

## Relationship between Health Expenditure and GDP in an Augmented Solow Growth Model for Pakistan: An Application of Co-integration and Error-Correction Modeling

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### Abstract

*This paper examines the temporal interdependence between gross domestic product and health expenditure per capita for Pakistan in an augmented Solow growth model suggested by Mankiw, Romer and Weil (1992) for the period of 1973-2001. This paper is an extension of the MRW model by incorporating health capital proxied by health expenditure to the augmented Solow model. Moreover, an openness variable is also included in the model in order to capture the effect of technological changes on growth. The paper employs co-integration, ECM methodology and several diagnostic and specification tests. The empirical findings show a significant and positive relationship between GDP and Health Expenditure, both in the long- and short-run.*

### 1. Introduction

Since the classic pioneering work of Solow (1956), there have been significant developments in the theoretical and empirical literature on endogenous growth models. This initial work analysed economic growth by assuming a neoclassical production function with decreasing returns to capital in which rates of saving and population growth were considered exogenous. The model was augmented by Mankiw, Romer and Weil (1992) with the inclusion of human capital known as the MRW model. Later, Barro (1997); Gemmell (1996) found human capital as a significant factor in determining growth. Similarly, Müller and Upadhyay (2000) examined a significant impact of interaction between human capital and openness as a measure for the country's ability to absorb technological advances; this has a significant effect on total factor productivity. An important issue in this perspective has been highlighted by Siddiqui, Afridi, and Haq, (1995) that improvement in the health status of the population is an important

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component of human capital formation. Improved health status of a nation creates an outward shift in the labour supply curve and increases productivity of labour with an increase in the productivity of investment in other forms of human capital, particularly education.

Most of the studies in this area have been based on the cross-country panel data (see for example Blomqvist and Carter 1997; Gerdtham *et al.* 1992; Hansen and King 1996; Hitiris and Posnett 1992; Knowles and Owen 1997; Nancy and Paul 2001; Temple 1999) with no indication of any time-series country specific study. Moreover, with the exception of Hansen and King (1996), Nancy and Paul (2001), the previous studies have not focused on the stationarity and co-integration properties of the data.

The objective of this study is to examine the presence of co-integration between Gross Domestic Product (GDP) and health capital proxied by health expenditure per capita in an augmented Solow growth model for Pakistan. Although the Solow model has been augmented in different ways, there are a few studies that have examined the effects of health capital on growth; for instance, Knowles and Owen (1995; 1997) have examined the effects of incorporating health capital in the MRW model.<sup>1</sup>

This paper is an extension of the previous literature for numerous reasons. Firstly, it augments health capital in the Solow growth model for Pakistan. Secondly, the modeling approach is based on the multivariate maximum likelihood-based inference of co-integrated vector autoregression (VAR) models developed by Johansen (1988, 1991, and 1995). As is well known, the multivariate modeling strategy offers a major advantage in that multiple co-integrating relations can be modeled in a system without the need to impose arbitrary normalisations necessary in the single-equation Engle-Granger two-step co-integration approach.

The paper comprises five sections including the present one. Section 2 describes the growth model which has been augmented by inclusion of investments in human capital, particularly health. Section 3 presents issues pertaining to data. Section 4 offers the empirical analysis. The last section provides the conclusion.

## **2. The Health Capital Augmented Growth Model**

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<sup>1</sup> In their model, the labour variable in an aggregate production function of education and health was augmented. Their result suggests that, incorporating human and health capital as labour augmenting or as separate factors of production does not change the conclusions empirically.

We begin by specifying a Cobb-Douglas production function with two factor inputs, capital and labour,

$$Y_t = K_t^\alpha A_t L_t^{1-\alpha} \quad (1)$$

Where  $Y_t$  is real income,  $K_t$  represents physical capital,  $L_t$  is labour, and  $A_t$  is level of technology parameter reflecting how well a country does at transforming inputs into outputs.  $A_t$  is specified as:

$$\ln A_t = \Pi X_t \quad (2)$$

Where  $\Pi$  is the parameter vector to be estimated and  $X_t$  is a vector of variables determining total factor productivity (TFP). The vector  $X_t$  contains the log-level of the degree of openness of the economy  $O_t$  since a country that is more open to the rest of the world has greater ability to absorb technological advances generated in leading nations (Romer, 1992; Barro and Sala-i-Martin, 1995). For simplification, labour is assumed to grow exogenously at rates of 'a' defined as.

