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CONTRIBUTION OF HEALTH IN ECONOMIC GROWTH: An application of VECM approach for Pakistan

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Health is an important form of human capital. Microeconomic analyses suggest that health of the labour force makes an important contribution to productivity and income. Following the argument of Weil (2001), this study analyzes the possible links between economic growth and health for Pakistan. Thus the main goal of the study is to empirically investigate the importance of health as a direct and indirect cause of Pakistan's economic growth during 1960 - 2000. This is achieved by using VECM approach. The findings indicate that although growth tends to significantly improve health status in Pakistan but health is not Granger causing economic growth directly. There is, however, an indirect causal effect of health on the economic variables that could affect the process of economic growth in Pakistan (labour force, physical capital stock and human capital stock). Therefore, the study concludes that health is an important determinant of higher growth and a key tool available to policy-makers. These results would have important practical implications for public policy in Pakistan by providing policy-makers with a better technical understanding of development-related factors that are derived from the long-term changes in the health of the population.

I. Introduction

In recent years, there has been a burgeoning of empirical research into the factors affecting economPic growth in both the developed and the developing countries. This research interest was initiated by developments in the 'endogenous growth theory,' which emphasizes the role of technological progress, innovations and human resource development (in the form of education enhancement) in the growth

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process [Temple (1999), and Barro (1997)]. Several studies analyzed the impact of factors such as education levels, and showed, for example, that the more educated a population, the higher is its income. Surprisingly, perhaps, they have until recently paid less attention to the effects of health improvements. However, it is becoming increasingly clear that, a real relationship exists between a nation's burden of disease and its income [World Bank (1998), and WHO (1999)].

One key indicator of a population's health status is life expectancy.[1] Recent studies have shown that life expectancy, or survival rate, is a powerful predictor of income levels and of economic growth [Alesina et al., (1996)]. Researchers who performed this analysis suggest that three broad mechanisms are responsible for this effect: (a) improvement in productivity due to a healthier workforce and less absenteeism; (b) the increased incentives that both individuals and firms have to invest in human and physical capital, as life expectancy increases; and (c) the increase in saving rates, as workers have an incentive to save for retirement [Bloom and Williamson (1998)].

Although, labour productivity in the form of human capital, clearly contributes significantly to economic growth, most cross-country empirical studies identify human capital narrowly with education. This ignores the consideration of health as a crucial ingredient of economic growth [Schultz (1999), Strauss and Thomas (1998), Bhargava (1997)]. On economic growth, neither classical nor neoclassical authors gave much attention to the role of human capital, accumulated through education and health as sources of growth. Mankiw et al., (1992), later postulated that there is a significant relationship between investment in human capital and economic growth. While, at the world level, there is substantial empirical evidence that accumulation of capital is an important determinant of economic growth Barro [(1991) and (1997)], and Leveine and Renelt (1992) show that the rate of output growth is strongly related to the initial quantity of human capital.

Strong cross-country correlations between measures of aggregate health such as life expectancy or child mortality and the per capita income are well established [Schultz and Tansel (1992), Bloomet et al., (2000), Strauss and Thomas (1998), Preston (1976), and the World Bank (1993)]. In the developing countries, there are numerous micro studies in the biological and social sciences showing benefits of better health on productivity [Basta et al., (1979), Spurr (1983), Bhargava et al., (1997), and Strauss and Thomas (1998)]. But quantifying the relationship between health indicators and economic productivity is more subtle in the developed countries. Stronks et al., (1997), Barro [(1991) and (1997)] and Sach and Warner (1997), also noted that a rapid increase in human capital development would result in rapid transitional growth.

[1] The age at which a newborn baby is expected to survive.

The study follows the argument of Weil (2001) to analyse possible links between economic growth and health. The present study involves an empirical application to the economy of Pakistan during the period 1960-2000. The main goal of the study is to empirically test the importance of health as a direct or indirect cause of Pakistan's economic growth since 1960. This is achieved by using VECM techniques. We will investigate the effects of a health indicator, adult survival rates (ASR) on economic growth.[2]

The rest of the paper is structured as follows. In Section II we briefly portray, in theoretical terms, the relationship between health, human capital, TFP and economic growth. Information about the data is given in Section III. The empirical analysis of a long-run stable relationship between human capital, health, physical capital, TFP, labour and economic growth is presented in Section IV. Finally Section V summarizes the results of the study for the Pakistan economy during the period 1960-2000, and also presents possible policy implications emerging from the study.

