is introduced to capture the nonlinearity effect.

2. X/Y = average share of exports in GDP; $g_x = \Delta X/X$ = rate of growth of exports in constant prices, $g_Y = \Delta Y/Y$ = rate of growth of total output in constant prices.

Next we consider the two-sector model (6) for estimating the intersectoral effects. Note that the externality impact of the export sector on the nonexport sector may be estimated by the marginal productivity parameter F_X and that of the nonexport sector on the export sector by G_N and hence the ratio F_X/G_N may be used as a measure of dominance of the export vs. the nonexport sector if it is greater than one. The empirical estimates for Korea are as follows:

Parameters	1964-83	1964-86	1969-86
F_X	1.92	1.00	0.99
G_N	0.28	0.31	0.32
F_X/G_N	6.9	3.2	3.1

Clearly the externality effect of the export sector and its impact on the rest of the economy is most dominant, i.e., it is roughly 3 to 7 times larger than the reverse effect and furthermore the gap between the two externality effects is diminishing over time. This superiority in marginal productivity effects of the export sector has been empirically supported by other research workers in the field [31][32][14]. For instance Amsden [2] identified for Korea three sources of growth effects, e.g., investment-embodying technology new to the user, strong economies of scale and learning by doing. Lee [25] estimated by using a dynamic neoclassical growth model for Korea that if 20% of GNP is used by the government and 30% of it goes to public investment which favors export-intensive products, then it generates a steady annual growth rate of at least 7.16% or more.

Now we perform cointegration tests on both the aggregate and two-sector models. Engle and Granger [13] suggested seven possible cointegration tests, among them the Co-integrating Regression Durbin Watson (CRDW) and the Dickey Fuller (DF) tests. In the case of the CRDW, after running the co-integrating regression, the Durbin Watson statistic is tested to see if the residuals appear stationary. If they are non-stationary, the Durbin Watson will approach zero and thus the test rejects non-cointegration (finds cointegration) if the DW is too big.

The DF tests the residuals of the co-integrating regression by running the following auxiliary regression,

$$\Delta\epsilon_t = \delta\epsilon_{t-1} + u_t, \quad \Delta\epsilon_t = \epsilon_t - \epsilon_{t-1} \tag{7}$$

Then the DF uses a test to determine whether or not δ is zero or negative. The t statistic for δ is then the DF statistic. If δ is found statistically to be equal to zero or negative, then the null hypothesis of non-cointegration is rejected. The augmented DF test runs the empirical regression of a more generalized form

$$\Delta\epsilon_t = \delta\epsilon_{t-1} + b_1\Delta\epsilon_{t-1} + \dots + b_p\Delta\epsilon_{t-p} + u_t$$

and performs a t-test to test whether or not δ is significantly less than zero.

An alternative method of modelling a nonstationary time series with changing mean and variance is to use integrated variables to define an ARCH (autoregressive conditional heteroscedastic) model that has been widely applied in dynamic modelling of nonstationary phenomena by Engle [11] and others [12]. Thus for a time series $\{y_t\}$ one decomposes the stochastic process into its conditional mean and conditional variance as

$$y_t = E_{t-1}(y_t) + \epsilon_t, \quad \sigma_t^2 = E_{t-1}(\epsilon_t^2)$$

where $E_{t-1}(y_t)$ is the conditional mean and σ_t^2 is the conditional variance of the series in year t both depending on the information set available up to the period t–1. The generalized ARCH model uses the model

$$\sigma_t^2 = a_0 + \sum_{i=1}^{p} \alpha_i \epsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_i \sigma_{t-i}^2$$

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

$$\sigma_t^2 = a_0 + \alpha_1 \epsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2 \tag{8}$$

where $\epsilon_t = y_t - \mu_t$ and $\mu_t = E_{t-1}(y_t)$. In case of our two sector model the errors ϵ_t are estimated by the deviations of $\dot{X}$ and $\dot{N}$ from their mean levels in the respective original cointegrating equations (6). Clearly if the condition $\hat{\alpha}_1 + \hat{\beta}_1 = 1$ holds for the estimated parameters $\hat{\alpha}_1$, $\hat{\beta}_1$ then the volatility due to shocks is of a permanent nature, i.e., the null hypothesis of cointegration cannot be rejected then.

