＜Original Articles＞

Health and economic development: a cross-national empirical analysis

Nobuhide HATASA

Like education, health is regarded as a necessary source of productivity because it can be a proxy of labor quality. Health can be an investment for future economic return and this positive impact of health on economy has been tested by a number of micro studies based on regional or country surveys. Based on a cross-country regression analysis, the author demonstrates that health measured by life expectancy has a positive impact on economic growth. Health status also has indirect impacts on economy through its influence on education. The empirical analysis upholds that health status has a positive effect on educational attainment. Health status is determined by such elements as education, level of income, and other health inputs and the regression outcomes support the significance of these three factors. Particularly in developing countries, economic factors are very relevant in determining the state of health. Income is important in maintaining a healthy body, and at the same time health is an essential condition for people to earn income. This interrelation between health and income may create either a vicious or virtuous circle.

Key words **:** health, economic growth, development, developing countries (Accepted for publication, September 28, 2001)

1 Introduction

Without exception, the most important factor that all people are equally concerned about is health. Health is the basis of any activity that people engage in. Healthy people are able to live longer, have more time to enjoy life, and have more opportunity to experience happiness. Health, along with education, is commonly regarded as one source of human capital in the sense that it has a close relation with labor quality. Productivity that is one of the key elements for economic development is substantially influenced by the physical condition of laborers, particularly when they undertake heavy or time consuming work. Each person's economic condition is more or less subject to his or her health status.

The purpose of this paper is to explore how the state of health affects economy and vice versa, and examine the relationship between health and economic development by adopting cross-national growth regression analysis. Health, like education, can be an investment for future economic return and this positive impact of health on economy has been tested by a number of micro studies based on regional or country surveys as discussed later. However, with the difficulty of measuring the state of health, it is not common that health indexes are incorporated into cross-country regression models as a qualitative or quantitative element of human capital. The paper examines the question of whether a health factor can be an explanatory variable for economic growth and other economic and educational indicators relevant to economic development by using cross-country data, and considers how the outcomes of micro studies can be applied to cross-country based analyses.

The paper first introduces former studies and puts forward hypotheses concerning the economic aspects of health, and then tests these hypotheses, constructing cross-national regression models. How health conditions are associated with economic development is the first issue dealt with in the paper. The indirect effect of health on economic development is also investigated. Since health status has a close relation to labor supply and educational attainment, how these are associated with economic growth is examined. Finally, determinants of health and the interrelation between health and income are discussed.

2 Review of Literature and Hypotheses

2.1 Health as a Source of Productivity

There is a theory called the nutrition-based efficiency wage theory, which describes the relation between

Institute of Asia-Pacific Studies, Waseda University
Address: Sodai-Nishiwaseda bldg. 6F., 1-21-1 Nishiwaseda, Shinjuku-ku, Tokyo 169-0051
Tel: 03-5286-3961, Fax: 03-3232-7075
E-mail: hatasa@wiaps.waseda.ac.jp

productivity and nutrition.[1] While the main focus of this theory lies in the rigidity of wages in developing countries, the theory starts with a hypothesis concerning a relationship between health and productivity. According to this theory, healthy workers are regarded as more efficient than those who are not, and the productivity function curve is depicted as either of an S curve or a concave curve (Dasgupta & Ray, 1986, pp. 1014-1015). A laborer's health condition is measured by food consumption, calorie intake per day, height, and so on. The productivity function curve with an S shape illustrates that the marginal rate of return increases until the point where the rate is equal to average productivity. Then it decreases afterwards. On the other hand, the concave curve starts from a minimum health threshold, below which people cannot participate in the labor market, and the marginal rate of return decreases continually. Whichever the shape of the curve might be, this theory describes a positive relationship between health and productivity.

A number of empirical studies have been done in order to account for the relationship between nutrition and productivity.[2] For example, Strauss (1986) collected data on the average household caloric intake per adult living in rural Sierra Leone and ran nonlinear two stage least squares, plugging the data into an agricultural production function. He found a strong positive effect of better nutrition on farm productivity especially when calorie intake stays low. Other recent studies also support the positive relationship between nutritional status and labor productivity (Sahn & Alderman, 1988; Deolalikar, 1988).

2.2 Other Economic Effects of Health

This section focuses on the impact of health on education and labor supply, and examines the indirect economic impacts of health. Health and nutrition may have not only a direct impact on labor productivity as discussed earlier, but also an indirect impact on it (Behrman, 1993, pp. 1756-1763). If there is a right hand side variable which determines economic growth and which is at the same time influenced by health status, health is regarded as having an indirect impact on productivity. It is assumed that this sort of explanatory variable is one indicating the number in the labor force and the level of educational achievement.

