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Human Resource Development and Economic Growth in Bangladesh: An Econometric Analysis

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Abstract

This study empirically verifies the contributions of human resource development (HRD) efforts in the growth process of Bangladesh. In order to conduct the empirical analysis, a hypothetical growth model is constructed in light of two prominent endogenous growth models, ie, Lucas (1988) and Romer (1986, 1990), and a couple of econometric tests, ie, Augmented Dickey-Fuller (ADF) unit root test and Engle-Granger cointegration are done. In this research, the Engle-Granger cointegration tests have suggested a positive correlation between HRD activities and economic growth process of Bangladesh. Among the HRD activities, investments in education have played a stimulating role and R&D expenditures have made a weak but positive contribution in growth. Besides HRD, there is also evidence that 'exports' have played an important role in Bangladesh's growth.

Keywords: Growth theory, HR development, Bangladesh, Unit root test, Cointegration test

1. Introduction

In the post-world war II era, the regional capacity to provide financial resources to education and accumulation of knowledge with diffusion effects enabled a number of economies to enjoy fast and robust economic growth rates (Ke and Bergman, 1995; Heraud, Hussler, Munier and Ronde, 2003). In middle-income economies, workforces with more education and knowledge were better able to switch to other companies or initiate their own businesses and, thus, appropriated the knowledge-spillovers for their economies (Mutti, 2004). The *human resource profile* of these economies, therefore, appeared to be one of the most important explaining factors of their faster growth experiences. The importance of human resources in the growth of these economies can be rightly explained in the following ways:

> Human resources constitute the ultimate basis for the wealth of nations. Capital and natural resources are passive factors of production; human beings are the active agents who accumulate capital, exploit natural resources, build social, economic and political organization, and carry forward national development. Clearly, a country which is unable to develop the skills and knowledge of its people and utilize them effectively in the national economy will be unable to develop anything else (Harbison, 1973, p.3).

Regardless of physical capital, the importance of human resource development (HRD) in the process of economic growth has been theoretically outlined in a couple of leading endogenous versions of the neoclassical theory of growth: Lucas (1988) and Romer (1986, 1990). These models indicated the importance of human capital and intangible capital as the source of technological progress leading to economic growth. In the year 1962, Gary Becker first explained 'human capital' under a theoretical framework and suggested to treat education as an investment to increase productive capacity and higher earning potentials of the labour force (Machin and Vignoles, 2005: 3). In a similar fashion, Uzawa (1965) defined 'human capital' by the purposive education and training of workers. Intangible or less tangible capital is referred to good institutional arrangements, transparent government, absence of corruption, free press and media, facilities and practices to adopt ideas and diffusion of advanced knowledge, stable politics, etc. (Webster & Jensen, 2006). Webster & Jensen (2006) highlight the importance of intangible capital as follows:

> In recent times, it has been argued that intangible capital plays an increasingly important role in modern capitalist economies: academics, policymakers and the popular press talk about the emergence of a 'new economy' dominated by investments in human capital and 'knowledge workers' (p.82).

In their empirical studies, Yah and Lloyd (1986), Mattisson (1997), Erixon (1998), Rowen (1998), Kim and Nelson (2000), Harmon, Oosterbeek and Walker (2000), Temple (2001), among others, pinpointed the significant role that heavy investment in HR development (HRD) activities played in the economic emancipation and progress of the East Asian economies. The experiences of these countries highlight that as quality of people upgrades and transforms into 'dated labour' (workers with state-of-the art *know-hows* and *know-whys*), the contribution of these people to further development of the country enhances to a great extent. The reason is simply that a well-educated population is able to produce more qualified outputs and adapt quicker to new technology than a poorly education population (Becker, 1993). Another aspect of labour upgrading is that human beings are the source of new ideas and of innovation (Barro, 1991). Government decisions to invest in development of HR and accumulation of knowledge may, therefore, be a result in a growing economy as well as an important instrument in fostering economic growth.