II. Conceptual Framework

The basic neoclassical Solow (1956) model of economic growth, assumes that disembodied technological progress is exogenous to the model. New theories of economic growth [Lucas (1988)] went beyond the limitations of exogenous technological innovation underlying the work of Solow, by considering accumulation of human capital with health as a crucial source of economic growth. Health proxied by life expectancy (or the adult survival rate) in a country is a broad measure of population's health, though it need not accurately reflect the productivity of the labor force. For example, due to poor childhood nutrition, ability of individuals to perform productive tasks diminishes at an early age. But, if there is an easy access to medical care, life expectancy leads to enhancing the productive ability of individuals [IIPS, (1995)]. The productivity loss will be underestimated if life expectancy was used as the sole indicator of health [Murray and Lopez (1996)]. At a general level, capital formation requires that a high proportion of skilled labor force remains active for a number of years; as experience is important for technical innovations that take years of investments in research and development. Because detailed information on such variables are mostly not available we have based our analysis on the adult survival rate as an indicator of health. Moreover, in particular, as investments in education critically depend on survival probabilities, expenditure on children's education is influenced by parents' subjective probabilities of survival. ASR incorporates all these issues, and are potentially important for explaining economic growth.

[2] Data on health indicators at the national level typically comprise of variables such as life expectancy, child mortality, adult survival rates, etc.

This study provides an opportunity to disentangle the effects of health and economic variables on growth because the country is at the stage of economic and social development. When poor health is likely to lead to reduced physical work capacity. The dependence of economic growth on life expectancy until a certain threshold suggests that it would be useful to model the GDP or growth rates using a production function [Christensen et al. (1973), Sargan, (1971), and Boskin and Lau (1992)]. It is also likely that the impact of health indicators such as the adult survival rate (ASR) on growth rates would depend on the level of GDP. This study tries to explore these issues. We expect that health, in the form of adult survival rates, makes a positive and statistically significant contribution to aggregate output. Considering the above arguments we formulate our theoretical model taking into account both economic and health variables to explain economic growth. The study includes variables such as productivity (proxied by Total Factor Productivity growth) human capital, physical capital, output growth-GDP, economically active population (labour force) of Pakistan and the ASR (indicator of health).

We start this formulation first by explaining how the TFP measure is being derived within the context of neoclassical growth model. The method used for calculation is adopted from Kim and Lau (1994), Sargent and Rodriguez (2001), Eichengreen (2002) and Fatima et al. (2003).

Considering a simple Cobb-Douglas production function of the form:

$$Y = AK^{\alpha} L^{1-\alpha} \tag{1}$$

By dividing equation (1) by the labour input

$$\dot{Y} = \dot{A} + \alpha\dot{k} \tag{2}$$

where:

$\dot{y}$ is labour productivity or output per labour.

$\dot{k}$ is capital intensity or the capital labour ratio.

$\dot{A}$ is the rate of growth of TFP.

α is the rate of growth of capital intensity.

The dots (•) on the variables represent the rate of change in each variable. TFP is being measured by the use of equation (2), which is obtained by substracting the contribution of growth in the capital labour ratio from labour productivity growth.[3]

$$\dot{TFP} = \dot{LP} + \hat{\alpha}\dot{k} \tag{3}$$

[3] In the neo-classical framework, capital stock is not an exogenous determinant of growth. Rather, it is an endogenous variable which depends on TFP growth. In a long run steady state a situation where

Where, *LP* is labour productivity and $\hat{\alpha}$ is the marginal productivity of capital (under the assumption of perfect competition and constant return to scale this parameter is equal to the capital share in output). Variables used in the calculation of TFP are taken from the Penn World Table compiled by Summer and Heston (1991).

After calculation of TFP, theoretical framework for the study based on the following equation is formulated:

$$Y_t = f(TFP_t, HC_t, H_t, I_t, L_t) \quad (4)$$

where Y_t is GDP representing economic growth, HC_t is the secondary school enrollment used to represent human capital,[4] I_t represent physical capital stock series,[4] L_t represent the economically active population (labour force), TFP_t represent total factor productivity growth, and H_t represent a proxy for health as discussed before.