2.2.1 Health as a Driving Force of Labor Supply

What makes health different from education in terms of its relation with economic development is that it also has a positive impact on the number in the labor force and the working hours (Mushkin, 1962, pp. 132-133).[3] Whether people have high education or not does not necessarily control labor supply since they are nonetheless obliged to earn income for their living. Only when most jobs in a country require high skills and advanced knowledge, does education have a strong effect on the supply of labor. The relationship between education and labor supply hinges substantially on economic and social conditions and therefore is not consistent. The impact of education on labor force participation is considered to be very small, compared with the effect caused by the health factor.

Health status always has a close relation with labor participation. This strong relationship is implied from the minimum health threshold mentioned above. A person whose health condition is below the threshold is not able to work even though he or she wants to do so. The number in the labor force decreases when more people stay below the threshold. On the other hand, if a person who is currently unemployed due to malnutrition and is under the threshold level recovers from the illness and returns to his or her job, labor supply increases.

The following is a modified form of the labor supply function introduced by Strauss & Thomas (1998, pp. 779-781):

$L = L[H, D, N, P, W(H, S, A, E, B, T, e_w), e_l]$.

According to this function, labor supply (L) depends on the state of health, H; demographic characteristics, D; non-labor income, N; preferences with regard to jobs and non-labor activities, P; real wage, W; and others, e_l. Real wage is a function of health, H; schooling, S; age, A; experience, E; ability, B; type of job, T; and others, e_w. This function contains two kinds of health factors: one has a direct effect on labor supply (L) and the other has an indirect effect on L through its impact on real wage.

Parsons (1982, pp. 81-91), using the data for US males, tested a probit model for labor force participation of males by incorporating the above five elements. Mortality rate, age, social security benefit and local welfare, prior unemployment experience, and hourly wage rate are the indexes used for the variables of H, D, N, P, and W listed in the labor supply function. He found that mortality rate, age, social security benefit and local welfare, and prior unemployment experience are

[1] This theory was first introduced by Leibenstein (1957) and Mazumdar (1959), pp. 190-197. A discussion regarding the appropriateness of the theory is found in Swamy (1997), pp. 85-98.

[2] You can find a summary of these studies in Behrman (1993).

[3] Grossman (1972, pp. 223-255) focused on the characteristic that health determines the amount of time people can spend for earning and constructed a model of the demand for health.

negatively associated with labor force participation while hourly wage rate is positively related with it. His micro study supports a positive relationship between the state of health and labor force participation.

2.2.2 A Positive Relationship between Health and Education

Health and nutrition have been considered to affect educational attainment of children in developing countries. For example, Moock & Leslie (1986, pp. 33-52) collected data in the Terai region of Nepal and constructed a probit model to explain school participation and ran OLS in order to assess school progress. They found that the measurement of height-for-age which is used to diagnose chronic malnutrition has a positive effect on both school enrollment and progress. Jamison (1986, pp. 299-309), whose survey is based on data for China, also states that height-for-age is positively related with school performance.[4] Having reviewed a number of empirical analyses and socioeconomic surveys regarding the impact of health and nutrition on education, Behrman (1996, pp. 23-37) casts some doubt on its influence but still supports the notion that health has a considerable impact on educational attainment.

2.3 Determinants of Health

There are a number of micro studies in which regression models are constructed in order to explain what determines health (Williamson & Boehmer, 1997; Lena & London, 1995; Hertz, Herbert, & Landon 1994; Rogers & Wofford, 1989; Strauss, Gertler, Rahman, & Fox, 1993). For example, Strauss, Gertler, Rahman, & Fox (1993), following Grossman's idea (1972), argue that health status is influenced by health related inputs which can be measured by calorie intake, physical exercise, and income; individual and family characteristics such as age, gender, and education; and community characteristics such as availability and quality of health infrastructure and environmental factors. Their regression analyses indicate that education and income have a strong effect on the state of health.

2.4 Hypotheses

From the micro studies discussed above, the following three hypotheses can be inferred. First, the state of health is assumed to be positively associated with economic growth. If we regard health as a source of productivity, it also closely relates to the income growth rate. Healthy workers are considered to be more productive than those who are not and thus the improvement of laborers' health status definitely contributes to an increase in the level of income.

Second, health may have indirect impacts on economic growth. If we suppose that the increase in laborers and the rise in educational attainment contribute towards the growth of income per capita and that a health factor is positively associated with the former, it is reasonably assumed that the improvement of health status causes further economic development through its influence on labor supply and educational achievement.

Finally, the state of health is considered to be affected by level of income. While health is a critical factor for laborers to be productive and for a country to make an economy grow, income is also an important source for people to keep healthy and for a country to generate productive workers. The relationship between health and economic development is therefore not simply assumed to be one-way. There may exist a reverse causation between health status and economic development.