$$L_t = L_0 e^{at} \quad (3)$$

Defining  $k_t = (K_t/L_t)$  and  $y_t = (Y_t/L_t)$  as the stock of capital and the level of output per unit of labour respectively, the evolution of capital is governed by

$$\dot{k}_t = \omega_t^k y_t - (a + \delta)k_t = \omega_t^k k_t^\alpha - (a + \delta)k_t \quad (4)$$

Where a dot indicates change over time,  $\omega_t^k$  is a fraction of output invested in physical capital in period t, and  $\delta$  is the rate of depreciation. The stock of capital ( $K_t$ ) converges to the steady state value of capital ( $k_t^*$ ) defined as.

$$k_t^* = [\omega_t^k / (n + g + \delta)]^{1/(1-\alpha)} \quad (5)$$

Substituting the value of  $k_t^*$  from (4) in (1) and taking natural logs on both sides, the steady state income per capita is written as:

$$\ln y_t = \beta_0 + \frac{\alpha}{1-\alpha} \ln \omega_t^k - \frac{\alpha}{1-\alpha} \ln(n+g+\delta) + \varepsilon_t \quad (6)$$

Where  $\beta_0$  is the intercept and  $\varepsilon_t$  is the random disturbance term. Equation (6) is the simplified form of the Solow model and has been used as the basic model in empirical specifications (see for example Summer and Heston 1988; Barro and Sala-i-Martin 1992; Islam 1995). Later on human capital was included as another input of production (see Barro and Lee (1993), Benhabib and Siegel (1994), Soderbom and Teal (2001)). Augmentation of human capital in the growth model proved to be useful concerning the prediction power and the size of  $\alpha$ , exclusion of human capital creates a specification biased. The production function in equation (1) is now written as:

$$Y_t = K_t^\alpha H_t^\beta A_t L_t^{1-\alpha-\beta} \quad \alpha + \beta < 1 \quad (7)$$

Where H is the stock of human capital (a proxy by average level of education) in addition to the growth in physical capital in equation (3). The stock of human capital growth is determined by:

$$\dot{h}_t = \omega_t^h y_t - (a + \delta)h_t = \omega_t^h h_t^\beta - (a + \delta)h_t \quad (8)$$

Where  $\omega_t^h$  is a fraction of output invested in human capital in the time period t and  $h_t = (H_t/L_t)$  is the human capital per unit of labour. Hence, the equation (6) is now written as:

$$\ln y_t = \beta_0 + \frac{\alpha}{1-\alpha-\beta} \ln \omega_t^k + \frac{\beta}{1-\alpha-\beta} \ln \omega_t^h - \frac{\alpha+\beta}{1-\alpha-\beta} \ln(n+g+\delta) + \varepsilon_t \quad (9)$$

Similar to the human capital augmentation, the Solow model can be augmented to investments in health. The evolution of health expenditure is determined by.

$$\dot{e}_t = \omega_t^e y_t - (a + \delta)e_t = \omega_t^e h_t^\gamma - (a + \delta)e_t \quad (10)$$

Where  $\omega_t^e$  is a fraction of output invested in health capital in the time period t and  $e_t = (E_t/L_t)$  is human capital per unit of labour. Now the equation (9) is written as:

$$\ln y_t = \beta_0 + \frac{\alpha}{1-\alpha-\beta-\gamma} \ln \omega_t^k + \frac{\beta}{1-\alpha-\beta-\gamma} \ln \omega_t^h + \frac{\gamma}{1-\alpha-\beta-\gamma} \ln \omega_t^e - \frac{\alpha+\beta+\gamma}{1-\alpha-\beta-\gamma} \ln(n+g+\delta) + \varepsilon_t \quad (11)$$

The model in equation (10) can be estimated with OLS. In the new endogenous growth theory it has been argued that the degree of absorption of technological advances increases with increases in the openness of a country. Considering this view the openness variable (proxied by trade intensity) is also included in this model in order to capture the effect of technical progress. This will also attenuate the specification bias and increase the robustness of the inferences drawn. Similarly, the addition of human and health capital along with physical capital improves the performance of the Solow model. Investments in human, health and physical capital are expected to have a positive effect on per capita income. Similarly, the openness variable is also expected to have a positive influence on per capita income. It helps in removing the lack of technological needs, so that an increase in the market size or in the availability of production technology affects the returns to innovation and therefore leads to higher per capita income.

