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ECONOMIC GROWTH, INTERNATIONAL TECHNOLOGICAL SPILLOVERS AND PUBLIC POLICY: THEORY AND EMPIRICAL EVIDENCE FROM ASIA

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Abstract

This paper examines, within the new growth theory framework, the contribution of international technological spillovers using panel data for eleven Asian countries over the period 1970-93. A country's productivity growth is shown to depend not only on its domestic R&D investment but also on the R&D investment of its trading partners. The evidence for such a positive international technological spillovers is strong. This paper also shows that the beneficial effects of international technological spillovers on productivity growth are stronger in South East Asian countries than that of South Asian countries.

KEY WORDS; Economic Growth, Technology Spillovers, Asia

Economic Growth, International Technological Spillovers and Public Policy: Theory and Empirical Evidence from Asia

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A substantial body of economic literature suggests that the nations in the world economy are becoming increasingly interdependent. The degree at which the interdependence of nations has increased towards the last quarter of the twentieth century is unprecedented compared with any preceding historical time. Countries that are integrated into the world economy interact with one another in several ways. Among them trade in goods, transmission of technical information and foreign direct investment are the prominent ones. Many of these global interactions generate forces that accelerate growth in every country (Grossman and Helpmen, 1991). However, several economists suggest reasons why international integration might impede economic growth (Hayyar, 1995).

It is a widely held view that nations vary greatly in their growth performance. The differences in growth experience across nations are not simply the outcome of a random process. Traditional theory of growth has focused on factor accumulation as the driving force behind growth. Technological progress has often been treated as an exogenous process in the long-run analysis of economic growth. The new theory of economic growth, popularly known as "Endogenous Theory of Growth," suggests that technological innovations are becoming an increasingly more important contributor to economic growth. These theories are of the view that innovations feed on knowledge that results from cumulative R&D experience of a nation. The cumulative R&D experience contributes to the stock of knowledge which enhances, on the one hand, the productive capacity of an economy and, on the other hand, adds to the domain of social knowledge. Thus, the cumulative stock of knowledge not only stimulates economic growth of an economy but also generates spillovers which act as an external effect in enhancing productive capacity of all other countries. However, one implication of this view would be that with international transmission of knowledge capital, the cost of research is smaller in every location. The countries that opt for economic isolation will forfeit many spillover benefits. In contrast, it has been argued that as the knowledge from commercial oriented R&D capital spillover

creates public domain knowledge, a country must invest in R&D and education to acquire technical capabilities needed to make use of public domain knowledge to enhance its productivity and productive capacity. The implication of this view is that the nurturing of technological capability through interventionist policy is a must for realization of spillovers and boosting economic growth.

It is a well known fact that the less developed countries undertake little R&D expenditure and thus cannot add much to innovations and to the domain of public knowledge. But that R&D expenditure seems to be sufficient to adapt, imitate and develop technological capability on the basis of transferred technology from the technological leaders. Therefore, it is generally true that the technological leaders export goods to some less developed countries for a while and the trade pattern later reverses. Policies that promote capacity to copy or learning activities induce an increase in the returns. In the recent past, it has been growlingly felt that the companies that engage in the development of new technologies (be it for manufacturing of new goods, improved performance of existing products, or cheaper production processes) face difficulties in appropriating the fruits of their labor. If innovation is a principal engine of economic growth and agents innovate to capture or hold a share of market they would not retain otherwise, then the protection of intellectual property rights (IPRS) may boost long-run economic growth.

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share of market they would not retain otherwise, then the protection of intellectual property rights (IPRS) may boost long-run economic growth.

East Asia has a remarkable record of high and sustained economic growth. From 1965 to 1990, its 23 economies grew faster than those of all other regions. This has attracted the attention of the role of public policy in developing economies. The East Asian economies provide a range of policy framework extending from Hong Kong's nearly complete laissez-faire to the highly selective policy regime of Japan and Korea. It is worth noting here that these economies have differential performance in terms of growth and catch up process. Therefore, Asian continent is a fertile ground to test endogenous growth theory developed recently. Thus the present paper is a modest attempt to examine the inter-relationships in economic growth processes and the empirical estimates of technological spillovers from industrially advanced countries to eleven Asian countries have been reported.