The first-order partial derivatives of each of the above equations are all expected to be positive. We expect $\partial Y / \partial TFP_t$ to be positive because economists have recognized since long that Total Factor Productivity (TFP) is an important factor in the process of economic growth [Adenikinju, et al., (2001); Abdelhak, (2000); Nehru et al., (1994); and Edward (1997)]. However, there is a controversy about its methodology and the assumptions on which it is based. Total Factor Productivity measures the synergy and efficiency of the utilization of both capital and human resources. It is also regarded as a measure of the degree of technological advancement associated with economic growth. Higher TFP growth indicates efficient utilization and management of resources, materials and inputs, necessary for production of goods and services. TFP also refers to the additional output generated through enhancement in efficiency arising from advancement in worker education, skills and expertise, acquisition of efficient management techniques and know-how, improvements in an organization, gains from specialization, introduction of new technology and innovation or upgrading of existing technology and enhancement in Information Technology (IT).

all per capita variables are growing at a constant rate, the growth of capital intensity is the same as the rate of growth of labour productivity. This argument is sometimes referred to as the Harrodian rate of technical progress [see, Cas and Rymes (1991)] or the adjusted rate of growth. In the long run the entire labour productivity growth is ultimately the result of TFP growth. In other words, in the long run, if TFP were to stop growing, capital intensity would also stop growing, and there would be no further labour productivity growth (Diminishing returns to capital are responsible for arriving at such a conclusion).

[4] In the absence of appropriate data human capital is proxied by secondary school enrollment. Mankiw, Romer and Weil (1992) and Coe, et al., (1997) also used the same proxy for human capital measurement.

[5] Series on physical capital stock is derived by using Perpetual Inventory method.

We expect $\partial Y/\partial HC_t$ *and* $\partial Y/\partial I_t$ to be positive because Mankiw, et al., (1992), working on augmented Solow model considered human capital and physical capital as crucial determinants of economic growth. In addition it has also been found that education and economic growth have a positive correlation; hence, human capital attained through education enhances economic growth [Barro (1999), (1991), Barro and Sala-i-Martin, (1995), Chuang, (2000), Kruger and Lindalil (1999), Temple (2001), (1999), Freire-Seren (1999), Stores-Letten, et al., (2000), Bassanini et al., (2001), and Aghion et al., (1998)]. Noneman, et al., (1996) further estimated that the effect of the share of GDP invested in human capital on per capita income levels is apposite. As far as physical capital stock is concerned all the studies indicate a significant role of physical capital stock on economic growth.

Furthermore, economic growth also depends on the country's economically active population. As has been argued, productivity depends on the economically active population (labour), quality of labour force (human capital), and its stock of physical capital [Miller et al., (2000), Abdelhak (2000), Nehru et al., (1994), Edward (1997), Adenikinjui et al., (2001), Rao et al., (1995), Lucas (1993) and Coe, et al., (1997)]. Here, it is worth considering that enhancement of productivity (which leads to economic growth) depending on the country's active population, and the quality of that active population in turn depends on health. Health, as argued earlier, improves the productive ability of the work force. Hence, $\partial Y/\partial L_t$ is expected to positively effect economic growth.

III. The Data

For empirical estimation this study used the data on ASR, (representing the health situation in Pakistan), economic growth is proxied by nominal GDP, and is taken from the World Development Indicator (WDI), economically active population (L) is taken from the Penn World Table, while TFP (representing productivity level of the country) and physical capital stock (I) are derived by taking the relevant variables from the Penn World Table [compiled by Summer and Heston (1991)]. Analysis is performed by using the annual data spanning the period from 1960 to 2000.

In the absence of a suitable measures of human capital especially for developing countries, it is very difficult to calculate a human capital series. Most of the studies have used some proxy for human capital. In this study, data on secondary school enrolment is used as a proxy for human capital. Mankiw et al., (1992), and Coe et al., (1997) also used the same proxy for human capital. Data on secondary school enrollment representing human capital is taken from the Economic Survey of Pakistan.

IV. Empirical Analysis

The preliminary step in our analysis is concerned with establishing the degree of integration of each variable. For this purpose we have tested for the existence of a unit root in the level and first difference of each of the variables in our sample, using the well-known Augmented Dickey-Fuller procedure (ADF). ADF test statistic checks the stationarity of the series. The result presented in Table 1 reveals that all variables are non-stationary in their level form. However, the stationarity property is found in the first/second differencing level of the variables. After establishing that all individual series under consideration are stationary (that is all the series are integrated of order one or two), we proceed to study the long run behavioral relationships among these variables. This is done through VAR based multivariate co-integration test developed by Johansen and Juselius (J-J) in 1990.

