Complementarities between Exports and Human Capital in Economic Growth: Evidence from the Semi-industrialized Countries*

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I. Introduction

Export orientation and human capital investment have both received widespread attention in the literature on economic growth. Over the past several decades, numerous researchers have modeled exports as an engine of economic growth, with the presumption that higher exports can lead to greater capacity utilization, economies of scale, adoption of more efficient technology, or higher foreign exchange in order to import superior capital goods and raw materials. Recently, R. E. Lucas, Jr., and C. Azariadis and A. Drazen, among others, have built theoretical models in which sustained long-run growth is driven by the human capital investment of optimizing households.[1] This theoretical research has also generated renewed interest in cross-country growth regressions designed to evaluate the empirical significance of various structural and policy indicators. In a recent review of the empirical literature, R. Levine and D. Renelt analyzed the determinants of the average annual growth rate of GDP per capita for a sample of 101 countries over the period 1960–89.[2] By applying the method of extreme bounds analysis,[3] Levine and Renelt demonstrated that the statistical significance of nearly every structural and policy indicator is highly sensitive to the inclusion of additional explanatory variables. The only variables found to possess fairly robust predictive power were the rate of investment, the growth rate of international trade, and the initial level of real GDP per capita. However, two critical issues have remained unresolved concerning the role of exports and human capital in the determination of long-run economic growth.

First, while Levine and Renelt found a highly robust relationship

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between GDP growth and the growth rate of international trade, the channels through which trade influences GDP growth remain unclear. Three different measures of the growth rate of international trade (i.e., total exports, total imports, and total trade) have a nearly identical quantitative impact and explanatory power, providing support for the hypothesis that trade influences growth primarily by financing imported capital goods and raw materials.[4] Previous empirical studies also found a statistically significant relationship between the growth of the export/GDP ratio and economic growth in developing countries,[5] whereas Levine and Renelt found no robust relationship between growth of the export/GDP ratio and growth of GDP per capita. This finding appears to be inconsistent with theoretical models in which the export sector contributes to economic growth through increasing returns to scale, more rapid adoption of foreign technology, or more efficient utilization of scarce resources.

Second, in contrast to previous studies that found a significant positive relationship between human capital investment and economic growth, Levine and Renelt determined that neither secondary school enrollment nor other measures of human capital have a robust influence on GDP growth in their subsample of developing countries.[6] This result is difficult to reconcile with the theoretical models mentioned above, as well as with broad international evidence for high private and social rates of return to education.[7]

There are several potential explanations for the lack of a robust relationship between economic growth and either export orientation or human capital investment variables. Of course, a simple explanation would be that these factors are truly insignificant in determining long-run economic growth. Levine and Renelt favored an alternative explanation: ‘‘If one is unable to find robust partial correlations in a cross-section regression, this means that there is not enough independent variation in that variable to explain cross-country differences in growth.’’[8] In this case, the presence of multicollinearity within a set of explanatory variables would prevent the identification of an independent effect for any particular variable. Nevertheless, there is a third possible explanation that should be considered; certain variables may have nonlinear effects on GDP growth. Thus, the lack of robustness would not be due to the inclusion of too many collinear variables in the regression but, rather, to the exclusion of a critical nonlinear transformation of the variables in question.

In this article we address these issues, using a panel of 10-year GDP growth rates for 30 semi-industrialized developing nations over the time period 1965–84. (The data sources are described in app. A; sample statistics are given in table 1.) Apart from some minor differences (described in app. B), the countries in the sample are the same as those originally chosen by H. B. Chenery and later analyzed by other researchers.[9] The sample selection is based on the level of industrial output per capita

TABLE 1

SAMPLE STATISTICS: CHARACTERISTICS OF THE SAMPLE OF 30 SEMI-INDUSTRIALIZED COUNTRIES OVER THE 2 DECADES 1965–74 AND 1975–84

Variable	Mean	Standard Deviation	Minimum	Maximum
GDP growth	.0502	.0215	.00352	.0885
Initial GDP per capita (US$, PPP-adjusted)	2,662	1,561	615	8,323
Initial GDP per capita (logs)	7.72	.604	6.42	9.03
Population growth rate	.0232	.00867	−.00126	.0418
Investment/GDP	.232	.0558	.0890	.351
Total export growth rate	.0625	.0464	−.00903	.268
Total export share of GDP	.247	.163	.0481	.867
Total export share growth	.0163	.0180	−.00242	.101
Manufactured export share of GDP	.066	.114	.00365	.654
Manufactured export share growth	.00800	.0129	−.00451	.0840
Average education (years)	4.13	1.89	.660	8.37
Primary school enrollment (%)	94.6	19.3	40.0	124.1
Secondary school enrollment (%)	37.3	18.6	6.50	83.0
Literacy rate (%)	68.1	22.9	20.7	93.9
Education expenditure share of GDP (%)	3.65	1.45	1.57	7.58

and the share of industrial production in GDP and excludes the major petroleum-exporting nations. Although this sample excludes the OECD countries as well as the lowest-income developing countries, the sample still contains a great diversity of countries. Per capita GDP in 1965 ranges from about $600 for India to about $5,200 for Israel, while the share of exports in GDP during the 1965–74 period ranges from less than 5% for India to almost 80% for Hong Kong.