3 Methods

3.1 Framework of the Cross-Country Regression Models

Cross-country growth regression models constructed in this paper as table 2 describes are based on the extended version of neoclassical model (Barro, 1997, pp. 1-12). The extended version of neoclassical model includes government policies, human capital, and technological diffusion, in addition to labor and physical capital, as determinants of economic growth, while recognizing the long-term growth of the endogenous growth theory.

One of the important features of the theory behind the neoclassical model is the principle of transition dynamics called "conditional convergence." This principle accounts for a phenomenon that the further an economy is below its steady state, the faster the economy grows. This implies that if countries in the world have the same steady states, poor countries can achieve higher growth rate on average than rich countries, and, consequently, the gap between the poor and the rich will be narrowed.[5]

Another cornerstone of this neoclassical growth theory is the assertion that liberalization of national markets tends to cause an additional domestic and foreign investment, to augment the rate of capital accumulation,

[4] There are several other studies that support the positive impact of health conditions on educational achievement. See Johnston, Low, Baessa, & MacVean (1987), pp. 501-506 and Bouis & Haddad (1992).

[5] Empirical tests on this principle are in Barro (1991) and Mankiw, Romer, & Weil (1992).

and thus to contribute positively towards economic growth. Besides, trade liberalization gives a country opportunities to access new technologies in foreign countries and to face more severe competition in the world market. Imports brings in a country not only foreign products but also technologies attached to them. If a country wants to export goods and services, it has to compete with other countries. This sort of worldwide competition is often beneficial for a country to innovate new and more advanced technologies and to create more efficient production system and environment.

Considering these characteristics of the neoclassical growth theory mentioned above and covering the core argument of this theory, the author adopts the following five factors as fundamental determinants of economic growth: initial income, physical capital, quantity of labor, quality of labor, and openness.[6] These five factors picked up as sources of economic growth construct only the basis of this model. This means that it is possible to incorporate additional variables when a person wants to examine the relationship between the growth rate of per capita output and a certain economic, social, or political phenomenon.

A dependent variable used in the model is the GDP per capita growth rate, which is calculated from the annual GDP per capita, adjusted by Purchasing Power Parity (PPP) and denoted by constant 1987 international $. Since the time span observed in the model is a long-term, the data for the GDP per capita growth rate are further averaged over 10 years from 1985 to 1995. Initial income, an indicator to determine the presence of conditional convergence, is denoted by GDP per capita in 1985. Physical capital and openness are indicated by the share of gross domestic investment in GDP and the share of trade in GDP respectively. Under the neoclassical growth model, population growth rate is assumed to indicate labor quantity. Quality of labor is a measure to roughly estimate how much a country has skilled and healthy laborers, and technologies. The labor quality is proxied by educational variables and some health measures as discussed later.

The other cross-country regression models are also based on the data averaged over 10 years from 1985 to 1995. Social indicators are very scarce since it is very costly and time consuming to obtain them. Many of social data are collected only in five or ten years because of the above reasons and the fact that those indicators do not change much in a year. Taking an average of ten years is justified in the sense that it is helpful to get as many data as possible and to reduce a measurement error.

The independent variables are assumed to be exogenous; however, the models sometimes incorporate an explanatory variable which is not sure to be endogenous or exogenous. When we encounter this situation, the author sets the variable as an initial or stock form in order to avoid the uncertainty of endogeneity. It is important to keep in mind that the initial income variable appeared in table 2 is not the one to make the variable exogenous but to show the presence of conditional convergence.

All the analyses conducted in this paper are based on cross-country data which are taken from the World Bank Database called World Development Indicators. The database contains various economic and social indicators for 210 countries in the world, including developing and developed countries without any regional preference. When there are missing observations, the number of sampling countries is reduced automatically.

Detailed explanations and descriptive statistics for each variable, and correlation numbers among concerned variables are shown in table 1. Figure 1 depicts the prospected relationships among the variables appeared in regression models. Arrow signs indicate a direction of impacts among these variables and names of variables are shown in the parentheses. Since education and health are interrelated, the direction of arrow sign is aimed at both sides.

The estimation method applied to the regression estimates is ordinary least squares (OLS). It is very plausible that the assumption of homoscedasticity is unreasonable when we examine cross-sectional data. If heteroscedasticity is present, ordinary least squares parameter estimators are unbiased and consistent but not efficient. In addition, a critical problem arising from using the OLS estimates of the variances of each of the estimated parameters in the generalized linear regression model is that interval estimation and hypothesis testing can no longer be trusted. Consequently, an alternative estimator of the variance-covariance matrix must be generated. White's heteroscedasticity-consistent covariance matrix (White, 1980) is the one that leads to an appropriate estimator for the variances of the OLS estimators. White's general test (White, 1980) is conducted to determine whether heteroscedasticity is present or not. If we reject the hypothesis of homoscedasticity at the 10 percent level of

[6] For reference, Levine and Renelt surveyed 41 growth studies and found that the investment share, population growth, initial income level, and a measure of human capital are often included in the right-hand side variables. See Levine (1992 a) and Levine (1992 b), p. 945.