### 3. The Data

The data has been acquired from various issues of the *Economic Survey of Pakistan* and Statistical Supplements published by the Ministry of Finance. The data is on an annual basis covering the time period of 1973-2001. The time series includes population, real GDP, real gross fixed capital formation, real physical capital<sup>2</sup> and gross enrollments in primary, secondary and tertiary levels of education taken as a proxy for human capital, because enrollment rates measure the quantitative additions in the form of years of schooling to the stock of human capital. Health expenditure is taken as a proxy for health capital whereas trade intensity defined as trade to GDP ratio is taken as a proxy for openness.

### 4. Methodology and Empirical Findings

Following the convention for time series methodology, the order of integration of the individual series has been tested prior to the co-integration analysis and estimation of the Error-Correction Model (ECM).

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<sup>2</sup> The construction of the capital series is discussed in Annexure I

The Augmented Dickey-Fuller (ADF) and Phillips-Parren (PP) tests are used for this purpose. The ADF test is based on the following equation:

$$\Delta S_t = \alpha + \beta t + \delta S_{t-1} + \sum_{j=1}^p \gamma_j \Delta S_{t-j} + e_t \quad (12)$$

The lag  $p$  is chosen to render the residuals free of serial correlation. We then test the composite null hypothesis  $H_0: \beta = 0, \rho = 1$  using the Dickey-Fuller (1981) statistic  $\phi_3$ . If  $H_0$  is rejected, there is no unit root and the presence of drift and trend can be ascertained by conventional  $t$ -test on  $\alpha$  and  $\beta$  respectively. If  $H_0$  is not rejected we re-estimate Equation (11) setting  $\beta = 0$  and then use the Dickey-Fuller (DF) statistic  $\tau_\mu$ , to test the hypothesis  $H'_0: \rho = 1$ . If  $H'_0$  is favoured, we get additional confirmation about the presence of a unit root. We may then resort to the statistic  $\phi_2$  to test the null hypothesis  $H''_0: \alpha = 0, \rho = 1$ . Rejection of  $H''_0$  argues for the presence of a unit root with drift, and its non-rejection is defined as having a unit root without drift. The same procedure is repeated for the first differenced (growth) series, and if necessary for higher-order differenced series until a stationary series is obtained. However, the Dickey-Fuller test methodology suffers from a restrictive assumption that the error term is i.i.d. When economic time series exhibit heteroscedasticity and non-normality in raw data, then Phillips-Perron (PP) test is preferable to the DF and ADF tests.

Phillips and Parren (1988) developed a generalisation of the Dickey-Fuller procedure that allows for the distribution of the errors. The procedure considers the following regression equation.

$$S_t = \tilde{a}_0 + \tilde{a}_1 S_{t-1} + \tilde{a}_2 (t - T/2) + u_t \quad (13)$$

Where  $T$  is the number of observations and disturbance term  $u_t$  is such that  $E(u_t) = 0$ , but there is no requirement that the disturbance term is serially un-correlated or homogenous. The ADF test is very sensitive to the assumption of independence and homogeneity. It is for this reason that the PP test is preferred to the ADF test.

The results of the ADF and PP tests, applied to level and first difference data, are reported in Annex II Table 1. It is observed from the results that none of the series are non-stationary at level, but all the series are stationary at first difference (at 5% level of significance). Once the order of integration of the series is determined the next step is the co-integration analysis.

#### 4.1. Co-integration analysis

The test for co-integration is given in Annex III Table 1. The Johansen technique (Johansen, 1988, 1991; and Johansen and Juselius, 1990) has been used to test the existence of co-integration in the underlying series. Both, the maximum eigenvalue ( $\lambda_{\max}$ ) and trace ( $\tau$ ) test statistics have been used to determine the number of co-integrating vectors  $r$ . The null hypothesis tested was that there can be no co-integrating vectors among the variables of equation (10). The result shows that the null hypothesis of no co-integration is rejected in both tests at the 1% significance level. Therefore, there is a strong and stable long-term relationship existent among the variables in equation (10).

Given that the Johansen co-integration technique indicated the existence of more than one co-integrating vector, the question is whether it is better to have one or many co-integrating vectors among the underlying series. The existence of many co-integrating vectors may indicate that the system under examination is stationary in more than one direction and hence more stable (Dickey *et al.*, 1994).

#### 4.2. Long-run parameter estimates

The long-run parameters estimated by using the Johansen technique are normalised on the basis of the GDP variable by setting its estimated coefficient at -1. The coefficients and their respective standard errors are given in Table 1.