By focusing on a more homogeneous sample of countries than those examined by Levine and Renelt, our intention is to shed further light on the role of exports and human capital in determining long-run economic growth. In examining these issues within the sample of semi-industrialized countries, we find the same sensitivity to changes in time period, selection of countries, and explanatory variables that was documented by Levine and Renelt. However, we find strong and robust evidence of an interaction between average education and growth in the export/GDP ratio, which previous empirical studies have not considered. These results indicate a high degree of complementarity between trade policies and education expenditures and provide new empirical support for the hypothesis that export orientation contributes to economic growth through increasing returns to scale and other sectoral productivity differentials and not merely by relaxing import capacity constraints. In addition, we find that growth in the manufactured exports/GDP ratio has a strong influence on economic growth, whereas growth in the ratio of primary commodity exports to GDP has negligible influence, indicating that increasing returns and other efficiencies are mainly concentrated within the manufactured export sector.[10] These findings provide further support for development policies that stimulate long-run economic growth by simultaneously promoting investment in human capital as well as investment in the manufactured export sector.

The remainder of this article is organized as follows. Section II examines the relationship between growth of the export/GDP ratio and economic growth and considers preliminary evidence for the importance of the manufactured export sector in comparison with the primary commodity export sector. Section III examines the relationship between human capital investment and economic growth. Section IV documents the absence of any significant linear relationship between human capital variables and GDP growth and demonstrates the robustness of the interaction between average education and the growth of the manufactured export/GDP ratio. Section V summarizes the conclusions of our analysis.

II. Exports as an Engine of Growth

A large body of literature has considered various circumstances that can cause total factor productivity to be higher in export-oriented industries than in non-export-oriented industries: greater-capacity utilization, economies of scale, more efficient adoption of foreign technology, and stronger incentives for efficiency due to competitive pressures abroad.[11] We can estimate some of these effects by specifying the following aggregate production function:

$$\begin{aligned} Y_{it} &= A_{it} L_{it}^{\alpha_1} K_{it}^{\alpha_2} \\ A_{it} &= B_{it}\left[1 + \eta\left(\frac{X}{Y}\right)_{it}\right] X_{it}^{\theta}, \end{aligned} \tag{1}$$

where Y_{it}, L_{it}, K_{it}, and X_{it} are, respectively, the GDP, labor, stock of capital, and exports and A_{it} is the total factor productivity level of country i in period t. This specification permits total factor productivity, A_{it}, to be endogenously determined by the volume of exports (reflecting the influence of externalities or alleviation of import capacity constraints) and the share of exports in GDP (reflecting the superior productivity of the export sector), as well as exogenous influences represented by the residual productivity factor, B_{it}. G. Feder derived essentially the same specification under the following assumptions: a proportional difference, δ, between the marginal products of capital and labor in the export and nonexport sectors; an external effect of exports on the total factor productivity of the nonexport sector, with constant elasticity θ; and approximate equality of the marginal and average productivity of labor in the nonexport sector.[12] In this case, it can be shown that $\delta = (\eta + \theta)/(1 - \eta - \theta)$. By taking the natural logarithm and then the first difference of this production function, using the approximation that $\log(1 + z) \cong z$ when z is small, and denoting the natural logarithm of an upper-case variable by its lower case and the first difference of a variable by a dot over it, we obtain the following equation:

$$\dot{y}_{it} = \alpha_{0t} + \alpha_1 i_{it} + \alpha_2 \left(\frac{I}{Y}\right)_{it} + \alpha_3 \dot{x}_{it} + \alpha_4 \Delta \left(\frac{X}{Y}\right)_{it} + \epsilon_{it}, \qquad (2)$$

where I is the investment rate, $\Delta(X/Y)$ is the average annual change in the export/GDP ratio during decade t, and the coefficients α_3 and α_4 correspond to the production function parameters θ and η. In this specification, if $\alpha_3 + \alpha_4 = 0$, then the export sector has no total factor productivity advantage relative to the rest of the economy.