Table 1

(a) Variable Definitions

C = constant
EDUP = the average gross primary school enrollment rate over 1986-95
EDUS = the average gross secondary school enrollment rate over 1986-95
GDP85 = GDP per capita, PPP (constant 1987 international $) in 1985
GDPG = the average annual growth rate of GDP per capita, PPP (constant 1987 international $) from 1986 to 1995
IMDPT = the average percentage of children under 12 months who were vaccinated against DPT from 1986 to 1995
IMMEA = the average percentage of children under 12 months who were vaccinated against measles from 1986 to 1995
INV = the average gross domestic investment (% of GDP) over 1986-95
LE = the average life expectancy at birth from 1986 to 1995
LE85 = life expectancy at birth in 1985
LF = the average growth rate of total labor force from 1986 to 1995
LITE = 100 - ILITE, where ILITE = the average illiteracy rate from 1986 to 1995
LITE85 = 100 - ILITE85, where ILITE85 = illiteracy rate in 1985
PHYS = the average number of physicians per 1,000 people from 1986 to 1995
POP = the average annual population growth rate over 1986-95
PUTE = the average pupil-teacher ratio in primary education from 1986 to 1995
SAFEW = the average percentage of population who could access safe water from 1986 to 1995
TRADE = the average share of trade in GDP over 1986-95.

(b) Descriptive Statistics

	EDUP	EDUS	GDP85	GDPG	IMDPT	IMMEA	INV	LE	LE85
Mean	94.05	58.69	4555.45	1.14	73.88	71.86	23.07	65.20	61.07
Standard Deviation	21.35	32.75	4298.47	4.23	20.18	18.72	8.76	10.18	11.19
Observations	168	163	137	157	193	194	173	198	188

	LF	LITE	LITE85	PHYS	POP	PUTE	SAFEW	TRADE
Mean	2.07	71.49	60.81	1.30	1.85	28.22	69.96	32.53
Standard Deviation	1.13	22.80	25.24	1.30	1.27	13.03	25.06	33.84
Observations	174	140	105	176	201	184	146	154

(c) Correlation Matrix

	GDPG	GDP85	LITE	LITE85	LE	LE85	LF
GDPG	1.000	0.123	0.352	0.353	0.429	0.422	-0.311
GDP85	0.123	1.000	0.505	0.508	0.623	0.621	0.185
LITE	0.352	0.505	1.000	0.984	0.809	0.830	-0.066
LITE85	0.353	0.508	0.984	1.000	0.827	0.848	-0.089
LE	0.429	0.623	0.809	0.827	1.000	0.952	-0.002
LE85	0.422	0.621	0.830	0.848	0.952	1.000	-0.068
LF	-0.311	0.185	-0.066	-0.089	-0.002	-0.068	1.000

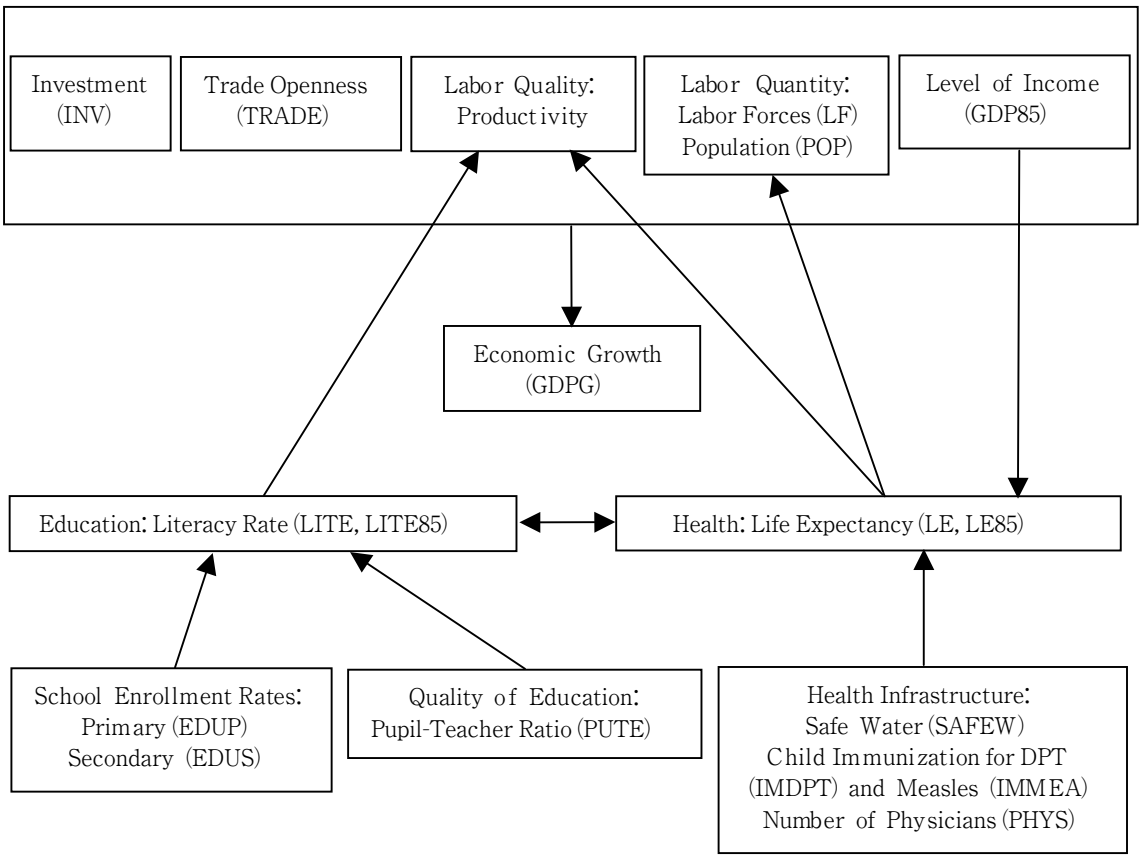
Note: Source of the data is World Development Indicators 1998 on CD-ROM.