For the purpose of an empirical study, this study has chosen Bangladesh– one of the next-11 emerging market economies located in South Asia – as a case study. For empirical testing, first, a theoretical framework is developed in light of the growth models of Lucas (1988) and Romer (1986, 1990), and, then, some econometric tests, eg, Augmented Dickey-Fuller (ADF) unit root test and Engle-Granger cointegration, are conducted on Bangladesh's growth experience for the period 1991-2010. Bangladesh – formerly the eastern wing of Pakistan – emerged on the world map as an independent state on 16 December 1971. Bangladesh's independence was expected to lead to higher economic growth and greater well-being of the people than would have been possible with continued partnership with Pakistan (Sharif, 2011). In this connection, this study finds it appropriate to examine the extent to which that expectation has been fulfilled by the course of economic growth taking place since then. As Gertler (2006), Lall, Weiss and Zhang, (2005), Rodrik (2006) and Xu (2007) suggested, one way to conduct this empirical examination is to look at the contribution of technical progress (via human capital and knowledge accumulation) in the growth process of an economy. This study has, therefore, made an attempt to investigate empirically the contribution of HRD efforts in the growth process of Bangladesh.

2. Comparative Education and R&D Scenario in Bangladesh

The experience of the East Asian NIEs suggests that these economies succeeded in achieving higher growth rates than the world averages due to the large base of human capital mainly as a result of investments on education, health, R&D, etc. At the outset, a large fraction of unskilled workforce and a minuscule physical capital were the core resources for their industrial development. With the accumulation of human capital stock, these countries eventually attracted high value-added MNCs and caused faster economic growth (Khan, 2007). Although lagging behind the East Asian counterparts, Table 1 shows that Bangladesh has performed really well in comparison to Japan and the South Asian neighbours. In light of the current level of investment on HRD in the South Asian countries and Japan, it would not be difficult for Bangladesh to develop the skills required for attracting investment in hi-tech industry, eg, engineering, chemicals, etc.

Table 1 about here

Virmani and Rao (1999) highlighted that global industrial R&D per head nearly trebled in 13 years, from $23 in 1985 to $72 in 1997. In the industrial countries, the figures were $122 and $402, and in the developing world, they were $0.7 and $4.6. East Asia (excluding China) spends $31 per capita on R&D, compared to only $0.3 for South Asia and $6.3 for Latin America (Lall, 2002). A picture of the R&D expenditure in Bangladesh is compared with respect to the Japan, East Asian Tigers economies (South Korea, Taiwan and Singapore) and South-East Asian emerging economies (Indonesia, Malaysia and Thailand) in Table 2.

Table 2 about here

Behrman and Fischer (1980), in their case studies on R&D in developing countries (DCs), indicate that R&D activity in the developing world is only able to adapt imported product and process technologies to local conditions. But there is evidence which suggests that the DCs also perform R&D activities oriented towards a search for and developing new products and processes (new from the point of view of the Third World) as well as (c) basic research (Brundenius and Goransson, 1993; Parthasarathi, 1987). Some of the trends observed in technology transfer (TT) in the DCs indicate that R&D has not been playing a leading role in those countries. Due to lack of recognition of the role of research in innovation, DCs usually spend a negligible amount on R&D (Virmani and Rao, 1999).

Bangladesh, being a DC, is no exception in this regard. As Table 2 shows, R&D expenditure in Bangladesh has been very insufficient as compared to the leading Asian NIEs during 1994-2008. Empirical validation of this observation by checking R&D's contribution in Bangladesh' growth is, therefore, of interest in this study.

3. The Theories of Economic Growth

Much of the recent work on economic growth in relation to HRD can be viewed as refining the basic economic insights of classical economists. For instance, Solow (1956), Swan (1956) and Cass (1965) expanded the work of J.S.Mill (1848) and developed the neoclassical growth models. In these models, no floor for HRD concepts like 'human capital' and 'knowledge' has been explored or analysed. For example, the Solowian theory only assumed technical progress as exogenously determined without making any further analysis on it. Then the models of new growth theory attempted to endogenise HRD by examining its driving forces. Among all, Lucas (1988) has been one of the first theorists who incorporated 'human capital' into the production function. The contribution of the work of Romer (1986, 1990) and Stockey (1991) to new growth theory have also been given great attention in the literature for their attempts to explain technical progress through accumulation of 'knowledge'. As Babatunde & Adefabi (2005) explained, "Endogenous growth theory predicts positive externalities and spill-over effects from development of a high valued-added knowledge economy which is able to develop and maintain a competitive advantage in growth industries in the global economy (pp.3-4)". Due to their relevance to this study, some important insights of the growth models by Lucas (1988) and Romer (1986, 1990) are highlighted here.