Neoclassical growth models predict a negative relationship between initial per capita GDP and long-run growth rate of GDP, with the implication that in the long run all countries will have the common growth rate dictated by the common technological knowledge.[13] Some previous studies found empirical support for this relationship, using the Penn World Tables.[14] However, in the sensitivity analysis of Levine and Renelt, the initial level of GDP per capita becomes statistically insignificant if the OECD countries are excluded from the sample or the time period is limited to the years 1974–89.[15] To the extent that per capita GDP measures the level of development of the financial institutions and other infrastructures that foster economic growth, we may expect that low-income countries will have relatively low GDP growth, whereas middle- and higher-income countries might follow the negative relationship predicted by the neoclassical models. Thus, instead of assuming B_{it} to be constant across countries, we allow for a quadratic relationship between the natural logarithm of B_{it} and the natural logarithm of initial per capita GDP. This leads us to estimate the following regression model:

$$\begin{aligned} \dot{y}_{it} = \alpha_{0t} + \alpha_1 i_{it} + \alpha_2 \left(\frac{I}{Y}\right)_{it} + \alpha_3 \dot{x}_{it} \\ + \alpha_4 \Delta \left(\frac{X}{Y}\right)_{it} + \alpha_5 y_{0it} + \alpha_6 y_{0it}^2 + \epsilon_{it}. \end{aligned} \qquad (3)$$

The parameter estimates of model (3) are given in column 1 of table 2. The estimated coefficients and *t*-statistics for our sample are nearly identical to those obtained by Feder. For example, Feder estimated $\alpha_3 = 0.131$ and $\alpha_4 = 0.305$, while we obtain the estimates $\alpha_3 = 0.134$ and $\alpha_4 = 0.337$. Since Feder's sample included the single decade 1964–73, while our sample includes the 2 decades 1965–74 and 1975–84, the similarity between these estimates confirms the lack of evidence for any structural change between the 2 decades. If we interpret these estimated coefficients according to Feder's aggregate production function, we find that the productivity differential parameter $\delta = 0.89$; that is, the export sector has about 89% higher total factor productivity than the nonexport sector. We also estimated Feder's original specification, excluding the terms involving initial per capita GDP; we did not find much difference in the estimates of the parameters α_1, α_2, α_3, and α_4. However, the inclusion of the quadratic function of initial GDP per capita raises the adjusted R^2 relative to Feder's specification, and both quadratic coefficients are statistically significant at the 1% confidence level.

A. Primary versus Manufacturing Exports

At this point it is useful to consider the hypothesis that the productivity differential associated with the export sector is actually concentrated within the manufactured export sector rather than the primary commodity export sector. For example, we might expect that foreign technology can be adopted relatively quickly by manufacturing industries, whereas region-specific factors related to climate and soil conditions tend to make the adoption of foreign technology more difficult. It is straightforward to modify the aggregate production function (eq. [1]) in order to allow for this differential by assuming that

$$A_{it} = B_{it}\left[1 + \delta_m\left(\frac{MX}{Y}\right)_{it} + \delta_p\left(\frac{PX}{Y}\right)_{it}\right]X_{it}^{\theta}, \tag{4}$$

where (MX/Y) is the ratio of manufactured exports to GDP and (PX/Y) is the ratio of primary commodity exports to GDP. The above specification leads to the following modified version of model (3):

$$\begin{aligned}\dot{y}_{it} = {} & \alpha_{0t} + \alpha_1 i_{it} + \alpha_2\left(\frac{I}{Y}\right)_{it} + \alpha_3\dot{x}_{it} + \alpha_4\Delta\left(\frac{MX}{Y}\right)_{it} \\ & + \alpha_5\left(\frac{PX}{Y}\right)_{it} + \alpha_6 y_{0it} + \alpha_7 y_{0it}^2 + \epsilon_{it},\end{aligned} \tag{5}$$

TABLE 2

LINEAR EFFECTS OF EXPORT SHARE IN GDP: DEPENDENT VARIABLE, GDP GROWTH (1965–74 and 1975–84)

Variable	Model 3 (1)	Model 5 (2)	Model 6 (3)	Model 3 (4)	Model 6 (5)
No. of observations	60	60	60	56	56
Excluded countries	None	None	None	Hong Kong and Korea	Hong Kong and Korea
Constant	−.409	−.433	−.432	−.424	−.431
	(−2.06)	(−2.10)	(−2.13)	(−2.05)	(−2.06)
Population growth rate	.617	.700	.700	.642	.692
	(3.18)	(3.43)	(3.59)	(3.18)	(3.48)
Investment/GDP	.122	.138	.138	.124	.133
	(3.97)	(4.54)	(4.64)	(3.88)	(4.15)
Initial GDP per capita	.115	.119	.119	.119	.120
	(2.19)	(2.19)	(2.22)	(2.18)	(2.17)
Squared initial GDP per capita	−.00790	−.0082	−.0082	−.00818	−.00826
	(−2.31)	(−2.29)	(−2.32)	(−2.29)	(−2.29)
Total export growth rate	.134	.150	.149	.161	.198
	(3.41)	(3.43)	(3.85)	(2.66)	(4.02)
Total export share growth	.337	. . .	. . .	.220	. . .
	(2.99)			(1.08)	
Manufactured export share growth	. . .	.371	.371	. . .	.136
		(2.40)	(2.51)		(.36)
Primary export share growth	. . .	−.0012	. . .	. . .	. . .
		(−.01)			
Time effect (1975–84)	−.0153	−.0162	−.0162	−.0162	−.0165
	(−4.88)	(−5.00)	(−5.08)	(−4.92)	(−4.96)
Adjusted R^2	.725	.707	.713	.693	.672
Durbin-Watson statistic	1.98	1.90	1.90	1.87	1.85
Structural change Chow statistic	1.72	1.83	1.17	1.15	1.08
	(6, 46)	(7, 44)	(6, 46)	(6, 46)	(6, 46)

NOTE.—*t*-statistics are given in parentheses.

where $\Delta(MX/Y)$is the average annual change in the manufactured export/GDP ratio during decade t and $\Delta(PX/Y)$is the average annual change in the primary commodity export/GDP ratio during decade t.