significance, it is considered that there exists heteroscedasticity and the White heteroscedasticity-consistent standard errors and covariance is utilized for inference instead of conventional one.

3.2 Data Selection: Incorporating Health into the Models

There are a lot of indexes which are considered to evaluate health status. One frequently used type of data

Figure 1
Relationships among Variables



is nutrient intake such as per capita calorie intake and per capita protein intake. Another popular index is anthropometric; height, weight, weight-for-height, and body mass index (BMI). Other measurements include general health status (GHS), morbidity, and activities of daily living (ADLs) (Strauss & Thomas, 1998, pp. 789-796).

Depending on availability and convenience, different indexes are used. For the empirical studies of the nutrition-based efficiency wage theory, data of nutrient intake are often employed. For the comparative studies between nations, data such as height, weight, and BMI are more applicable since they are very simple and obtainable in any country. Some of these measures can be categorized into the following three. Height, considered to be a cumulative measure of nutrient status, is a long-run proxy of health status, while weight-for-height and BMI are medium-run proxies of nutrient status. Per capita calorie and protein intake indicate the short-term condition of nutrition intake and are regarded as inputs of health status (Haddad & Bouis, 1991, p. 46; Thomas & Strauss, 1997, pp. 160-161).

When we come to a cross-country growth regression model, it is known that none of the above indexes for health is available in a useful manner. However, there exist two kinds of cross-country data which are frequently used and can be regarded to assess health outcomes: life expectancy and mortality rate. Even though both data are closely related as their correlation (–0.95) indicates, life expectancy is a more appropriate index for health status than mortality rate.

The adult mortality rate is a probability of dying between the ages of 15 and 60; therefore, it does not show the health condition for all ages. On the other hand, life expectancy at birth covers a wider range of people since it is a result of mortality patterns on the whole. Barro (1997, p. 22, and Barro & Sala-I-Martin, 1995, p. 432) employed the log of life expectancy at birth as a proxy of health and found that it has a strong and positive relation with economic growth. He states that life expectancy reflects not only good health but also "desirable performance of society" and that "higher life expectancy may go along with better work habits and higher level of skills" (Barro & Sala-I-Martin, 1995, p. 432).

4 Results and Analyses

4.1 A Direct Impact of Health on Economic Growth

Under the cross-national growth regression model, the variable indicating the quality of human capital is often tested and educational achievement is usually incorporated as a measure to describe it. In the first equation of table 2, literacy rate in 1985 was used as a stock of human capital. The equation illustrates that the variable for literacy rate is significant and positively contributes to boosting the GDP per capita growth rate by 0.023 per unit. It is noteworthy that the regression model upholds the conditional convergence theory, since the initial level of GDP is negatively associated with the growth rate. According to the neoclassical growth theory mentioned earlier, investment share, trade openness, advanced skills of labor, and technological progress are positively associated with per capita output, while higher population growth rate is negatively associated with it. Therefore, all the other independent variables that are statistically significant at the 10 percent level have the expected signs.

In the second equation, the literacy rate variable is now replaced by health status, life expectancy in 1985, which is also regarded as a measure to describe the quality of human capital. It has a positive effect on GDP per capita growth rate as expected and is statistically significant. While the level of significance of the health variable increases dramatically, the goodness of fit becomes worse, compared with those presented in the first equation.