The empirical results of the different cointegration tests for Korea over the period 1964-86 may now be discussed for both the aggregate and sectoral models. In case of the estimated aggregate model

$$\dot{Y}_t = c + \hat{\alpha}\dot{I}_t + \hat{\beta}\dot{L}_t + \hat{\gamma}\dot{X}_t + \epsilon_t;\ R^2 = 0.641,\ DW = 2.033,\ \hat{\rho} = 0.037$$

the results are as follows:

Test	DW	DW*	t	t*	Test of H_0
CRDW	2.033	0.455	–	–	Reject
DF	–	–	-4.591	-4.07	Reject

Note: 1. One asterisk denotes the critical value of the test statistic for α=1%. In the case of the CRDW, this is the critical value for q=3, i.e., three independent variables.
2. The null hypothesis for both tests is non-cointegration. Thus, our results seem to reject H_0 in favor of cointegration.

For the two-sector model (6) the results of the cointegration test appear as follows:

Nonexports sector ($\dot{N}$)

Test	DW	DW*	t	t**	Test of H_0
CRDW	1.916	0.511	–	–	Reject
Eq.(8)	–	–	-0.847	-1.717	Accept ($\alpha_1+\beta_1=1$)
			Exports sector ($\dot{X}$)		
CRDW	2.452	0.511	–	–	Reject
Eq.(8)	–	–	-0.924	-1.717	Accept ($\alpha_1+\beta_1=1$)

Note: 1. One asterisk denotes the critical value of the DW statistic with 1% level of significance. The null hypothesis here is non-cointegration.

2. Two asterisks denotes the critical value of t at 5% level and eq.(8) tests whether or not $\alpha_1+\beta_1=1$. Thus the null hypothesis of a constant variance and by implication the cointegration of the variables seems to be accepted here.

Clearly the statistical results from the cointegration tests above seem to support two broad propositions. One is that the estimated parameters in the aggregate and sectoral models do indeed reflect a long run equilibrium relationship between the variables involved. Secondly, the growth model based on first differences seems to exhibit persistence in variance, which implies that any exogenous shocks to the system due to technological innovation would have permanent effects on output growth. We have to note in concluding this section that we applied two other tests of cointegration mentioned by Engle and Granger [13], e.g., the portmanteau statistic based on the autocorrelation coefficients of residuals and the Box-Pierce statistic but since the results are not different they are not discussed here. For some computational detail the reader may consult with España [15].

Tests of demand dominance

Now we turn to the question: which of the two forces, demand or supply played a more dominant role in the dynamic growth process of the Korean economy? Empirical modeling of this issue involves disequilibrium analysis, since demand does not necessarily equal supply in such a framework. Two types of econometric tests can be applied here. One is by estimating the disequilibrium model

$$D = D(p,z_1);\ S = S(p,z_2) \qquad (9)$$
$$Q = \min(D,S)$$

where we consider for example a commodity market where demand (supply) is influenced by price and an exogenous variable z_1 (z_2 for supply) but both D and S are unobserved. What is observed is Q which is the minimum of D and S. For macroeconomic situations such a disequilibrium formulation in terms of labor and goods markets has been analyzed by Benassy [5]. A second method is to consider which of the two constraints, the savings-investment gap and the foreign exchange constraint has been binding on the rapid economic growth in Korea. Since foreign exchange is the most important element of demand growth and inadequate domestic savings the most important limitation on capacity expansion of output, the disequilibrium denoted by $Q = \min(D,S)$ is replaced in this approach by

$$g = \min(g_d, g_x) \qquad (10)$$

where g is the observed growth rate of per capita income or output, g_d and g_s are respectively the foreign-exchange constrained growth rate and savings-constrained growth rate of per capita output. Bacha [3] used this framework and distinguished between a programming view and a structuralist 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 standard Keynesian open-economy multiplier model and its optimal value is chosen by policymakers by maximizing national growth rate subject to the capacity constraints. In the structuralist view the maximum export ratio is lower than the desired level and the foreign exchange constraint is binding so that there is less than full capacity utilization. On applying Bacha's steady-state growth equation the following estimates are obtained for Korea:

	1967-76	1972-81	1977-86	1967-86
g_s	12.07	10.86	8.75	10.69
g_d	9.31	8.52	8.15	9.32

Clearly the foreign exchange constraint has been binding (i.e., $g_d \leq g_x$). This view is also confirmed by other independent estimates. For example Kwon [24] estimated an index of capacity utilization rate of the Korean manufacturing sector over the period 1961-80 and found that it rose from 0.46 during 1961-64 to about 0.75 in the 1970's and almost to full capacity in the late 1980's. Although this capacity utilization index is defined as the ratio of actual consumption of electricity to the maximum possible consumption, it is suggestive of the general pattern. As Lee [25] noted that the Korean government exercises complete control over the allocation of foreign loans between industries and sectors and because of this the actual rates of growth of national income during the first three five-year plans in Korea (1961-76) consistently exceeded the target rates set by the planners and did so during the second five-year plan (1967-71). Thus the fundamental philosophy underlying the planning process in Korea has been that the planners have always been prepared to borrow abroad to achieve a target rate of growth, i.e., to pursue an expansionary demand policy in order to maintain a high rate of growth.

In applying the test for the disequilibrium model (9) we convert it to a macrodynamic framework and specify the demand supply functions in a growth rate form

$$\Delta D = F(I, \Delta G)$$

$$\Delta S = H(I, \Delta L)$$

$$\Delta Q = \min(\Delta D, \Delta S)$$

Here the demand equation ΔD represents the typical Keynesian variables represented by investment demand (I) and autonomous government expenditure (ΔG), where investment demand includes both domestic and foreign demand. The supply equation is the production function with capital and labor inputs. Estimating these two equations by linear regressions for Korea over the period 1967-86 we obtain the estimated series of $d = \Delta D$ and $s = \Delta S$. Then to test whether $d > s$ or $s > d$ we obtain the following regression

$$d = a + bs$$

of estimated demand and supply. For Korea the following result is obtained

$$d = \underset{(1.6)}{225.1} + \underset{(1.3)}{0.860^{*}s}, \quad R^2 = 0.86, \ DW = 2.2$$

Clearly $d < s$, hence $q = \Delta Q = d$. A similar set of calculations for the other countries in our sample produced the following results:

	q=min(d,s)	$g_X=\Delta X/X$	$g_Y=\Delta Y/Y$
Korea	d	16.1	8.0
Taiwan	d	13.4	8.1
Japan	d	8.7	5.4
Belgium	s	6.1	3.0
Philippines	s	4.2	3.6
Germany	d	5.3	2.7

Clearly the demand factor was more binding in the dynamic growth process of the successful NICs in Asia. Since this implied that the demand-induced growth was more persistent, i.e., less volatile and the planners in Korea targeted it as a long run objective, the response of supply was in the typical Keynesian fashion, i.e., increased capacity utilization in the short run and building capacity ahead of demand in the long run. The latter was greatly helped in Korea and Taiwan by a policy of low real interest rates and significant increasing returns to scale.

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 [30]. 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 [26] 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. Thus the external benefits of human capital can be captured by specifying the production function as

$$y = Ax^{\beta}h^{\gamma} \tag{11}$$

where the three variables y, x and h denote output, physical and human capital per effective worker respectively. The term h^{γ} is interpreted as an external effect, which multiplies the productivity of a worker at any skill level just as the intercept term A. It has also a spillover effect on other workers.