The parameter estimates of the above model are reported in column 2 of table 2. We find that the coefficient on manufactured export share growth is positive and highly significant, whereas the coefficient on primary export share growth is almost equal to zero and is statistically insignificant. All of the other coefficients are not significantly different from those obtained for model (3). Imposing the zero restriction on the primary export share growth variable, we then estimated the following model:

$$\begin{aligned} \dot{y}_{it} = \alpha_{0t} + \alpha_1 i_{it} + \alpha_2\left(\frac{I}{Y}\right)_{it} + \alpha_3\dot{x}_{it} \\ + \alpha_4\Delta\left(\frac{MX}{Y}\right)_{it} + \alpha_5 y_{0it} + \alpha_6 y_{0it}^2 + \epsilon_{it}. \end{aligned} \quad (6)$$

The estimation results for equation (6) are given in column 3 of table 2. The adjusted R^2 is nearly identical to that of equation (5), reinforcing our conclusion that essentially the entire productivity differential associated with the export sector is, in fact, concentrated within the manufactured export sector. Furthermore, by excluding primary commodity exports, the resulting productivity differential $\delta = 1.08$ indicates that for the average country in our sample, the manufactured export sector is more than twice as productive as the rest of the economy. R. M. Kavoussi estimated the growth equation version of this aggregate production model (eq. 5) under the restriction that $\delta_p = 0$ for a sample of 36 middle-income developing countries, and he also found that δ_m was positive and statistically significant.[16] Without starting from an explicit production function, Balassa added the ratio of manufactured exports to total exports to equation (5) and specified only the linear form for the initial GDP per capita (i.e., assumed that $\alpha_7 = 0$ in eq. [5]), and found that the coefficient on this ratio was positive but marginally significant.[17]

B. Fragility of Results

With statistically significant and intuitively plausible coefficient estimates, relatively high explanatory power, no evidence of serial correlation or structural change, and comparable estimates by others, the GDP growth model of equation (6) looks nearly ideal. Unfortunately, just as in the analysis of Levine and Renelt, we find that the statistical significance of the total export share growth or manufactured export share growth variables is relatively fragile. If Hong Kong is excluded from the sample, the total export share variable becomes only marginally significant in Feder's original specification and in the modified specification of equation (3), and the manufactured export share variable becomes completely insignificant in equation (6).[18] As reported in columns 4 and 5 of table 2, when both Hong Kong and South Korea are excluded from the sample, the export share variables become statistically insignificant in both models (3) and (6). It should be noted that none of the other coefficients of equation (6) is significantly affected by the exclusion of Hong Kong or South Korea.

Thus, the statistical evidence for a productivity differential between the export sector and the rest of the economy is highly dependent on the inclusion of Hong Kong and South Korea in the sample. Since, due to data limitations, our sample of countries does not include Singapore or Taiwan, it may well be the case that all of the East Asian newly industrializing countries (NICs) have experienced large productivity advantages of the manufactured export sector. Given the available data, however, one might be inclined toward the opinion of Levine and Renelt that the variation in the export share growth variables across the rest of the sample countries is insufficient to provide strong support for the productivity differential hypothesis. In fact, in Section IV we show that this productivity differential becomes strong and robust when we properly control for the influence of human capital investment.

III. Human Capital as an Engine of Growth

To what extent does investment in education affect economic growth? A wide range of theoretical models has treated human capital as a critical factor in determining the growth rate of output.[19] Furthermore, microeconomic studies for numerous developing countries have found that individuals with greater education tend to have relatively higher earnings.[20] For example, using data from seven developing countries, G. Psacharopoulos found that average earnings of individuals with secondary school education are 2.4 times those of individuals with primary school education.[21] Of course, education investment also involves substantial costs per student in terms of structures, personnel, and foregone earnings; and these costs increase dramatically at higher education levels (i.e., 4.75 times higher for secondary education relative to primary education, based on Unesco data for eight developing countries).[22] Based on earnings differentials and total costs for 30 developing countries, Psacharopoulos calculated that social rates of return to education investment are relatively high, averaging about 25% for primary education and about 15% for secondary education.[23]

Unfortunately, microeconomic evidence on rates of return to education does not provide a complete representation of education's impact on economic growth. On the positive side, educated workers may provide externalities within the firm or industry that are not completely reflected by the prevailing wage differential. Educational investment may also contribute indirectly to economic growth by reducing fertility and improving health and life expectancy (as suggested by numerous empirical studies in developing countries).[24] On the negative side, the level of education may be used as a screening device in hiring decisions (e.g., as a signal of higher ability or socioeconomic background), so that relative earnings do not reflect the true productivity differential due to higher education. Unionization and other market imperfections may augment the earnings differential associated with education and thereby exaggerate its true impact on productivity.