**Table 1: Estimated long-run parameters**

Normalised on the basis of GDP per capita		
Equation	Coefficient	Std. Error
$Y_t^r$	-1	-
$K_t^r$	0.29*	0.04
$H_t$	0.37*	0.04
$E_t$	0.13*	0.03
$O_t$	0.11*	0.09
Constant	-1.61*	0.17

Note: \* indicates significance at the 1%-level.

**Short-run ECM estimation:**

According to Engle and Granger (1987) co-integrated variables must have an ECM representation. The major advantage of the ECM representation is that it avoids the problems of spurious correlation between dependent and explanatory variables, and makes use of any short- and long-run information in the data. Table 2 presents the sign of the cumulative coefficients and their respective lag structures. The respective lag length for each variable and the sequence in which the variables are entered in the ECM have been selected by using Akaike (1969) FPE criterion and the Caines, Keng and Sethi (1981) "Specific Gravity" (SGC) criterion respectively<sup>3</sup>. Refer to Annex IV, Table 1 for details about the short run elasticities and their respective t-statistics.

**Table 2: Error-correction Specification**

Growth Equation:

$$\Delta Y_t^r = - \sum_{i=1}^2 \alpha_{1i} \Delta Y_{t-i}^r + \sum_{j=1}^5 \alpha_{2j} \Delta K_{t-j}^r + \sum_{k=1}^3 \alpha_{3k} \Delta H_{t-k}^r + \sum_{m=1}^2 \alpha_{4m} \Delta E_{t-m} - \sum_{n=1}^1 \alpha_{5n} \Delta O_{t-n} - \alpha_6 EC_{t-1} + \varepsilon_t$$

Where the symbol  $\Delta$  is the first difference operator,  $\varepsilon_t$  is a white noise. The regressor  $EC_{t-1}$  corresponds to the one year lagged error-correction term and it is expected that  $\alpha_6 < 0$ . With the dynamic specification of the model the short-run dynamics are influenced by the deviation from the long-run relationship depicted by  $EC_{t-1}$ . Notice that the ECM model in Table 2 does not contain an intercept term. The reason is that the error-correction  $EC_{t-1}$  already includes an estimate of it.

The empirical results show that health expenditure is a statistically significant and reliable determinant of growth. Hence, in the short-run growth is an increasing function of all three types of capitals. However, the

<sup>3</sup> For details see Akaike, H. (1969) "Statistical predictor identification" and Caines, P.E.C., Keng, W. and Sethi, S.P. (1981) "Causality analysis and multivariate autoregressive modeling with an application to supermarket sales analysis"



openness variable shows a significant but negative effect on growth in the short-run.

Various diagnostic and specification tests have been applied in order to check the validity of the policy conclusions, which are gathered from the estimation of the ECM model (for detail see Annex IV Table1).

## **5. Summary and Conclusion**

Based on the economic modeling of previous studies using annual data of Pakistan's economy, the paper investigated the possible co-integration between health expenditure and GDP in an augmented Solow growth model in a Cobb-Douglas functional form. It used Johansen co-integration analysis, ECM methodology and different diagnostic tests. Before proceeding to testing for co-integration, unit-root tests were performed using ADF and PP tests. The reported t-values resulting from the ADF and PP test indicated that the underlying series appear to be stationary in first differences. The Johansen co-integration test confirms the existence of a strong and stable long-term relationship among the variables in the growth model.

The ECM technique is applied to avoid the spurious regression phenomenon. The ECM model estimates confirm the existence of a short- and long-term positive and significant relationship between health expenditure and economic growth. Furthermore, the short-run parameters of the other two capitals (i.e. physical and human capital) also have a significant positive effect on the growth variable. In terms of adjustments made to the long-run equilibrium, the error-correction term  $EC_{t-1}$  is found to be statistically significant. The specification and diagnostic test yields satisfactory results. Hence an inclusion of health expenditure as a proxy for investment in health capital also improves the significance of the coefficients of human and physical capital in the growth model.

## ANNEXURE I

## Construction of Capital Stock Series

**Initial capital stock:** The procedure for estimating the overall initial capital stock is shown in Table 1 below. A depreciation rate of 5 % is assumed<sup>4</sup>. Hence, the average life span of capital is 20 years (i.e.  $1/0.05 = 20$  years). If the 5 percent depreciation rate is indeed true, then the amount invested in 1953 would have zero value in 1973. Thus, the value of investment in 1953 of Rs. 7910 million in 1981 prices will be zero in 1973 as shown in the Table. Similarly, the investment in 1954 of Rs. 8856 million will have a remaining value of Rs. 442 million in 1973, while for 1955 investment will have remaining value of Rs. 954 million. If one continues this process until 1973, then one can obtain the value of the overall capital stock in 1973, which is Rs. 22,8266 million at 1980-81 prices.