Table 2 reports the results of both trace and eigenvalue tests. The results of the trace test support the existence of five co-integrating vectors for total factor productivity (TFP_t), physical capital (I_t), labour (L_t), human capital (HC_t), health (H_t) and GDP_t. A look at the maximal eigenvalues also indicates that the three co-integrating vectors in the system are significance at the 5 per cent level. The results, therefore, provide strong evidence of a long run relationship among the variables under study. This implies that each of the coefficients associated with the variables enter the long-run co-integrating vector at a statistically significant level. The implication of these results is that, in general, all variables included in our system adjust in a significant fashion to clear any short-run disequilibrium.

Evidence of co-integration among these variables has several implications. First, it rules out 'spurious' correlation and the possibility of Granger non causality which in turn implies at least a unique channel for Granger causality to emerge (either unidirectional or bidirectional). Second, the actual number of cointegrating (or equilibrium) relationship(s) found will result in a corresponding number of residual series, and hence error-correction terms (ECTs) which we may embed as exogenous variables appearing in their lagged-levels as part of the Vector Error-Correction Model (VECM).

Table 3 reports the results of VECM formulation. According to Engle and Granger (1987), co-integrated variables must have ECM representation. Technically, the error correction term (ECT_{t-1}) measures the speed of adjustment back to the co-integration relationship. The ECT_{t-1} posited to be a force causing the integrated variables to return to their long run relationship when they deviate from it, and thus the longer the deviations, the greater would be the force tending to correct the deviation [Banerjee, Galbraith and Henry (1994)]. The coefficients on the lagged values of ΔTFP_t, ΔL_t, ΔH_t, ΔHC_t, ΔI_t and ΔGDP_t are short run parameters measuring the immediate impact of independent variables on the dependent variable.

TABLE 1

Unit Root Test

	level		1st difference		2nd difference	
	intercept	trend	intercept	trend	intercept	trend
I_t	-0.555347	-2.142314	-3.242719**	-3.146672	-7.308231*	-7.292061*
GDP_t	0.566377	-2.173404	-3.917469*	-4.072614**		
HC_t	1.868886	-1.041686	-4.688507*	-5.934339*		
L_t	1.558217	-1.989565	-1.717851	-2.433408	-3.832919**	-3.807162**
H_t	1.969985	0.15424	-0.318971	-1.571648	-4.5193*	-4.478628*
TFP_t	0.019566	-1.575231	-3.927964*	-3.841233**		

Note: Critical values are: -3.61, -2.94, -2.61 (significant at the 1%, 5%, 10% levels respectively when the 1st difference is constant), and -4.22, -3.53, - 3.21 (significant at the 1%, 5%, 10% levels respectively when the 1st difference is constant and trend).
* (**) significant at the 1% (5%) level.

TABLE 2

Johansen Maximum Likelihood Test for Co-integration

	Likelihood Ratio	5 per cent Critical Value	1 per cent Critical Value	maximum Eigen values	5 per cent Critical Value	1 per cent Critical Value
R=0	188.58050*	114.90	124.75	57.4474*	43.97	49.51
R<=1	131.13310*	87.31	96.58	46.97665*	37.52	42.36
R<=2	84.15645*	62.99	70.05	35.626**	31.46	36.65
R<=3	48.53045*	42.44	48.45	22.64551	25.54	30.34
R<=4	25.88494**	25.32	30.45	19.82784**	18.96	23.65
R<=5	6.05710	12.25	16.26	6.0571	12.25	16.26

Note: * (**) significant at the 1% (5%) level. Johansen co-integration test provides five co-integrating equations at the 5% significance level.

TABLE 3

Granger Causality based on Vector Error Correction Model

Dependent Variable	F-statistics for $\Sigma\Delta GDP_{t-i}$	F-statistics for $\Sigma\Delta I_{t-j}$	F-statistics for $\Sigma\Delta HC_{t-k}$	F-statistics for $\Sigma\Delta L_{t-l}$	F-statistics for $\Sigma\Delta H_{t-s}$	F-statistics for $\Sigma\Delta TFP_{t-s}$	t-statistics for ECT_{t-1}	Direction Causality
ΔGDP_t	8.00*	6.13*	2.36	1.41	0.47	0.47	-2.76*	I -> GDP
ΔI_t	18.00*	3.00***	7.50*	6.00*	3.0***	1.5	-7.07*	GDP -> I HC -> I L -> I H -> I
ΔHC_t	2.44	2.44	11.00*	4.28**	4.89**	1.83	-3.47*	L -> HC H -> HC
ΔL_t	3.73**	4.26**	2.13	8.52*	4.79**	0.53	-.504*	GDP -> L I -> L H -> L
ΔH_t	3.50**	3.50**	4.00**	3.00***	1.00	9.0*	-3.79*	GDP -> H I -> H HC -> H L -> H TFP -> H
ΔTFP_t	0.37	0.11	1.10	0.11	3.30***	5.13**	-2.16**	TFP -> H

Note: *, **, *** represent significance at the 1%, 5% and 10% levels, respectively.