Aggregate production function analysis using macroeconomic data has provided somewhat inconclusive evidence on the significance of educational investment as a determinant of economic growth. Using the entire Penn World Tables data set, previous studies found a positive relationship between school enrollment rates and average GDP growth rates.[25] However, Levine and Renelt determined that this statistical relationship is not robust to small changes in the sample countries or the time period or inclusion of additional explanatory variables.[26]

The lack of significance of any linear effect of education investment can be shown by estimating the following equation:

$$\dot{y}_{it} = \alpha_{0t} + \alpha_1 i_{it} + \alpha_2 \left(\frac{I}{Y}\right)_{it} + \alpha_3 \dot{x}_{it} + \alpha_4 y_{0it} + \alpha_5 y_{0it}^2 + \alpha_6 H_{it} + \epsilon_{it}, \quad (7)$$

where H_{it} is the average value of the human capital variable during decade t. Using various measures of human capital investment and attainment, we found no significant relationship with GDP growth. Average education, primary school enrollment, secondary school enrollment, literacy, and the ratio of public education expenditures to GDP are all statistically insignificant, while the other coefficients, $\alpha_1, \ldots \alpha_5$, have robust estimates and significance levels in all the specifications. For reference, we report in column 1 of table 3 the parameter estimates of model (7), taking average education as a measure of human capital H_{it}.[27]

One might explain this lack of significance of human capital by supposing that lagged rather than current school enrollment influences the contemporaneous growth rate of GDP (since a few years may pass before students enter the labor force and become productive). However, if H_{it} is defined as the school enrollment rate 5 years prior to the start of decade t, this lagged variable is statistically insignificant. One might also wish to consider a quadratic relationship between human capital investment and GDP growth; but further regressions yield no statistical support for such a relationship. Or human capital could be complementary to physical capital (as suggested by the work of L. J. Lau, D. T. Jamison,

TABLE 3

INTERACTION BETWEEN HUMAN CAPITAL AND EXPORTS SHARE: DEPENDENT VARIABLE, GDP GROWTH (1965–74 and 1975–84)

Variable	Model 7 (1)	Model 7′ (2)	Model 9 (3)	Model 9 (4)	Model 11 (5)
No. of observations	45	45	45	45	45
Constant	−.389	−.394	−.644	−.601	−.426
	(−1.61)	(−1.66)	(−2.87)	(−2.82)	(−2.06)
Population growth rate	.659	.667	.486	.479	.298
	(2.59)	(2.71)	(2.27)	(2.26)	(1.16)
Investment/GDP	.149	.137	.108	.101	.111
	(4.07)	(3.36)	(2.99)	(2.95)	(3.38)
Initial GDP per capita	.105	.109	.184	.172	.122
	(1.67)	(1.74)	(3.09)	(3.06)	(2.26)
Squared initial GDP per capita	−.00711	−.0075	−.0123	−.0116	−.00823
	(−1.72)	(−1.83)	(−3.19)	(−3.17)	(−2.31)
Total export growth rate	.194	.198	.149	.140	.137
	(4.83)	(5.10)	(3.75)	(3.78)	(3.71)
Total export share growth	. . .	. . .	−.196	. . .	. . .
			(−.66)		
Average education (in years)	−.000396	. . .	. . .	. . .	. . .
	(−.29)				
Average education × (investment/GDP)	. . .	.229	. . .	. . .	. . .
		(.44)			
Average education × export share growth	. . .	. . .	.105	.0724	. . .
			(1.98)	(3.67)	
Average education × manufactured export share growth	. . .	. . .	. . .	. . .	.0986
					(3.94)
Secondary school enrollment (%)	. . .	. . .	−.000393	−.000277	−.000318
			(−2.20)	(−1.81)	(−2.03)
Time effect (1975–84)	−.0164	−.0171	−.160	−.0157	−.0136
	(−4.02)	(−4.33)	(−4.60)	(−4.59)	(−3.48)
Adjusted R^2	.650	.662	.755	.759	.752
Durbin-Watson statistic	1.70	1.68	2.35	2.41	2.03
Structural change Chow statistic	1.41	1.69	.95	1.10	.75
	(6, 31)	(6, 39)	(8, 27)	(7, 29)	(7, 29)

NOTE.—*t*-statistics are given in parentheses.

and F. F. Louat) or unskilled labor or exports;[28] but we find no evidence for an interaction between any human capital measure and the investment rate (see the second column [model (7′)] in our table 3 for estimates of one such model),[29] population growth rate, or export growth rate. Finally, one might suppose that the productivity benefits of human capital depend on the level of development, but we find no evidence for an interaction between any human capital measure and initial GDP per capita (or squared initial GDP per capita). At this point, one might feel ready to conclude that human capital investment is simply unimportant in determining GDP growth for our sample of semi-industrialized countries, but in fact this is not the case, as we shall show in the next section.