As Lucas (1988) suggests, one of the most important forms of capital accumulation is acquisition of skills through schooling, on-the-job training, etc. which are nothing but investments in human capital. If an economy invests a sufficient amount of resources in human capital accumulation, it will enjoy a long run steady state growth (Easterly, 1991, 2001). The consideration of human capital as a new factor of production has made the Lucas' (1988) growth model different from the Solowian (1956) neoclassical model (ie, output of an economy depends on the use of inputs – physical capital and labour – subject to some exogenous technological factor). Otherwise, the Lucas model is found almost resemblant to the Solow model. The Lucas' production function can be shown in the following equation form:

$$Y = AK(t)^{\beta} [u(t)h(t)L(t)]^{1-\beta} [h_{\delta} (t)^{\gamma}] \quad \dots \quad \dots \quad \dots \quad (1)$$

where,

Y = f (Physical capital, Human capital, Labour),

AK(t) = [Constant (assumed) level of Technology, A] [Capital, K(t)],

L(t) = Labour force,

h(t) = Level of skill acquired by each labour of the force through education,

u(t) = Non-leisure time devoted to current production,

[u(t)h(t)L(t)] = Efficiency / productivity of labour force,

$[h_{\delta} (t)^{\gamma}]$ = External effects of human capital.

Romer (and his colleagues) believed that technological progress is crucial for understanding growth. Therefore, he first revived the theory of growth by adding an endogenous factor, ie, knowledge (eg, about how to make things) to the neoclassical production function which considers 'knowledge' as exogenous and as a public good (freely accessible to all). He treated 'knowledge' as an important input in production for each firm, leading to the production of new knowledge. Griffith (2000) argued that diffusion of knowledge depends largely on R&D spending and showed using econometric evidence that "R&D expenditure plays a role in assimilating the research discoveries of others as well as its conventional role as a source of innovation. (pp.5-6)" However, Romer's view can be expressed in the following single equation:

$$Y = F (R, K, H) \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (2)$$

where,

R = Research,

K = Physical capital, and

H = Human capital.

In equation (2), the representation of research and human capital, ie, the consideration of a broader concept of capital including physical and human components, depicts the absence of diminishing returns to capital.

As outlined in Sharif (2011, fig. 3.3, p.49), the theories of endogenous growth have shifted attention to the importance of education, learning, research activities, and, more generally, the spread of ideas as the causal factors of technical progress leading to a country's economic growth. These theories, in this way, have also been able to venture into the 'residual' and break down total factor productivity (TFP) in technical factors. Although the growth theorists have highlighted the importance of investing in labor in a multiple ways such as education and training (human capital), research, learning, among others, this study will focus on 'human capital' and 'knowledge' for empirical examination.

4. Empirical Methodology & Data

To check the contribution of HRD in growth for the period 1991 – 2010, a hypothetical growth model (for Bangladesh) is formulated (equation 3 below) on the basis of the review of theoretical literature and thus tested on time series data. Recent research works (eg, Roy & den Berg, 2006; Babalola & Aminu, 2010; Dauda, 2010) have shown that many macroeconomic time series contain unit roots and applying ordinary estimation techniques, eg, OLS, to estimate relationships with unit root variables may yield misleading inferences. According to Adebayo (2006), "In the literature, most time series variables are non-stationary and using non-stationary variables in the model might lead to spurious regressions. The first or second differenced terms of most variables will usually be stationary" (p.14). This study, therefore, used (a) the Augmented Dickey-Fuller test to examine unit roots and (b) the Engle-Granger Approach to conduct the cointegration test. This study also used error-correction mechanisms to take care of short-term dynamics. Altogether, the importance of using these procedures in this study can be explained in the following ways from Ekanayake (1999):