In the physical cap ital stock equation, the coefficients of lagged values of ΔHC_t, ΔH_t, ΔL_t, and ΔGDP_t are all found to be Granger causing ΔI_t in the short run. For the human capital equation the coefficients of ΔH_t, and ΔL_t are found to be Granger causing hu}an capital form!tion in Pakistan. In the health equation, Granger causality is found to be running from ΔGDP_t, ΔHC_t, ΔL_t ΔTFP_t and ΔI_t towards ΔH_t. For TFP_t, we found the lagged independent variable ΔH_t Granger causing TFP growth in the short-run. In the economic growth equation, the coefficients of lagged values of ΔI_t, are statistically significant, showing the impact of the variable on ΔGDP_t in the short run, while the coefficient of lagged value of ΔL_t, ΔH_t ΔHC_t and ΔTFP_t are insignificant, thus indicating no immediate impact on ΔGDP_t in the short run. As far as the economically active population (labour force) is concerned, the coefficients of lagged values of independent variable ΔGDP_t, ΔI_t and ΔH_t are found to be significantly impacting L_t, while ΔHC_t and ΔTFP_t show no impact on ΔL_t in the short run.

Whereas, the value of ECT_{t-1} (the error correction term in all the equations) are also found to be statistically significant at the one per cent level except ECT_{t-1} of ΔTFP_t, which are found to be significant at the 5 per cent level suggesting existence of a powerful long run causality running from the independent variables to the dependent variables in the entire system of equations. Hence, it can be concluded that the model itself is converging towards long run equilibrium.

From Table 3 it is also evident that causation is bidirectional between economically active population of Pakistan and physical capital stock, physical capital stock and economic growth, human capital stock and health, health and economically active population, health and total factor productivity and health and physical stock. While, unidirectional causality is also found running from human capital stock to physical capital stock, from economically active population (labour force) to human capital formation and from economic growth to stock of economically active population and health. Health is also found to be Granger causing labour force, physical capital stock and human capital in the short-run. So, our results support the hypothesis that health Granger causes economic growth, although causation is indirect. Health is indirectly Granger causing growth by affecting the variables that cause economic growth in Pakistan (labour force, physical capital stock and human capital stock).

V. Conclusions and Policy Implications

In the light of a number of recent studies showing the adverse impact of poor health on economic growth [Bhargava et al., (2001), Gallup and Sachs (2000), McCarthy et al., (2000), Arcand, (2001)], this study provides a comprehensive review of the theoretical underpinnings and empirical evidence of the health-productivity relationship. This health-productivity relationship goes well beyond the obvious impact of health on the capacity to work both in terms of the energy level and working time. The econometric analysis of this paper has shown that improved health in Pakistan can account for the growth of total factor productivity, human capital, economically active population (labour force) and physical capital stock. Specifically, following results for the period 1960 to 2000 have been obtained: there is a positive influence of health on GDP growth although it is not found to be causing economic growth. Human capital, physical capital stock, total factor productivity and labour are also positively correlated with health. Results of this paper has also illustrated that a key mechanism through which health affects growth is via TFP.

The results of this study suggest that poor health can indeed reduce aggregate productivity by impacting on the growth of labour force and human capital. This in turn reduces the growth in physical capital stock and slows down the growth process in the economy. We believe that the impact of health on TFP occurs largely through the impact on labour productivity. The analysis also suggest that the effect of health on human capital is also important. It is reasonable to believe that human capital (labour force with knowledge and qualification) enhances technological progress, which is important for physical capital formation in a country. At a general level, capital formation requires that a high proportion of skilled labor force remains active for a number of years. Health is that factor which remains indispensable to maintain the number of this skilled labour force. So, health is indirectly contributing to the process of economic growth in Pakistan by affecting growth of physical capital stock, human capital, total factor productivity and economically active population. Hence, from the above discussion we conclude that, health may be considered a fundamental variable leading to economic growth in the long run. These results may have important practical implications for public policy by providing policy-makers with a better technical understanding of development-related factors. While the Government of Pakistan should remain determined to limit the economic and social damage caused by poverty, the most important challenge facing Pakistan's health system in the medium and longer term may be to consolidate health improvements and expand coverage to rural and underdeveloped areas and to adapt to the changing health profile of the population.