4.2 Indirect Economic Impacts of Health

We are also concerned about the other effect of health: its indirect impact on economic growth. This section first examines how labor force participation affects economy. Up until now, the variable for population growth rate has simply been assumed to indicate a quantitative aspect of

Table 2
Regressions for Growth Rate of Per Capita GDP

Dependent Variable is GDPG				
	(1)	(2)	(3)	(4)
C	3.012	4.070	3.124	3.496
	(0.968)	(1.633)	(1.130)	(1.266)
LOG	-0.730	-1.506	-0.631	-1.377
(GDP85)	(-1.823)*	(-4.675)**	(-2.109)**	(-2.856)**
INV	0.212	0.103	0.129	0.107
	(5.178)**	(2.811)**	(2.805)**	(2.695)**
POP	-0.926	-0.281	-1.309	-1.070
	(-2.937)**	(-1.006)	(-2.278)**	(-2.290)**
TRADE	0.010	0.024	0.023	0.023
	(2.261)**	(3.025)**	(2.821)**	(2.879)**
LITE85	0.023	-	-	-
	(1.768)*			
LE85	-	0.110	-	0.093
		(3.224)**		(2.040)**
LF	-	-	1.022	0.973
			(1.741)*	(2.106)**
R^2	0.548	0.269	0.236	0.263
Adjusted R^2	0.518	0.238	0.202	0.224
No. of Obs.	81	125	119	119

Note: The OLS estimation method with the White heteroscedasticity-consistent standard errors & covariance is used except the fourth equation in which the OLS estimator is applied. For notations, see table 1. t-statistics are given in the parentheses. Source of the data is World Development Indicators 1998 on CD-ROM.
* significant at the 10 percent level
** significant at the 5 percent level

labor.[7] However, as you may perceive, the population growth rate alone is not enough to explain the quantitative changes in human capital. The population growth rate can have either a negative or positive effect on the economic growth rate depending on demographic conditions. If the increase in population is explained mostly by the growth of the economically active population, population growth rate may have a positive impact on GDP per capita growth. However, if it is not, an increase in population may simply lead to the reduction of a shared income. Since the growth models described in table 2 generate a negative sign in front of the variable for the population growth rate, the latter case is considered to apply.

To express the impact of quantity of human capital on GDP growth, the variable for the average growth rate of total labor force was added to the equation (the third equation of table 2). It has a positive effect as expected and stands significant with 92 percent confidence. In the fourth equation, the confidence level becomes as good as 96 percent and the positive relationship between the labor force growth rate and GDP per capita growth rate suggests the importance of the quantity of labor force on economic development.

If we assume that health status does matter to labor supply, this positive contribution of the labor force growth rate towards boosting per capita GDP growth implies the presence of an indirect impact of health on economic development. However, it is found that it is not feasible to construct a cross-country regression model for labor force participation due to a lack of several important pieces of data, such as non-labor income, real wage, and preferences with regard to job and non-labor activities.

The next concern is thus aimed at whether health can be a cause for the enhancement of educational attainment. It is already shown in the previous section that education is positively and significantly associated with economic development. Based on what could be inferred from former studies, a health indicator (life expectancy) was incorporated as an explanatory variable into the equations for literacy rate as shown in table 3. Literacy rate is generally considered to have a strong relation to the school enrollment rates or years of schooling, and the quality of education, which can be indicated by such figures as drop out rate, spending on education per student, and pupil-teacher ratio. School enrollment rates were incorporated in the models; however, the school enrolment for tertiary education was not employed, based on the idea that the skills and knowledge acquired at the university level are not as relevant to productivity as those acquired at the primary and secondary level (Wolff & Gittleman, 1993, p. 165). Pupil-teacher ratio was selected as the variable to indicate the quality of education.

These factors relating to education and health were regressed against the literacy rate. As the first equation of table 3 shows, this model turned out to be robust, indicating a relatively higher adjusted R^2 and t-statistics. Since the pupil-teacher rate is not significant, it was eliminated from the equation and the consequences are shown in the second equation. The health variable has the expected sign and is highly significant; this is also true of each of the educational variables. The other regression analyses, shown in the third and fourth equation of table 3, were conducted to compare the models with a health measure and the ones without it. The regressions in table 3 support the hypothesis that a health factor is one of the determinants of educational achievement. The improvement of health conditions is considered to have an indirect effect on economic growth through its positive impact on educational attainment.

4.3 Determinants of Health

As those micro studies mentioned earlier show, educational and economic variables are very commonly incorporated in the model which explains health status. Income is a good indicator to measure the state of nutrition as it can be used to purchase food. It is also a useful instrument to estimate whether people are able to purchase medical services necessary to sustain their health. Education helps to improve health status in the sense that it provides knowledge of what to eat and how to live. We are able to learn how to prevent diseases and how to cure them through education.