IV. Interaction between Exports and Human Capital

We postulate that the export sector can utilize human capital more efficiently than can the rest of the economy. For example, educated workers may be able to adapt more quickly to the sophisticated technology and rapid production changes required for competitiveness in world markets. In this case, the productivity differential associated with the export sector will rise with the average level of education H_{it}; we incorporate such productivity differential by assuming A_{it} in the aggregate production function (1) is of the following form:

$$A_{it} = B_{it}\left[1 + \eta_0 + \eta_1 H_{it}\left(\frac{X}{Y}\right)_{it}\right]X_{it}^{\theta}. \tag{8}$$

By taking the natural logarithm and then the first difference of this equation,[30] and allowing for the quadratic relationship between initial GDP per capita and productivity growth as well as a direct impact of human capital investment on GDP growth, we obtain the following equation:

$$\begin{aligned}\dot{y}_{it} = {} & \alpha_{0t} + \alpha_1 i_{it} + \alpha_2\left(\frac{I}{Y}\right)_{it} + \alpha_3\dot{x}_{it} + \alpha_4 y_{0it} + \alpha_5 y_{0it}^2 \\ & + \alpha_6\Delta\left(\frac{X}{Y}\right)_{it} + \alpha_7 H_{it}\Delta\left(\frac{X}{Y}\right)_{it} + \alpha_8 H_{it} + \epsilon_{it},\end{aligned} \tag{9}$$

where H_{it} is the average level of education in decade t and is either the average primary school enrollment rate or the average secondary school enrollment rate in decade t.

We estimated the above model, and the estimates are reported in column 3 of table 3. From these estimates we find that the interaction between average education and the growth of the export/GDP ratio (i.e.,

α_7) is statistically significant, while the growth of the export/GDP ratio (i.e., α_6) by itself is not significant. Referring back to the production function in equation (8), this indicates that $\eta_0 = 0$ and that η_1 is significantly positive. According to this evidence, the export sector cannot be more productive than the rest of the economy without utilizing relatively educated workers; that is, the externalities and increasing returns to scale attributed to the export sector in newly industrializing countries like Hong Kong and Korea cannot be achieved without simultaneous public investment in education. We reestimated model (9), imposing the restriction that $\alpha_6 = 0$. These parameter estimates are shown in column 4 of table 3. The main difference we notice is that the estimate of the interaction between average education and export share is more significant.

We also find that when we control for the interaction between average education and the growth of the export/GDP ratio, the level of either primary or secondary school enrollment has a significant negative impact on GDP growth (in table 3 we show only the estimates for secondary education), while the level of average education does not have any significant influence. The simplest interpretation for this result is that contemporaneous costs of educational investment are significant at the macroeconomic level. As in many theoretical growth models, and as suggested by the microeconomic evidence noted above, the opportunity costs of resources devoted to human capital investment may be relatively large. Earnings are forgone by currently enrolled students; relatively highly educated individuals work as teachers rather than in private industry; and scarce government finances are devoted to investment in education structures and equipment rather than in other types of productive infrastructure (e.g, telecommunications, transportation).

Next we reexamine the hypothesis considered in Section III, that the productivity differential is actually concentrated within the manufactured export sector rather than the primary commodity export sector. We consider the following form for A_{it}:

$$A_{it} = B_{it}\left[1 + \eta_0 + \eta_1 H_{it}\left(\frac{MX}{Y}\right)_{it} + \eta_2 H_{it}\left(\frac{PX}{Y}\right)_{it}\right] X_{it}^{\theta}. \qquad (10)$$

Taking natural logarithms and first differences, and imposing the restriction that $\eta_0 = 0$, we then estimate the following equation:

$$\dot{y}_{it} = \alpha_{0t} + \alpha_1 i_{it} + \alpha_2\left(\frac{I}{Y}\right)_{it} + \alpha_3 \dot{x}_{it} + \alpha_4 y_{0it} + \alpha_5 y_{0it}^2 + \alpha_6 H_{it}\Delta\left(\frac{MX}{Y}\right)_{it} + \alpha_7 H_{it}\Delta\left(\frac{PX}{Y}\right)_{it} + \alpha_8 \dot{h}_{it} + \epsilon_{it}. \qquad (11)$$

The estimates of the above model show that the interaction between average education and the growth of the manufactured export/GDP ratio is positive and highly significant, whereas the interaction between average education and the growth of the primary commodity export/GDP ratio is nearly zero and statistically insignificant.[31] Thus, as we discussed in Section II.A, there is no evidence that the primary commodity export sector in semi-industrialized countries has a higher productivity level than the rest of the economy has.