> These econometric techniques have gained popularity in recent empirical research for a number of reasons including (a) the simplicity and relevance in analyzing time-series data, and (b) the ability to ensure stationarity and to provide additional channels through which Granger-causality could be detected when two variables are cointegrated. (p.45)

For the empirical estimation, all yearly data for the period 1991 - 2010, without the loss of any year are used. The estimated model is based on a hypothetical single linear equation which was formulated on the basis of Lucas and Romer (refer to equations 1 and 2 above) and the advances in growth theory that have developed new growth factors, such as *government spending* (GOV) and *trade* (INT) in the aggregate production function. For example, Loizides and Vamvoukas (2005:125) conducted an econometric analysis for the period 1960-95 and showed that the share of government spending in GNP resulted in economic growth in UK and Ireland both in the short run and in the long run. Although the empirical literature accounted different causal factors for growth, these typically argued that increasing volumes of trade had positive correlations with economic growth (Calderon and Poggio, 2010, Ekanayake, 1999; Kormendi and Mequire, 1985; Tyler, 1981; Balassa, 1978; Heller and Porter, 1978; Michaely, 1977). Due to their empirical significance, government spending (GOV) and trade (INT) are incorporated in equation 3 to verify their causal effects in Bangladesh's economic growth.

The proposed hypothetical linear equation is as follows:

$$\beta_0 + \beta_1 TCA_t + \beta_2 HCA_t + \beta_3 ICA_t + \beta_4 INT_t + \beta_5 GOV_t + U_t \quad \ldots \quad \ldots \quad (3)$$

where,

t = 1,2, … , T;

Yt highlights real annual GDP, ie, the dependant variable in the linear regression equation;

TCA (tangible capital assets) depicts the real gross fixed capital formation – GFCF (deflated by consumer price index) to represent physical capital accumulation;

HCA (human capital assets) indicates the share of yearly education-investments in GDP;

ICA (intangible capital assets) highlights R&D expenditures in share of GDP to proxy for 'accumulation of

knowledge';

INT shows exports value in share of GDP to represent trade factor; and

GOV refers to total yearly public expenditure.

The data on real GDP, real GFCF and exports were sourced from different issues of International Monetary Fund (IMF) and International Financial Statistics Yearbooks; budget allocation to education, R&D expenditures and government spendings were collected from Bangladesh Bureau of Statistics (BBS) yearbooks.

5. Econometric Test Results

By the use of time series data for the period 1991-2010 and with an application of the above-mentioned empirical techniques, this study obtained the following results:

5.1 ADF (Augmented Dickey-Fuller) Unit Root Results

Prior to the ADF test, a null hypothesis of trend = 0 (ie, no trend) and $\rho = 1$ (ie, presence of unit root) is made. Then the ADF Unit Root Test is conducted in three steps:

First, the null hypothesis of trend = 0 and $\rho = 1$ is checked for its significance (see Table 3, column 3). Table 3 displays that the H_0 : (trend, ρ) = (0, 1) cannot be rejected for any of the variables, depicting the presence of a unit root but no trend.

Second, since the H_0 cannot rejected, the significance of representation of the series without a trend term, $\beta = 0$ (see Table 1, column 4) is tested. The second step exhibits that for each variable the hypothesis of a unit root in labels cannot be rejected at the 1% level, but at 5% level for the HCA and the GOV. This position indicates the necessity of differentiation of the variable to obtain stationary variables in third step.

Third, the difference in each series is checked for its stationary (see Table 1, column 3).

Table 3 about here

The final result, presented in column 4 of Table 4, highlights that all variables are stationary and integrated of order one, I(1). But a note of caution is order here. As Campbell and Perron (1991) suggest, the unit root hypotheses are not easy to evaluate. In view of the evaluation difficulties, although HCA and GOV may well be stationary in labels, the variables would in this empirical examination be treated as non-stationary. Thus, because of the non-stationary situation a regression of these variables would not be reliable, unless the variables are co-integrated. As the variables are integrated of same order, the existence of co-integrating relationship is tested and thus the co-integrated models are formulated.