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References

Abdelhak, S., 2000, Sources of economic growth: An extensive growth accounting exercise, IMF Staff Papers, 47(1).

Adenikinju, A., L. Soderling, C. Soludo, and A. Varoudakis, 2001, Structural factors affecting manufacturing competitiveness: Comparative results from Cameroon, Cote D'Ivoire, Nigeria and Senegal, Development Centre Seminars with IMF and the AERC, Policies to promote competitiveness in manufacturing in sub-Saharan Africa, International Development, Augustin K. Fosu, Saleh M. Nsouli, and V. Aristomene, eds., IMF/AERC/OECD.

Aghion, P., and P. Howitt, 1998, Endogenous growth theory, Cambridge, Massachusetts: MIT Press.

Alesina, Alberto, and Roberto Perotti, 1996, Income distribution, political instability and investment, European Economic Review, 40(6):1203-28.

Arcand, J.L., 2001, Undernourishment and economic growth – The efficiency cost of hunger, Rome: Food and Agriculture Organization.

Banerjee, A.J.D., J.W. Galbraith, and D.F. Henry, 1994, Cointegration, error-correction and the econometric analysis of non-stationary data, Oxford: Oxford University Press.

Barro, R.J., 1997, Determinants of economic growth, Cambridge, Massachusetts: MIT Press.

Barro, R.J., 1991, Economic growth in a cross section of countries, Quarterly Journal of Economics, 106(2): 407-443.

Barro, R.J., 1999, Human capital and growth in cross-country regression, Swedish Economic Policy Review, 6.

Barro, R.J., and X. Sala-i-Martin, 1995, Economic growth, McGraw Hill.

Bassanini, A., and S. Scarpetta, 2001, Does human capital matter for growth in OECD countries?, Evidence from pooled mean-group estimates, OECD Economics Department, Working Paper No.282.

Basta, S.S., M.S. Soekirman, D. Karyadi, and N.S. Scrimshaw, 1979, Iron deficiency anemia and the productivity of adult males in Indonesia, American Journal of Clinical Nutrition, 32: 916-925.

Bhargava, A., 1997, Nutritional status and the allocation of time in Rwandese households, Journal of Econometrics, 77: 277-295.

Bhargava, A., D. Jamison, L.J. Lau, and C. Murray, 2001, Modeling the effects of health on economic growth, Journal of Health Economics, 718: 1-18.

Bloom, D.E., and D. Canning, 2000, Health and wealth of nations, Science, 287: 1207-1209.

Bloom, D.E., J.G. Williamson, 1998, Demographic transitions and economic miracles in emerging Asia, The World Bank Economic Review, 12(3): 419-455

Boskin, M., and L.J. Lau, 1992, Post-war economic growth in the group of five countries, A new analysis, Discussion Paper, Stanford University.

Cas, Alexandra, and Thomas K. Rymes, 1991, On concepts and measures of multifactor productivity in Canada: 1961-1980, Cambridge: Cambridge University Press.

Christensen, L.R., D.W. Jorgenson, and L.J. Lau, 1973, Transcendental logarithmic production frontiers, Review of Economics and Statistics, 55: 28-45.

Chuang, Y., 2000, Human capital, export and economic growth: A causality analysis for Taiwan, Review of International Economics, 18(4): 712-720.

Coe, David. T., E. Helpman, and A.W. Hoffmaister, 1997, North-South R & D spillover, The Economic Journal, 107: 134-149, January.

Edwards, S., 1997, Openness, productivity and growth, What do we really know? National Bureau of Economic Research (NBER), Working Paper No.5978, Cambridge: Massachusetts.

Eichengree, Barry, 2002, Capitalizing on globalization, Asian Development Review, 19(1): 14-66.

Engle, R.F., amd C.W.J. Granger, 1987, Cointegration and error correction: Representation, estimation and testing, Econometrica, 55: 251-276.

Fatima, A., S. Alam, and M.S. Butt, 2003, International trade and total factor productivity growth in Pakistan: A multivariate cointegration analysis, Indian Journal of Quantitative Economics, 18(1&2): 31-54.