After imposing the restriction $\alpha_7 = 0$, we estimated equation (11); the parameter estimates are shown in the last column of table 3. The estimated equation displays a highly significant interaction between average education and the growth of the manufactured export/GDP ratio. Furthermore, this growth equation has a number of desirable statistical properties: the estimated coefficients show no sign of structural change between the 2 decades, the estimated residuals show no evidence of serial correlation (i.e., the disturbances for each country are uncorrelated across decades), and the model has an excellent degree of explanatory power (i.e., about 75% of the variation in GDP growth across the countries in the sample). Finally, in contrast to the models without human capital that were considered in Section III, we find that the exclusion of Hong Kong and Korea from the sample and the inclusion of regional productivity differences do not have statistically significant influence on these results (see table 4).

It is interesting to consider the economic significance of the influence of human capital investment based on the estimated coefficients in the last column of table 3. Since the productivity differential δ of the manufactured export sector is a nonlinear function of the level of average education,[32] this relationship is best illustrated by some examples. During the 1965–74 period, the working-age population of India had an average education level of 1.36 years, so that the manufactured export sector in India would be expected to have a productivity level about 40% higher than that of the rest of the economy. Unfortunately, since the manufactured export sector in India hardly grew at all as a share of GDP (i.e., only 0.1% per year), the productivity differential of the manufactured export sector had essentially no impact on GDP growth in India. In other words, India's restrictive trade policies prevented its economy from reaping a significant level of benefits from its existing stock of educated workers.

In contrast, during the same decade the working-age population of Korea had an average education level of 4.12 years, yielding a productivity differential of about 125% in the manufactured export sector. Furthermore, the manufactured export/GDP ratio in Korea grew rapidly, by almost 4% per year, so that the growth of the manufactured export/GDP ratio contributed about 1.6% to Korea's annual GDP growth during this period. Thus, the combination of a relatively educated work force and

TABLE 4

Sensitivity Analysis of Nonlinear Relationships: Dependent Variable, GDP Growth (1965–74 and 1975–84)

Variable	Model 9	Model 11	Model 9	Model 11
Excluded countries	Hong Kong Korea	Hong Kong Korea	None	None
No. of observations	41	41	45	45
Constant	−.385	−.395	−.647	−.684
	(−1.76)	(−1.81)	(−2.93)	(−3.11)
Population growth rate	.161	.225	.400	.446
	(0.54)	(0.80)	(1.56)	(1.77)
Investment/GDP	.0899	.098	.0534	.0750
	(2.49)	(2.80)	(1.32)	(2.03)
Initial GDP per capita	.115	.116	.186	.192
	(2.00)	(2.02)	(3.16)	(3.28)
Squared initial GDP per capita	−.00781	−.00787	−.0125	−.0128
	(−2.06)	(−2.08)	(−3.21)	(−3.30)
Total export growth rate	.105	.156	.120	.126
	(1.61)	(2.94)	(3.30)	(3.56)
Average education × total export share growth	.105	. . .	.0926	. . .
	(2.11)		(3.61)	
Average education × manufactured export share growth	. . .	.163	. . .	.112
		(2.15)		(3.74)
Secondary school enrollment rate	−.000391	−.000388	−.000435	−.000511
	(−1.94)	(−1.95)	(−2.58)	(−3.02)
European indicator	. . .	. . .	.0154	.0184
			(1.88)	(2.22)
Asian indicator	. . .	. . .	.00199	.00435
			(.33)	(.76)
Latin American indicator	. . .	. . .	−.00189	.00007
			(−.35)	(.01)
Time effect (1975–84)	−.0132	−.0135	−.0089	−.00860
	(−2.99)	(−3.10)	(−2.08)	(−2.02)
Adjusted R^2	.706	.709	.772	.776
Durbin-Watson statistic	2.22	2.21	2.50	2.48
Structural change Chow statistic	.82	.61	.85	.66
	(7, 29)	(7, 29)	(10, 23)	(10, 23)

Note.—*t*-statistics are given in parentheses.

manufactured export promotion policies by the government made a significant contribution to Korean economic growth during the 1965–74 period.

To evaluate the aggregate effects of human capital investment, Lau, Jamison, and Louat constructed an annual time series on average education for a set of 58 developing countries, using backward extrapolation and forward cumulation of school enrollment rates.[33] Combining the constructed series with published annual data on physical capital investment, labor-force growth, and land area, they estimated an aggregate production function over the period 1960–86. Although educational investment was determined to be statistically significant in explaining GDP growth, these results indicated that the impact of human capital investment varies dramatically across different continents and time periods. Lau, Jamison, and Louat found a statistically significant positive coefficient on secondary education for the East Asian region and a statistically significant negative coefficient on secondary education for the South Asian region. Our results suggest that these differences can be explained by two factors: the complementarity between average education and export orientation and the opportunity cost of human capital investment. Thus, a relatively closed economy like India may expend significant resources on educational investment but reap insignificant benefits due to the small size of its manufactured export sector.