Table 4 about here

5.2 Engle-Granger Co-Integration Results

Like the Augmented Dickey-Fuller (ADF) test, a null hypothesis of co-integration = 0 has been made. Then the column 8 in Table 5, ie, examining the residuals from the ADF-regressions, highlights the following results:

Table 5 about here

The ADF-statistics of -5.23 (-5.32) being larger than the critical values of - 4.48 (- 4.25), the null hypothesis of no co-integration in models 1 and 2 can be rejected at the 95% significance level, in favour of the alternative hypothesis of co-integration. On the other hand, the null hypothesis of no co-integration in model 3 (Table 5) cannot be rejected as the critical value (-4.15) exceeds the ADF-statistics (-3.41). Therefore, the conclusion would be no co-integrating relationships between growth and the explanatory variables when the international trade (INT) is excluded from the regression. In light of the cointegration tests, the following long-run equations can be established:

Model 1: GDP = 9.03 + .09 TCA + .13 HCA + .04 ICA + .11 INT + .03 GOV …….. (4)

Model 2: GDP = 9.55 + .10 TCA + .11 HCA + .01 ICA + .09 INT ……. (5)

All the variables, other than government expenditure (equation 4) and intangible capital (equations 4 and 5) have their anticipated signs. Interestingly, "human capital" exerts a positive long-run effect on growth. For example, the elasticity of GDP with respect to human capital (HCA) is high (.13 and .11 in models 4 and 5 respectively) – depicting a 1%

increase in investment in education (HCA) will result in .13% as well as .11% increases in GDP, if the other explanatory variables are held constant. Other than HCA, trade has strong relation with growth in a positive direction. Government expenditure has exerted a positive long-run impact on growth just in the opposite way it is expected to behave with growth. Now, comparing all the explanatory variables (other than tangible/physical capital) in both the models above, it is evident that investment in education (a proxy of human capital) has the highest rate of return as far as growth of GDP is concerned. The above growth models lead this paper to a very concrete decision that in an economy like Bangladesh, higher investments in HRD (eg, education) with investments in other factors contribute largely to the gross output. Besides human capital and international trade, the above formulated models pinpoint the necessity of drawing special attention to the qualitative- as well as quantitative- improvement in R&D activities.

6. Empirical Findings

Behind a country's unique and remarkable economic success, a plenty of factors are suggested by academics, business people and policy-makers. But this paper has attempted to identify the special role of HRD from the viewpoint of economic growth-differentials among countries. To depict the HRD efforts, two variables, ie, 'human capital' (education) and 'intangible capital' (R&D expenditure) are utilised in the light of two leading new models of growth by Lucas (1988) and Romer (1986) respectively. For an empirical judgement of HRD's role in growth, Bangladesh's growth perspective was considered in this study.

The models to test for co-integrating relationships between growth and a set of explanatory variables including HRD made it possible to formulate two long-run equations for Bangladesh economy for the period 1991-2010. The regression analysis presented in the 'empirical examinations results' discussion focuses an important insight into the study. It shows positive long-run influence of HRD (here, human capital and knowledge) on growth and hence supports the theoretical hypotheses of Lucas (1988) and Romer (1986). This, in fine, materialises the prediction regarding HRD's positive consequences with particular emphasis on 'human capital', as assumed in the introduction of this study. The result indicates that purposeful investments in HRD (specially, education) have contributed to stimulate the growth of the economy.

Besides HRD, a positive effect on growth is noticed from the traditional variable supporting the theory of gains from world integration, knowledge spill-over and learning-by-doing (one form of 'human capital' accumulation). All these are the consequences of external trade that offers diffusion of knowledge and technical know-hows from the advanced world (Eknayake, 1999). Therefore, it is very natural to argue that 'knowledge', 'human capital' and 'trade' are interrelated and to some extent dependant on each other. As a result, since this study considers all these three variables, a question of some interrelationships between these may naturally arise which, consequently, may also raise a question of accuracy of the empirical findings. This may, therefore, illustrate a weakness of this empirical study.