Freire-Saren, J., 1999, Human accumulation and economic growth, Universitat Autonoma de Barcelona, Working Paper: 435-499.

Gallup, J.L., and J.D. Sachs, 2000, The economic burden of malaria: Cross-country evidence, Center for International Development, Harvard University, Working Paper No.52, Cambridge: Massachusetts.

International Institute for Population Sciences (IIPS), 1995, National Family Health Survey 1992-93, MCH and Family Planning, Mumbai: India.

Johanson, S., 1988, Statistical analysis of cointegration vectors, Journal of Economic Dynamic and Control, 12: 231-254.

Johanson, S., and K. Juselies, 1990, Maximum likelihood estimation and inference on cointegration with applications for the demand for money, Oxford Bulletin of Economics and Statistics, 52: 169-210.

Kim, L., and L.J. Lau, 1994, The sources economic growth of the East Asian newly industrialized countries, Journal of the Japanese and International economy, 8(3): 235-271.

Krueger, A., and M. Lindahl, 1999, Education for growth in Sweden and the world, National Bureau of Economic Research (NBER), Working Paper No.7190, Cambridge.

Levine, R., and D. Renelt, 1992, A sensitivity analysis of cross-country growth regressions, American Economic Review, 82(4): 942-63.

Lucas, R.E., 1988, On the mechanics of economic development, Journal of Monetary Economics, 22(1): 3-42.

Lucas, R.E., 1993, Making of miracle, Econometrica, 61(2).

Mankiw, N,G., D. Romer, and W. D. Neil, 1992, A contribution to the empirics of economic growth, Quarterly Journal of Economics, 107: 407-437.

McCarthy, F.D., H. Wolf, and Y. Wu, 2000, The growth costs of malaria, National Bureau of Economic Research (NBER), Working Paper No. 7541.

Miller, S.M., and M.P. Upadhyay, 2000, The effect of openness, trade orientation, and human capital on total factor productivity, Journal of Development Economics, 63: 399-423.

Murray, C.J.L., and A. Lopez, 1996, The global burden of disease, Cambridge: Harvard University Press.

Nehru, V., and A. Dhareshwar, 1994, New estimates of total factor productivity growth for developing and industrial countries, World Bank Research Working Paper No.1313, Washington, D.C.

Nonneman, W., and V. Patrick, 1996, A further augmentation of the Solow model and the empirics of economic growth for OECD countries, Quarterly Journal of Economics, 111: 943-953.

Preston, S.H., 1976, Mortality patterns in national populations, New York: Academic Press.

Rao, B.V.V., and C. Lee, 1995, Sources of growth in Singapore economy and its manufacturing and services sectors, The Singapore Economic Review, 10(1): 83-116.

Sach, J.D., and A.M. Warner, 1997, Sources of slow growth in African economies, Journal of African Economies, 6: 335-376.

Sargan, J.D., 1971, Production functions, Part 5 in qualified manpower and economic performance, P.R.G. Layard, J.D. Sargan, M.E. Ager, and D.J. Jones, eds., London: Allen Lane.

Sargent, Timothy, C., and Edgard R. Rodriguez, 2001, Labour or total factor productivity: Do we need to choose? Working Paper No.4, Economic Studies and Policy Analysis Division, Department of Finance, Canada: Ottawa.

Schultz, P., 1999, Productive benefits of improving health, Evidence from low income countries, mimeo, Yale University.

Schultz, P., and A. Tansel, 1992, Measurement of returns to adult health: Morbidity effects on wage rates in Cote D'Ivoire and Ghana, Economic Growth Center, Yale University, Discussion Paper No.663.

Solow, R., 1956, A contribution to the theory of economic growth, Quarterly Journal of Economics, 70: 65-94.

Spurr, G.B., 1983, Nutritional status and physical work capacity, Yearbook of physical anthropology, 26: 1-35.

Storesletten, K., and F. Zilibotti, 2000, Education, education policy and growth, Swedish Economic Policy Review, 7: 39-70.

Strauss, J., and D. Thomas, 1998, Health, nutrition and economic development, Journal of Economic Literature, 36: 766-817.

Stronks K., H. van de Mheen, J. van den Bos, and J.P. Makenbach, 1997, The interrelationship between income, health and employment status, International Journal of Epidemiology, 26: 592-600.

Summers, R., and A. Heston, 1991, The penn world table, An expanded set of international comparisons, 1950-1988, Quarterly Journal of Economics, 106: 327-368, The World Penn Tables Mark 5.6, Retrieved from data base on web site: http://datacentre.chass.utoronto.ca:5680/cgi-bin/pwt.