The second section of the paper discusses the theoretical developments and empirical literature on international growth linkages. The rationale underlying the empirical specification is presented in section three. The data sources and definitions of variables are provided in section four. Section five provides the empirical estimates and the method of estimation. The concluding remarks are presented in the final section.

Theory and Empirical Literature

An assessment of determinants of economic growth is of obvious importance, and numerous attempts have been made to judge the impact of different factors on economic growth. Accordingly, the vast literature on growth theory can be divided into three groups. The early post-Keynesian growth models (the Harrod-Domar Growth theory and its variants) have underlined the importance of savings and investment in promoting growth. The neo-classical models of economic growth emphasized the significance of exogenous technical progress as the dominant determinant of economic growth. The new growth theory, which is also known as "endogenous growth theory," however, stressed the role of R&D, human capital accumulation and externalities as the dominant factors that determine long-run economic growth. It is important to note that the concern of new growth theories

is to endogenous the growth rate of GDP which in turn requires the rate of investment to be endogenoused. Although it is ultimately the factor accumulation that accounts for growth, yet, for factor accumulation to grow, the returns to the capital stock should not diminish. The new knowledge, which prevents diminishing returns on capital stock, is produced by investment in research technology which exhibits diminishing returns. Moreover, the increase in knowledge will not be appropriated solely by those who undertake investment. Therefore, R&D effort gives birth to appropriable and non-appropriable growth of knowledge. The latter is called extenality or spillover effects (Grossman and Helpman, 1991). R&D spillovers are potentially a major source of endogenous growth in various recent new growth models (Romer, 1990; and Barro and Sala-i-Martin, 1995). These spillovers produce productivity growth. They do not influence growth in production in conventional inputs, but there are models of scale economies and capital embodied technical change that would indicate they do (Evenson and Westphal, 1994). Although the endogenous growth theory identified and stressed the R&D externalities as an important source of growth, yet the empirical support of such extenalties are lacking at the aggregate level.

Coe and Helpman's (1993) empirical evidence on R&D spillovers across countries is a seminal contribution in this direction. The relationship between total factor productivity and domestic and foreign knowledge capital stock has been examined in a sample of 22 industrial economies during the period 1971 to 1990. They have found that accumulated spending on R&D by a country and by its trade partner helps to explain the growth of total factor productivity. The most important finding of the study is that the foreign R&D capital stock, that is externality, has particularly large effects on the smaller countries. Evenson and Englander (1994) have enlarged the scope of their analysis to use information at sectoral level for eleven OECD countries and examined the relationship between TFP and domestic and foreign knowledge capital stock. They have found that the impact of foreign R&D stock is relatively low for the leader country where little R&D spillin is occurring. For the mean country and industry the R&D elasticities are almost similar to domestic elasticities.

Developing countries are apparently placed in a disadvantageous position in terms of

innovations and inventions. The bulk of R&D activity in most developing countries is adaptive rather than creative in nature. However, the process of industrialization in particular and growth process in general in these countries does involve substantial technical change (Pack and Westphal, 1986). Coe, et al, (1995) in an important empirical study, which is based on observations over the 1971-90 period for 77 developing countries, suggest that spillover from the developed industrial countries to the developing countries are substantial. However, in their study they have completely ignored the impact of domestic R&D stock on total factor productivity of economies on the pretext of non-availability of reliable data. It has been argued in technological capability literature that the developing countries must invest in R&D to acquire the technical capability needed to make use of the public domain knowledge to enhance its productivity (Cohen and Levinthal, 1989; Fransman and King, 1984). Thus, it is amply clear that international R&D spillovers will not contribute to productivity gains until developing countries invest in R&D.