In addition to educational and economic factors, health infrastructures, the condition of which is assessed by such figures as the number of hospitals and accessibility of safe water, are assumed to have a close relation to the state of health. Four variables which are considered to indicate the condition of health infrastructures and whose cross-national data are available were chosen as

[7] Under the simple Solow model, the labor force participation rate is fixed as constant; therefore, the population growth rate is always assumed equal to the labor force growth rate.
LF = LR*P, where P and LF is the number in population and labor force respectively, and LR denotes the labor force participation rate. If we take logs of both sides and derivatives of them with respect to time, we are able to get an incremental form of the equation: $\Delta LF = \Delta LR + \Delta P$. Since the labor force participation rate (LR) is assumed to be constant over time, ΔLR is regarded as zero. Consequently, $\Delta LF = \Delta P$.

Table 3
Regressions for Educational Achievements

Dependent Variable is LITE				
	(1)	(2)	(3)	(4)
C	-28.065	-29.864	36.997	19.886
	(-2.970)**	(-4.629)**	(4.806)**	(3.845)**
EDUP	0.210	0.227	0.304	0.307
	(3.929)**	(4.242)**	(4.712)**	(4.740)**
EDUS	0.121	0.126	0.355	0.471
	(2.086)**	(2.235)**	(5.397)**	(8.741)**
PUTE	-0.023	-	-0.357	-
	(-0.248)		(-2.923)**	
LE85	1.289	1.279	-	-
	(7.725)**	(8.374)**		
R^2	0.770	0.770	0.664	0.645
Adjusted R^2	0.761	0.764	0.655	0.639
No. of Obs.	115	118	115	118

Note: The OLS estimation method with the White heteroscedasticity-consistent standard errors & covariance is used for the first and second equation, and the OLS estimator is applied to the last two equations. For notations, see table 1. t-statistics are given in the parentheses. Source of the data is World Development Indicators 1998 on CD-ROM.
* significant at the 10 percent level
** significant at the 5 percent level

independent variables to construct regression models. These four explanatory variables are accessibility of safe water, child immunization rate for DPT and for measles, and the number of physicians.[8] Table 4 shows several results of the regression analysis regarding the state of health, life expectancy. It is interesting to note that all the economic, educational, and health variables have a positive sign and are statistically significant, and that each of the four models has a high and similar R^2 of around 80 percent.

What became apparent from the regression outcomes is that economic and educational attainments as well as health inputs do matter to health status, life expectancy. They also suggest that initial income is relevant to a condition of health and thus a recursive relationship may exist between health and economic factors. An increase in income generates a better health condition and the improvement of health status helps to grow income further. When we consider that the conditional convergence theory holds in the cross-country growth regression model, this scenario can be expected to continue until the income growth rate converges to zero.

The level of income is an essential factor to determine the state of health, particularly in developing countries. For the poor, health conditions are very susceptible to economic situations because what they eat is directly influenced by level of income. Since medical services are usually expensive, fluctuation of income may seriously affect accessibility of them. However, the situation is different in developed countries. If a person is wealthy enough, his or her health condition is not immediately damaged by a decline in income. Table 5 explicitly upholds this scenario. Among lower income countries,[9] the economic factor, initial income, continues to be significant to explain health status. On the other hand, this variable is no longer significant in the higher income countries. It seems that there exists a threshold with regard to level of income above which economic elements come to have little influence on health outcomes.

5 Concluding Remarks

Like education, health is regarded as a source of productivity, since it can be a proxy of labor quality. The empirical analysis upholds that health status represented by life expectancy has a positive effect on economic

[8] In order to avoid collinearity among the variables, these four variables are incorporated in the equations separately.
[9] The number of observations is divided into half, lower and higher income countries, after the countries are ordered by the level of the average GDP per capita.

Table 4
Regressions for Life Expectancy

Dependent Variable is LE				
	(1)	(2)	(3)	(4)
C	15.373	8.277	7.862	19.088
	(2.342)**	(1.488)	(1.412)	(3.147)**
LOG	3.275	4.381	4.448	3.772
(GDP85)	(2.705)**	(4.427)**	(4.448)**	(3.946)**
LITE85	0.204	0.198	0.207	0.193
	(6.895)**	(5.819)**	(6.003)**	(6.223)**
SAFEW	0.128	-	-	-
	(3.466)**			
IMDPT	-	0.111	-	-
		(3.542)**		
IMMEA	-	-	0.105	-
			(3.143)**	
PHYS	-	-	-	2.684
				(3.365)**
R^2	0.819	0.812	0.805	0.793
Adjusted R^2	0.812	0.805	0.797	0.785
No. of Obs.	81	85	85	81

Note: The OLS estimation method with the White heteroscedasticity-consistent standard errors & covariance is used. For notations, see table 1. t-statistics are given in the parentheses. Source of the data is World Development Indicators 1998 on CD-ROM.
* significant at the 10 percent level
** significant at the 5 percent level

growth. The state of health also has an indirect impact on productivity through its influence on education. It is empirically tested that the level of education positively affects economic growth and the state of health has a positive impact on educational achievement.