V. Conclusions

Previous empirical research on the determinants of GDP growth has yielded conflicting results. Using a panel of 30 semi-industrialized developing nations over the period 1965–84, our analysis finds the same sensitivity to changes in sample period, selection of countries, and explanatory variables that has been apparent in earlier studies. However, our analysis yields strong and robust evidence that this sensitivity is due to an interaction between average education and export orientation, which has been neglected by previous studies. These results indicate a high degree of complementarity between trade policies and education expenditures and provide new empirical support for the hypothesis that export orientation contributes to economic growth through increasing returns to scale and other sectoral productivity differentials and not merely by relaxing import capacity constraints. In addition, we find that growth in the manufactured exports/GDP ratio has a strong influence on economic growth, whereas growth in the ratio of primary commodity exports to GDP has a negligible influence, indicating that increasing returns and other efficiencies are mainly concentrated within the manufactured export sector. These findings provide further support for development policies that stimulate long-run economic growth by simultaneously promoting investment in human capital as well as investment in the manufactured export sector.

Appendix A
Data Sources

The following variables are taken from the 1989–90 *World Tables*[34] (abbreviations are given in parentheses):

National Accounts Section (in constant 1980 local currency): Gross Domestic Product (GDPMP), Gross Domestic Investment (INVGDI), and Total Exports of Goods and Non-Factor Services (EXPGNFS).

Foreign Trade (Customs Basis, in constant 1980 U.S. dollars, f.o.b.): Manufactured Exports (EXPMAN), Nonfuel Primary Product Exports (EXPNFP), Fuel Exports (EXPFUEL).

Balance of Payments (in constant 1980 U.S. dollars, f.o.b.): Merchandise Exports (EXPFOB), Non-Factor Services Exports (EXPNFS).

Social Indicators: Total Population (POPN), Primary School Enrollment Rate (PRMSCH), Secondary School Enrollment Rate (SECSCH).

Due to high inflation rates and large exchange rate fluctuations in certain countries, data from the Foreign Trade section were converted into constant local currency using the ratio of EXPGNFS to (EXPFOB + EXPNFS). The sources of all other variables are as follows:

Average Education of Working Age Population: Unesco Statistical Yearbooks;[35] a few observations that were missing from this source were available from the World Bank, ''Social Indicators Database'' (1965–74: Morocco; 1975–84: Chile, Côte d'Ivoire, Colombia, Egypt, and Syria).[36]

Education Expenditures as Share of GNP: Unesco Statistical Yearbooks.

GDP per Capita in Constant Purchasing-Power Dollars: Penn World Tables.[37]

Illiteracy Rate: World Bank, ''Social Indicators Database.''

Appendix B
Description of Sample

The following countries were included in the regressions:

Africa and the Middle East: Côte d'Ivoire, Egypt, Israel, Kenya, Morocco, Syria, Tunisia, and Turkey.

Asia: Hong Kong, India, Korea, Malaysia, Pakistan, Philippines, Sri Lanka, and Thailand.

Europe: Greece, Portugal, and Spain.

Latin America: Argentina, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, Guatemala, Mexico, Peru, and Uruguay.

In contrast to Feder's work,[38] Taiwan was excluded due to lack of recent data in the *World Tables;* Singapore was excluded due to the absence of exports data in the National Accounts section of the *World Tables;* and Yugoslavia was excluded due to its absence from the Penn World Tables data set.

The following measures of education were not available for certain observations (where 1 indicates 1965–74 period and 2 indicates 1975–84 period):

Average Education: Chile (2), Colombia (2), Costa Rica (2), Côte d'Ivoire

(1, 2), Dominican Republic (2), Egypt (1, 2), Guatemala (2), Malaysia (2), Morocco (1, 2), Portugal (2), Syria (2), and Uruguay (1).

Education Expenditures: Hong Kong (1, 2).

Literacy: Costa Rica (2), Côte d'Ivoire (1), Dominican Republic (2), Egypt (1), Guatemala (2), Hong Kong (2), Kenya (1), Korea (2), Malaysia (2), Morocco (2), Sri Lanka (1, 2), Syria (2), and Uruguay (1, 2).

Notes

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28. Lawrence J. Lau, Dean T. Jamison, and Frederic F. Louat, ‘‘Education and Productivity in Developing Countries: An Aggregate Production Function Approach,’’ Working Paper (Stanford University, Stanford, Calif., June 1990).

29. We specified other models that included interaction between education and the ratio of investment to GDP; none of them produced a significant estimate for this interaction term.

30. We also assume that the product of the export/GDP ratio and the school enrollment rate is relatively small; otherwise this product would also enter eq. (9). Our regression analysis supports this assumption; results are available upon request from us.

31. Details of these regressions may be found in Levin and Raut.

32. Based on the estimated parameters of our final model shown in the last column of table 3, we have $\delta = (0.14 + 0.10 \times E)/(0.86 - 0.10 \times E)$.

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