The Framework of Empirical Analysis

From the preceding discussion, it is amply clear that technological progress plays a significant role in explaining the long-run economic growth. The endogenous growth theory, however, views commercially-oriented innovation efforts that respond to economic incentives as a major engine of technological progress and productivity growth. This effort takes the form of investment in technological capability, which is the ability to make effective use of technological knowledge and generate sizeable spillover benefits. The developing countries which invest in R&D are able to receive international R&D spillover benefits. The impact on GDP growth and level of productivity of knowledge spillovers will be larger for those countries which are more integrated via international flows of trade. Thus, the impact of externality and the trade strategy is subject to security here. The model used here to test this hypothesis is derived, in a conventional manner, from a production function in which both domestic and foreign R&D capital stock as an input in addition to the capital and labor inputs have been included. The international R&D capital and labor inputs have been included. The international R&D capital stock is included in the production function in order to capture the

externalities, learning by watching and spillover effects associated with it. In the usual notation the production function can be written as follows:

(1) $Y = F(L,K,S,R)$

where:

Y is the gross domestic product;

L is the labor input;

K is the domestic capital stock;

S is the international spillover R&D capital stock, and

R is the domestic R&D capital stock.

We assume the production function to be an extended Cobb-Douglas function:

(2) $Y_{it} = A_{it} L_{it}^{\alpha} K_{it}^{\beta} R_{it}^{\gamma} S_{it}^{\delta} E_{it}$

where:

i is 1.2, ... 11 countries and

t is 1.2, ... 24 time period.

In the above specification of production function, the factor other than the own R&D capital stock and spillover capital stock which affect productivity and is observed by the country are summarized in the constant term A_{it}. E_{it} is the random disturbance term. Taking log of equation (2) we have the following regression equation:

(3) $y_{it} = a_{it} + \alpha l_{it} + \beta k_{it} + \gamma r_{it} + \delta S_{it} + e_{it}$

where

$e_{it} = \log(E_{it})$

In view of the well known and formidable problems associated with attempts to measure the capital stock especially in the context of the less developed countries, we follow the precedent set in numerous earlier studies by approximating the impact of capital stock by the share of investment in gross domestic product yielding the following equation:

(4) $y_{it} = a_{it} + \alpha l_{it} + \beta (I/Y)_{it} + \gamma r_{it} + \delta s_{it} + e_{it}$

It needs to be noted that there might be important interactions between the international spillovers capital stock and both import policy and education of a country, that is import shares and secondary school enrollment ratios. Therefore, we also estimate a regression equation based on the following specification:

(5) $\quad y_{it} = a_{it} + \alpha l_{it} + \beta(I/Y)_{it} + \gamma r_{it} + \delta s_{it} + \eta m_{it}s_{it} + \Theta en_{it}s_{it} + e_{it} \ldots$

Our particular interest is in the econometric analysis which quantify the parameter δ, that is the elasticity of output with respect to international R&D capital stock. We expect that the coefficient of international R&D capital stock in equations (4) and (5) is not only positive but also statistically significant and numerically greater for export oriented countries than inward oriented countries.

Data and Variables

The empirical analysis utilizes the official published data and covers the 11 Asian countries over the period 1970-93 period.[1] The data relating to the variables such as gross domestic product (Y), investment (Inv), Labor force (1) and merchandise import (M) has been collected from the World Bank data base published in the World Tables. The estimates of the research and development capital stocks are based on R&D expenditure data from the UNESCO (1985) and UN Year Book (1994). The research and development capital stock is calculated from R&D expenditure while using perpetual inventory method as follows:

$\quad$ Rstock$_i$ = (1-δ) Rstock$_{t-1}$ + R&DExp$_{t-1}$

where R&D exp$_{t-1}$ is the real R&D expenditure in the period t-l; the real R&D expenditure are the nominal expenditure deflated by R&D price index defined as follows:

$\quad$ R&DPI = 0.5WPI + 0.5CPI

where

$\quad$ WPI is the wholesale price index, and

$\quad$ CPI is the cost of living index of urban workers.

$\quad$ δ is the rate of depreciation or obsolescence, which is assumed to be 5 percent.

$\quad$ The benchmark for Rstock is computed by the method suggested by Griliches (1980). The

benchmark for the year 1970 is calculated as follows:

Rstock 1970 = R&D exp 1970/(g+δ)

where g is trend growth rate of R&D expenditures over the period 1970-93.