To avoid the empirical weakness of possible correlation between growth variables, economists cunningly take the shelter of 'residual' to explain growth differentials among countries by considering 'human capital' as an independent variable and 'knowledge' as 'total factor productivity' (TFP) or residual. In this way, they rescued the theory of Solow on the one hand, and, on the other, authorised the direct roles of 'human capital' (by endogenising it) and 'knowledge' by exogenising it as a public or free good. This tricky way of explaining 'knowledge' theoretically and Bangladesh's growth perspective in practice largely motivated me to take the way of considering 'knowledge' as an independent factor (distinct to 'human capital'), rather than putting it in residuals unlike the major previous growth studies. Howbeit, empirically, this study has well been successful to highlight the significance of 'human capital', among all other factors, in a country like Bangladesh's growth process.

Theoretically, 'government consumption' is assumed to affect growth negatively as it is related to non-productive government consumption and has distorting effects on the private markets. Piazolo (1995) observed that the total government consumption have had a negative impact on growth in South Korea, although Grier and Tullock (1989) and Barro and Sala-i-Martin (1995) found the positive impact in the East Asian context. Like the later studies, this study has got the positive influence of 'government expenditure' on Bangladesh's growth. It has been positive because, the defence expenditure has been kept included in the government consumption. Usually, its exclusion is mostly preferred as it is believed that defence expenditure is likely to stimulate productivity both in the public as well as in the private sector (Barro, 1991). Finally, like all other variables, 'physical capital' has also exerted a positive effect on growth.

7. Concluding Comments

The paper has discussed the effects of 'human resource development' efforts (through accumulations of 'human capital' and 'knowledge') in the process of continual economic growth in a country like Bangladesh. The concepts of endogenous growth theories by Romer (1986) and Lucas (1988) have been used in structuring the hypothetical growth model for Bangladesh. Thus, on the basis of these two endogenous growth models and also on the basis of *a priori* information regarding an emerging economy's growth experience, 'human capital' and 'knowledge' are assumed to be the main causal factors influencing economic growth. For empirical research, both these growth factors have been approximated by the total yearly investments in education and the total yearly spending on R&D in Bangladesh respectively.

Although the new growth theories have certainly overcome an important limitation of the basic neo-classical theory of growth by endogenising 'technical progress' and making these explainable, the problems of uncertainty of results still exist. It is because, both the cross-country and time-series studies suffer from the non-existence of a general theoretical framework in measuring the explanatory growth factors empirically. Besides, the absence of some perfect proxy for economic growth hampers the accuracy of empirical findings too. In line with these likelihoods, the findings of this study, as assumed in introduction and also in the above paragraph, are obviously subjected to this shortcoming. Other than this, the empirical results of the Bangladeshi experience in this paper stress and support the importance of HRD efforts (especially in education) in the process of economic growth, as suggested theoretically by Romer (1986) and Lucas (1988).

Finally, it is interesting to observe that although Bangladesh seems to allocate a negligible amount on R&D in the yearly budgets, the country still manages to enjoy some contributions from R&D in her economic growth (models 1 and 2). One of the reasons of minimum budget allocation could be the lack of recognition of the role of research in innovation where, normally, the operations/production personnel play major role while choosing technology, training, operations, etc., and the role of research comes much later (for more, see Sharif, 2011). In order to catch up the fast growing economies like the BRIC-economies and ensure smooth economic convergence as one of the next-11 market economies of the world, the government of Bangladesh needs to recognise the significance of the facilitation of industry-specific R&D activities, promote university-industry (U-I) linkages and partnerships as well as support the continuous development and grooming of R&D-personnel and prioritise them over operations/production staff in technology-related operations and decision makings. The outcomes of the investment in education would then complement the R&D activities & let the country enjoy 'multiplier' spillover effects from a knowledge-based human capital

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Table 1. Public Spending on Education (% of Government Expenditure), 2001-10

Country	2001	2004	2009-10
Case Country:			
Bangladesh	15.7	14.8	14.1
East Asian region:			
Japan	10.5	9.8	(d) 9.4
Korea	14.7	16.5	(d) 15.8
Hong Kong	22.4	23.2	22.1
Malaysia	20.0	25.2	20.5
South Asian neighbours:			
India	(a) 12.7	(c) 10.7	10.5
Pakistan	(b) 8.5	6.4	9.9
Sri Lanka	N.A.	N.A.	8.1
Sources: World Development Indicators, Various years.			
Notes: (a) year 2000; (b)1998; (c) 2003; (d) 2008; N.A. = not available.			