Table 1: Estimation of initial capital stock

	GCF	1953	1954	1955	1956	...	1971	1972	1973
1953	7910	7910	7515	7139	6782	...	791	396	0
1954	8856		8856	8413	7992	...	1328	1156	443
1955	9539			9539	9059	...	1908	1431	954
1956	10323				10323	...	2581	2065	1548
....	....					...	....	....	....
1971	27842					...	27842	26450	25128
1972	28373					...		28373	26954
1973	29712					...			29712
<b>Initial capital stock in 1973 at 1980-81 prices = 22,8266</b>									

**Capital Stock Series:** The series for capital stock was derived by using the perpetual capital inventory method. That is:

$$K_t = K_{t-1}(1 - \delta) + I_t$$

Where  $K_t$  is the capital stock in year  $t$ ,  $K_{t-1}$  is the capital stock in the previous year,  $\delta (=0.05)$  is the depreciation rate, and  $I_t$  is the investment in year  $t$ .

<sup>4</sup> Other studies have also applied 5 % depreciation rate (see Austria and Martin, 1992)

## ANNEXURE II

Table 1: Tests for Unit-Roots

VARIABLES	Level		First Difference	
	ADF	PP	ADF	PP
$Y_t^r$	-1.91	-1.79	-4.13*	-4.24*
$K_t^r$	-1.99	-14.77*	-3.49**	-3.84*
$H_t$	-2.37	-1.95	-4.26*	-5.66*
$E_t$	0.60	0.60	-3.17**	-4.60*
$O_t$	-2.36	-1.91	-4.79*	-4.25*
$L_t$	-1.20	-1.27	-3.67**	-5.22*

Note:  $*$ ( $**$ )( $***$ ) significant at 1%, 5% and 10% level.

**ANNEXURE III**

**Table1: Johansen Co-integration Test Results**

Maximal Eigen-value Test				Trace Test			
Null H <sub>0</sub>	Alternative H <sub>1s</sub>	Eigen- value	Critical Value (95%)	Null H <sub>0</sub>	Alternative H <sub>1</sub>	LR-ratios	Critical Value (95%)
r=0	r=1	42.67**	34.40	r=0	r>1	127.10**	76.1
r=1	r=2	32.87**	28.14	r≤1	r>2	84.43**	53.1
r=2	r=3	25.36**	22.00	r≤2	r>3	51.56**	34.9
r=3	r=4	16.66**	15.67	r≤3	r>4	26.20**	20.0
r=4	r=5	9.54**	9.24	r≤4	r>5	9.54**	9.2

*Note: \*\* significant at 5% level.*

ANNEXURE IV

Table 1: ECM Estimates

Variables	Coeff.	Short-run Elasticities	t-stats
$\Delta Y_{t-1}^r$	1.32		5.1
$\Delta Y_{t-2}^r$	-1.60		-7.0
$\Delta K_{t-1}^r$	-0.93		-1.3
$\Delta K_{t-2}^r$	5.50	<b>0.54</b>	4.4
$\Delta K_{t-3}^r$	-5.12		-4.9
$\Delta K_{t-4}^r$	0.11		0.2
$\Delta K_{t-5}^r$	1.13		2.6
$\square H_{t-1}$	0.43		5.3
$\square H_{t-2}$	-0.43	<b>0.20</b>	-5.1
$\square H_{t-3}$	0.25		5.5
$\square E_{t-1}$	0.03	<b>0.06</b>	1.5
$\square E_{t-2}$	0.05		4.2
$\square O_{t-1}$	-0.11		-2.7
$EC_{t-1}$	-0.48		-2.5
Adj. R <sup>2</sup> = 0.88		DW = 1.82	
F <sub>ar3</sub> = 0.19		F <sub>het</sub> = 0.67	
JB = 0.53			

EC is the error correction term obtained from the estimated long-run relationship. The last three tests are the diagnostic tests of the residuals from the estimation: F<sub>ar3</sub> is F-stats of up to 3<sup>rd</sup> order residual serial correlation, F<sub>het</sub> tests autoregressive conditional heteroscedasticity and JB is the Jarque-Bera test for normality of the residuals.

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