For each of 11 countries, the foreign research and development capital stock were consternated. Our foreign research and development capital stock is a bilateral import-share weighted average of the domestic research and development capital stocks of each country's trading partners. The R&D expenditure data for the trading partners, mostly industrially developed countries, was collected from the various issues of United Nations Year Book. The bilateral import shares were calculated for each year from 1970-1993 based on the data from the IMP's Direction of Trade statistics.

The secondary school enrollment ratio relative to the population of secondary school age as a proxy for human capital, which is considered as an index of capability, have been used in the analysis.

Econometric Specifications and Empirical Results

To carry out the investigation, we estimate the productivity effects of a country's own R&D capital stock and, international spillover R&D stock as well as physical capital and labor on the individual country's productivity growth, a panel data set for a sample of eleven Asian countries is constructed over the period 1970 to 1993. The estimates of the parameters of equation (4) and (5) will crucially depend upon whether we assume a_{it} to be fixed or random effects (Hsiao, 1986). The specification equations (4) and (5) assume that the intercept can vary over the country and over the periods. By assuming country (one factor fixed effects model) and time specific fixed effects (two-way or two factor fixed effects model), the intercept is specified as follows:

$a_{it} = a + \mu_i + \lambda t$

and e_{it}'s are iid and independent of regressors in equation (4) and (5).

The country and the specific constant terms may capture unmeasured disturbances to the growth of output. A large number of country specific factors that affect the value of the dependent variable but that have not been explicitly included as independent variables, can have the

characteristics of a random variable (one factor and two factor random effects model). The basic assumption here is that the regression disturbances are composed of three independent components - one component associated with time, another associated with cross-sectional units, and the third varying with both the dimensions as follows:

$$e_{it} = \mu_i + \lambda t + \omega_{it}$$

The fixed effect model and random effects model, both one factor and two factor, that is, with country effects and with country and period effects, are estimated using the William Greene's (1991) econometric software known as Limdep Version 6.0. According to Hsiao (1991) the choice of treating effects as fixed and random is a difficult one. In fact, there is a trade-off between efficiency and consistency in the random and fixed effects models, and this trade-off provides an empirical basis on which to make the decision between them. The Hausman (1978) provides a method to test whether the bias from the random effects model exceeds the gain in efficiency. On that basis, the results of the Hausman test reported clearly reject the random effects model in majority of the cases in favor of the fixed effects model. These estimates are shown in Table 1.

The estimated parameters in equation (4) are highly significant. The elasticities of labor, capital and domestic R&D capital stock are positive and highly significant. However, the estimated parameter of international spillover R&D capital stock is highly significant but of a negative sign. The country and period effects model also provides similar values of estimated parameters but the value of adjusted R^2 is slightly decreased and the estimated value of the autocorrelation dramatically increased. The estimated elasticities corresponds to equation (5), which includes the interaction of the international spillover R&D capital stock with both the import share and the secondary school enrollment ratio, are highly significant. However, the parameters of international spillover R&D capital stock and import share weighted international R&D capital stock, that is the interaction term, are having negative sign. It needs to be noted here that the estimated parameter of interaction of the international spillover R&D capital stock with school enrollment ratio is positive and significant. This result is indicative of the fact that country specific efforts to improve the scientific ability of its

Table 1: Estimated Coefficient of Fixed Effects Models.
(Dependent Variable is Logarithmic of Gross Domestic Product)

Sr No	Equation→ Independent variable↓	(4) With Country Effects	(4) Country and Period Effects	(5) With Country Effects	(5) Country and Period Effects
1.	Investment GDP ratio	0.1851* (5.284)	0.3464* (4.716)	0.0151* (8.99)	0.0135* (7.685)
2.	Investment of workforce	2.0793* (27.785)	2.3369* (29.063)	2.0339* (25.695)	1.8696* (7.654)
3.	Logarithmic of R&D capital stock	0.2319* (16.1444)	0.2408* (7.574	0.2003* (14.892)	0.2486* (17.089)
4.	Logarithmic of spillover R&D capital stock	-0.1477* (10.19)	-0.784*** (-1.707)	-0.1464* (-10.974)	-1.844** (-2.538)
5.	Import share multiply by spillover R&D capital stock	-	-	-0.0485* (2.650)	-0.0456** (2.337)
6.	School enrollment ratio multiply by spillover R&D capital stock	-	-	0.0447* (3.519)	0.0273** (1.198)
7.	Intercept	-	0.7032* (27.661)	-	12.997* (2.914)
8.	R^{-2}	0.9968	0.9879	0.9975	0.9978
9.	Estimated autocorrelation	0.4484	0.7379	0.4353	0.4523
10.	N	264	264	264	264