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 significant heterogeneity in the way the variables are defined. Secondly, data on capital stock are not generally available in a reliable form from the official statistics. For the first difficulty we consider separately a production function for the manufacturing sector in Korea for which data are available from Kwon [24]. Secondly, 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 [9] as follows:

$$K_t = \log 2 + \tfrac{1}{2} \log \sum_{i=0}^{t-1} (1\text{-}\delta)^i \, I_{t-1} + \tfrac{t}{2} \log (1\text{-}\delta) + \tfrac{1}{2} \log K_0$$

The results of fitting unconstrained Cobb-Douglas productions for the successful NICs are as follows:

	Constant	Log K	Log L	$\bar{R}^2$	DW
Korea (1964-87)	2.599*	0.362* (8.98)	1.563* (17.40)	0.994	1.25
Japan (1961-87)	0.076	0.429* (2.96)	1.663* (2.72)	0.998	2.00
Taiwan (1958-87)	6.187	0.630* (2.82)	1.825* (6.93)	0.998	0.89
Singapore (1960-80)	1.420	0.501* (2.01)	1.481* (3.84)	0.989	0.95
Hong Kong (1959-82)	2.310*	0.381* (7.42)	1.352* (5.81)	0.994	1.21

(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 [26] the spillover effects 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 more disaggregative way to estimate the scale effect is to concentrate on the manufacturing sector alone, which happens to be the most important sector in export growth performance of the successful NICs in Asia. For Korea time series data on output, capital and labor are directly available from Kwon [24] along with cost and price data over the period 1961-80. A direct way to estimate IRS in the export-intensive manufacturing sector in Korea is to fit a log linear cost function as follows:

$$\underset{(2.10)}{\text{Log } C = 0.168^*} + \underset{(4.57)}{0.797^*} \text{ Log } Y - 0.077 \text{ Log } Z, \quad R^2 = 0.921, \ DW = 2.1$$

where C is observed total costs, log C is its logarithmic value and Z is a proxy variable for measuring technical progress which is usually captured by a time trend. Clearly the overall degree of IRS is 1.25 which is the reciprocal of the elasticity coefficient 0.797 for output (Y). This implies that a ten percent increase in inputs (scale) increases output by at least 12.50 percent. The realized output increase may be higher since technical progress and presence of nonrival inputs have additional cost-reducing impacts. Clearly the manufacturing sector in the Korean economy has utilized scale economies most significantly over its growing phase and the high income elasticity of world demand for Korean exports has helped its growth upsurge tremendously.

A direct estimate of the productivity of human capital in the form of externality effects as in the specification (11) 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 [14] 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:

Table 4. Sources of growth of GNP in U.S., Korea and Japan

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	100.0	100.0	100.0

Sources: USA and Japan: Denison and Chung [10];
Korea: Enos and Park [14].

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 proportionaly less from advances in technology. Futhermore 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.

Conclusion

The econometric study focuses here on the basic structural and economic forces which contributed to the rapid economic growth of the economy of South Korea in recent years. This analysis applies the modern tests of cointegration to estimate a two-sector model of growth, where the export sector's role is quantified in terms of its externality effects. A test of disequilibrium is also applied for assessing if the demand has been the dominant factor in Korea's export promotion strategy. Finally, our study has evaluated in a broader context the experiences of the high growth economies of the Asian Pacific Rim, e.g., Japan, Korea and Taiwan, which provide a good testing ground for the new growth theory that has emerged over the last six years. Of all the successful NICs in Asia the Korean case provides in many ways an interesting example. Unlike Japan which is a mature exporter, Korea's experience is more recent; also Korea has followed policies more favorable to openness in trade.

Two major tenets of the new growth theory are empirically tested here against the Korean experience over the last two decades. The first is the externality effect of exports and its productivity growth, which played the role of a catalyst for other sectors' growth. One notes that the role of increasing returns to scale emphasized in new growth theory has been very prominent in Korea's growth and more so in the export-oriented sectors. This has helped the process of building capacity ahead of demand and planning for a steady long run rate of growth. Diversification of the export-mix, low interest rate policies and active state policies toward export promotion and outward looking development have contributed to this growth upsurge on the supply side.

Finally, the growth of human capital and the diffusion of skills across the board, which are strongly emphasized in new growth models have proved to be very significant in the growth process of Korea. 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.

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