Temple, J., 2001, Growth effects of education and social capital and the OECD, in: J.F. Helliwell, ed., The contribution of human and social capital to sustained economic growth and well-being, International symposium report, Human Resources Development, Canada and OECD.

Temple, J., 1999, The new growth evidence, Journal of Economic Literature, 37: 112-156.

Weil, D., 2001, Accounting for the effects of health on economic growth, Mimeo, Economics Department, Brown University.

World Bank, 1993, Investing in health, World Development Report, Washington: D.C.

World Bank, 1998, World Development Indicators (WDI) CD-ROM, Washington: D.C.

World Health Organization, 1999, Making a difference, Washington: D.C.

World Health Organization, 2001, World Development Indicators, Washington: D.C.

APPENDIX

Econometric Methodology

Following Johansen (1988) and Johansen and Juselins (1990) consider the following vector auto regressive (VAR) model.

Let X_t denote a vector of time series:[1]

$$X_t = (X_{1t}, X_{2t}, \ldots, X_{nt});\ n > 2 \tag{5}$$

in which all the X_t are assumed to be $I(1)$. This vector admits a representation as an autoregressive VAR(p):

$$X_t = \Phi_1 X_{t-1} + \ldots + \Phi_p X_{t-p} + \mu + e_t \tag{6}$$

with

$$e_t \sim I.N(0, \Omega)$$

where ϕ_i represents a matrix of parameters n x n, μ a vector of constants and Ω a matrix of covariances. This system can be represented as a system of error correction (VECM):

$$\Delta X_t = \sum_{i=1}^{p-1} \Gamma_i \Delta X_{t-1} + \Pi X_{t-p} + e_t \tag{7}$$

or, more generally, accepting the existence of a trend μ and exogenous variable $I(0)$: Z_t may be

$$\Delta X_t = \mu + \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_{p-1} \Delta X_{t-p+1} + \Pi X_{t-p} + \gamma\phi_t + \varepsilon_t \tag{8}$$

All the differenced X vectors will be made up of $I(0)$ variables; hence the n linear combinations of the variables $\Gamma_p \Delta X_{t-p}$ must also be $I(0)$, even if the original variables composing them were $I(1)$. Given that X_t is made up of n variables, the dimension of Γ is n x n and its rank equal to or less than n. In fact, the rank of Π will coincide with the number of linearly independent cointegration vectors which might exist among the n variables of X. If this number is assumed to be $r(r < n)$, it will be possible to define a matrix $\beta(n \text{ x } r)$, such that its columns are the cointegration vectors. That is:

$$\beta' X_{t-p} \sim I(0) \tag{9}$$

[1] In our case $X_t = (H_t, TFP_t, L_t, HC_t, I_t, GDP_t)$.

It will also be possible to construct a matrix $\alpha(n \times r)$, in which these will be contained in rows, the ratios with which the different cointegration relationships of the system enter in each equation. That is:

$$\alpha\beta' = \Pi \quad (10)$$

So, on the basis of these matrixes, the equation could be expressed as:

$$\Delta X_t - \alpha\beta' X_{t-p} = \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_{p-1} \Delta X_{t-p+1} + e_t \quad (11)$$

where ΔX_t and X_{t-p} can be substituted by the residuals which may result from the regression of each of them with regard to the $\Delta X_{t-1}, \ldots, \Delta X_{t-p+1}$, denominated R_{ot} and R_{pt}, respectively. Thus, the last equation is left:

$$R_{ot} - \alpha\beta' R_{pt} = e_t \quad (12)$$

the Likelihood function of which is $L(\beta, \alpha, \Omega)$. Once β is known, α and Ω can be estimated, by means of an R_{ot} regression on $\beta' R_{pt}$. Johansen shows the estimation of β by finding certain auto values and their corresponding autovectors. Nevertheless, the parameters α and β are not identified; and, in fact, any normalization of the corresponding matrices will be equally valid, hence the chosen normalization must be duly justified. Moreover, and in order to determine the number of cointegration vectors, Johansen (1988) proposes a test based on a Likelihood ratio derived from the Eigenvalue of the stochastic matrix and the trace of this matrix. Short-term elasticities were estimated by calculating the residual

$$RX_t = \Delta X_t - \hat{\Pi}_{MV} X_{t-p} \quad (13)$$

and regressing it on lagged differenced variables and the co-variables.