Note: 1. Figures in parentheses are t-values.
2. *Significant at 1% level; ** significant at 5% level; and *** significant at 10% level.

manpower that is the domestic capabilities induces spillover effects.

The fundamental assumption we made, while obtaining above mentioned results, is that the error term is serially uncorrelated. There are several ways in which the error term can have serial correlation; for instance, the effects of unobserved variables vary systematically over time or the effect of transitory variables whose effect lasts more than one period. The correction for autocorrelation by Cochrane-Orcutt transformation will correct for such a bias. The parameter estimates of the fixed and random effects model on Cochrane-Orcutt transformed data are reported in Table 2.

From the parameter estimates obtained from equation (4) and reported in Table 2, it can be seen that the sign of the international spillover R&D capital stock is dramatically changed. It is significant to note here that the elasticity of output with respect to international spillovers R&D capital stock is 0.1404 and is highly significant. However, elasticity of output with respect to both labor and domestic R&D capital stock exceeds that with respect to international spillover R&D capital stock. The parameter estimates obtained from equation (5) shows that the interaction term of international spillover R&D capital stock with school enrollment ratio is of negative sign and also non-significant. Therefore, after deleting this variable, we have obtained the parameter estimates only with one interaction term, that is, import share weighted international spillover R&D capital stock. All the estimated parameters have expected signs and are significant except the coefficient of investment - GDP ratio. The elasticity of output with respect to import share weighted international interaction term is positive and significant at 10% level. These estimates show that the international technological spillovers take place through the interaction with the import shares. Since the Hausman test rejects the fixed effects estimates, therefore, we have shown the parameter estimates from equation (4) and (5) obtained from the random effects model and also reported in Table 2. It is interesting to note here that all the parameters have the positive sign but the coefficients of two interaction terms are non-significant. These results indicate that the international technological spillovers from developed countries to the eleven Asian countries are positive. These countries are able to benefit from the innovations and inventions which originate in the developed countries but the benefits are obtained

Table 2: Estimated Coefficients of Fixed Effects and Random
Effects Models on Cochran-Orcutt Transformed Data
(Dependent Variable is Logarithmic of GDP)

Sr. No.	Equation→ Independent Variable↓	Fixed Effects			Random Effects	
		(4) With Country Effects	(5) With Country Effects	(5) With Country Effects	(5)	(4)
1.	Investment GDP ratio	0.0049*** (1.707)	0.0037 (0.855)	0.2730 (0.888)	0.0044 (1.018)	0.0052*** (1.836)
2.	Logarithmic of workforce	0.6001* (11.995)	0.8645* (10.928)	0.6125* (12.112)	0.4807* (8.219)	0.5133** (11.630)
3.	Logarithmic of R&D capital stock	0.3617* (15.660)	0.3732* (10.798)	0.3623* (15.753)	0.4387* (14.575)	0.4076* (18.635)
4.	Logarithmic of spillover R&D capital stock	0.1404* (7.753)	0.1034* (2.485)	0.1125* (4.819)	0.0750** (1.902)	0.1339* (7.603)
5.	Import share multiply by spillover R&D capital stock	-	0.0311 (0.683)	0.598** (1.877)	0.0562 (1.256)	
6.	School enrollment ratio multiply by spillover R&D capital stock	-	-0.0211 (-0.584)	-	0.0293 (0.864)	-
7.	Intercept	-	-	-	8.2090* (30.711)	8.1461 (0.2081)
8.	R_{-2}	0.9903	0.9808	0.9903	0.8696	0.8557
9.	Estimated autocorrelation	-0.2924	-0.1661	-0.2878	-0.1792	-0.2530
10.	N	253	253	253	253	253

Note: 1. Figures in parentheses are t-values.
        2. *Significant at 1% level; **significant at 5% level; and ***significant at 10% level.

both through simultaneously interacting with developed countries via trade and investing in education to generate domestic technological capabilities.