Table 2. Average Yearly R&D Spending in Selected Countries, 1994 to 2008

Country	R&D Spending as % of GNP	R&D Spending as % of GDP		
	(1994-1996)	(2001)	(2006)*	(2005-08)
Case Country:				
Bangladesh	0.01	0.03	0.03	0.03
East Asian region:				
Japan	2.99	3.07	3.30	3.11
South Korea	1.84	2.39	3.00	2.91
Taiwan	1.43	2.16	NA	1.59
Singapore	0.91	2.11	2.10	1.21
South-East Asian Economies:				
Indonesia	0.21	0.24	NA	0.15
Malaysia	0.13	0.70**	0.80	0.59
Thailand	0.23	0.14	NA	0.17

*Note:** 2002 data;*World Development Report 2007, Human Development Report 2007-08, country data. Sources: Averaged on the basis of World Economic Forum, different issues; World Bank. 2002. World Development Indicators 2002; BANSDOC R&D Survey, 1997, Dhaka; BCSIR R&D Overview 2009, Bangladesh; OECD, Main Science and Technology Indicators; South Korea's government, "2004 Research and development (R&D) activities"; Eurostat.*

Table 3. Results of ADF Unit Root Test

Variables	Lag Length	Dickey-Fuller Test With Trend *P(Xt-1)* *(t-stat.)*	Dickey-Fuller Test With No Trend
GDP	2	- 2.11	- 0.69
TCA	1	- 2.12	- 2.21
HCA	2	- 3.11	- 3.23*
ICA	2	- 1.45	- 2.63
GOV	1	- 2.39	- 2.97*
INT	1	- 3.09	- 2.03
Critical Values			
99%		- 3.96	- 3.41
95%		- 3.41	- 2.84
90%		- 3.13	- 2.55

Note: The tests are conducted with intercepts for all variables. (*), (**) imply that the Null Hypothesis (trend=0, ρ=1) is rejected at the 5% and 1% levels of significance. The critical values used in the tests above are from Fuller (1976: 373) and from Dickey and Fuller (1981: 1063).

Table 4. Results of ADF Unit Root Test

Variables (diff)	Lag Length	DF Test Statistic	Order of Integration
ΔGDP	1	- 3.91**	I (1)
ΔTCA	1	- 4.07**	I (1)
ΔHCA	1	- 4.65**	I (1)
ΔICA	1	- 4.41**	I (1)
ΔGOV	1	- 4.51**	I (1)
ΔINT	1	- 5.51**	I (1)
Critical Values			
99%		- 3.43	
95%		- 2.86	
90%		- 2.57	
Note: The tests are conducted with intercepts for all variables. (*), (**) imply that the Null Hypothesis (trend=0, ρ=1) is rejected at the 5% and 1% levels of significance. The critical values used in the tests above are from Fuller (1976: 373) and from Dickey and Fuller (1981: 1063).			

Table 5. Results of Engle-Granger Cointegration Tests

Cointegration Vectors							RESID ADF t-Statistic	Critical Values (5%)	Lag Length
Model 1									
GDP	Intercept	TCA	HCA	ICA	INT	GOV	- 5.23*	- 4.48	1
	9.03	.09	.13	.04	.11	.03			
Model 2									
GDP	Intercept	TCA	HCA	ICA	INT		- 5.32*	- 4.25	1
	9.55	.10	.11	.01	.09				
Model 3									
GDP	Intercept	TCA	HCA	ICA		GOV	- 3.41*	- 4.15	2
	8.83	.15	- .03	.05		.006			
Note: (*) indicates that the null hypothesis (H_0) of no cointegration is rejected at the 5% significance level. Critical values can be found in Charemza and Deadman (1992: 322). The ADF t-statistics are based on the ADF-regression without intercept and trend term. Also, the critical values found in Charemza and Deadman (1992) depend on the number of estimated coeficiencts in the cointegrating vector. However, the critical values have been simulated and are thus subject to some error. This is something to be aware of while at the time of drawing the conclusion of the cointegration (this study is no exception in this respect).									