Turning now to the public policy issue, the high performing Asian countries have adopted a public policy regime which is more open to the outside world and also developed domestic technological capabilities. Therefore, we expect that the international technological spillovers are substantially higher in the high performing (South-east) Asian countries compared with the medium performing South Asian countries. The separate parameter estimates obtained from equations (4) and (5) through random effects model for the high performing and medium performing Asian countries are reported in Table 3. The results reported in equation (4) indicate that the output elasticity of international spillover R&D capital stock in high performing Asian countries is 0.282 (significantly different from zero at 1% level), which compares to an estimated elasticity of medium performing Asian countries of 0.0346, a value which is only significant different from zero at 10% conventional level. The output elasticity of international spillover R&D capital stock from equation (5) is highly significant for the high performing Asian countries and is non-significant for the medium performing Asian countries. In essence, what these results indicate is that while international technological spillovers is a potent driving force in the productivity growth of the high performing Asian countries it exerts a meager influence upon the productivity growth of medium performing Asian countries. This strongly supports for the policy regime which is a judicious combination of trade policy and domestic institutional and technology policies.

Conclusion

This paper has investigated, within endogenous theory framework, the contribution of R&D capital and international spillover R&D capital, in combination with domestic investment and workforce to the productivity growth in Asian countries. We have used panel data on GDP, workforce investment to GDP ratio, domestic R&D investment and trading partners in R&D investment of eleven Asian countries over the period 1970-1993 to estimate the extended Cobb-Douglas production function. In the paper we considered two alternative categorization of countries according to policy

Table 3: Estimated Coefficients of Random Effects
Model on Cochrance-Orcutt Transformed Data

Sr No	Equation→ Independent Variable↓	South Asia		South East Asia	
		(4)	(5)	(4)	(5)
1.	Investment GDP ratio	-0.0032 (-1.069)	-0.0012 (-0.325)	0.0108* (4.545)	0.0112** (1.961)
2.	Log of labor	1.2702* (16.371)	1.2939* (17.161)	0.3079* (8.019)	0.2742 (4.235)
3.	Log of R&D capital stock	0.2448* (10.067)	0.2250* (9.091)	0.2556* (11.674)	0.2744* (5.651)
4.	Log of spillover R&D capital stock	0.0346*** (1.923)	0.0263 (1.135)	0.2820* (15.267)	0.1714* (2.353)
5.	Import Share Multiply by spillover R&D capital stock	-	-0.0004 (-0.865)	-	0.0003 (0.555)
6.	School enrollment ratio multiply by spillover R&D capital stock	-	0.0032 (1.487)	-	0.0009** (1.751)
7.	Constant	4.6917* (16.438)	4.6151* (18.252)	9.0899* (42.845)	9.222* (26.240)
8.	R_2	0.8870	0.8779	0.8949	0.9446
9.	Estimated autocorrelation	-0.2116	-0.1834	0.2283	0.3080
10.	N	115	115	138	138

Note: 1. Figures in parentheses are t-values.
         2. *significant at 1% level: **significant at 5% level: and *** significant at 10% level.

regime, that is, high performing Asian countries (HPAC) and medium performing Asian countries (MPAC). We specify the models which eliminate unobserved heterogeneity due to omitted factors of production and specification tests are used to select a well behaved model. The final parameter estimates show evidence for the international technological spillovers for the Asian countries. More specifically, the HPACs show amazingly strong international technological spillovers compared than that of the MPACs. An important policy implication which emerges from the empirical evidence is that the public policy which encourages faster growth of international technological spillovers would be conducive to generate higher productivity growth in the developing countries.

Note

1. The eleven Asian countries included in the data set are as follows: (1) Bangladesh; (2) China; (3) India; (4) Indonesia; (5) Korea; (6) Malaysia; (7) Nepal, (8) Pakistan; (9) Philippines; (10) Sri Lanka; (11) Thailand.

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