Health conditions are determined by such elements as education, level of income, and other health inputs. The regression outcomes indicated that about 80 percent of life expectancy as a proxy for health conditions is explained by the above three factors. Economic factors are relevant to health status, particularly in developing countries. When a person is around the poverty line, the level of income greatly influences the accessibility of health services and nutrition intake and therefore his or her health status is assumed to be very sensitive to it.

Income is an important foundation to maintain a healthy body and at the same time health is an essential condition for people to earn income. This interrelation between health status and income situation may create either a vicious or virtuous circle. If people become seriously ill, they are forced to reduce working hours or be shut out from the job market, and their income decreases. With this lower income, they may not be able to take in enough nutrition to recover from illness and be productive in the labor market. Once people suffer from serious diseases, they may continue to be poor unless they get some help from others. On the other hand, if a person is rich, he or she may relatively easily keep a healthy condition through sufficient nutrition and health services.

In order to examine the validity of the above inferences regarding the economic impacts of health and the relationship between health and income, further research is encouraged on a country or regional basis. There are many kinds of cases in which the above scenarios are not at all appropriate. The relationship between health and income may not be circular and the improvement of health conditions does not necessarily contribute to raising the level of educational achievement. A country based time-series analysis may give different answers to these questions. Micro level research is significant in the sense that it can provide more explicit information peculiar in a certain area, considering its culture and political and economic structure.

To improve the cross-country analysis incorporated in this paper, the following two obstacles have to be overcome. First, more sophisticated statistical analysis is

Table 5
Regressions for Life Expectancy by a Level of Income

Dependent Variable is LE				
	Lower Income Countries			
	(1)	(2)	(3)	(4)
C	6.576	-0.220	-0.033	22.132
	(0.515)	(-0.021)	(-0.003)	(2.067)**
LOG	4.625	5.893	5.786	3.227
(GDP85)	(2.306)**	(3.645)**	(3.573)**	(1.934)*
LITE85	0.204	0.158	0.168	0.159
	(4.494)**	(3.532)**	(3.750)**	(3.991)**
SAFEW	0.117	-	-	-
	(2.528)**			
IMDPT	-	0.107	-	-
		(2.673)**		
IMMEA	-	-	0.109	-
			(2.406)**	
PHYS	-	-	-	11.053
				(4.854)**
R^2	0.603	0.606	0.591	0.687
Adjusted R^2	0.571	0.576	0.559	0.662
No. of Obs.	41	43	43	41
	Higher Income Countries			
	(5)	(6)	(7)	(8)
C	37.564	23.145	25.429	45.102
	(4.252)**	(2.047)**	(2.306)**	(5.880)**
LOG	0.573	2.308	2.450	1.226
(GDP85)	(0.378)	(1.586)	(1.675)	(1.230)
LITE85	0.157	0.208	0.210	0.153
	(3.747)**	(4.317)**	(4.019)**	(3.382)**
SAFEW	0.178	-	-	-
	(3.070)**			
IMDPT	-	0.136	-	-
		(2.079)**		
IMMEA	-	-	0.094	-
			(1.542)	
PHYS	-	-	-	1.877
				(2.997)**
R^2	0.629	0.523	0.499	0.516
Adjusted R^2	0.598	0.486	0.459	0.475
No. of Obs.	40	42	42	40

Note: The OLS estimator is applied to the first and fourth equation, and the OLS estimation method with the White heteroscedasticity-consistent standard errors & covariance is used for the rest of equations. For notations, see table1. t-statistics are given in the parentheses. Source of the data is World Development Indicators 1998 on CD-ROM.
* significant at the 10 percent level
** significant at the 5 percent level

essential to enhance the quality of data and to reduce missing observations and explanatory variables even though this sort of data problem that everyone faces is very hard and costly to solve. In particular, it is urged to construct a cross-national regression model for labor force participation with an abundant data source and a practical specification. Second, finding a more efficient estimation technique and better specifications is needed to produce statistical outcomes which reflect reality more closely. Even though the cross-national analysis leaves much room for further consideration, it is still a useful statistical instrument in that it can provide a general notion which many people or countries can share.

It is likely that health has much to do with economic development. To enhance the conditions of health is essential not only from the perspective of human rights but also in the economic sense. Particularly in developing countries which need economic growth and whose educational achievement is low, policymakers are urged to implement policies which improve the state of health. Creating losers regarding health is not acceptable because health is the most essential factor for people's economic and social activities and they are very hard to escape from the vicious circle as mentioned. Governments are responsible for giving people an equal chance to be winners. They should at least guarantee a minimum food supply and health services needed for the poor to be able to sustain a threshold level of health condition so that they can participate in the labor market and eventually support themselves.

References

1) Barro, Robert J. (1991). Economic Growth in a Cross Section of Countries. *The Quarterly Journal of Economics* 106 (2).
2) Barro, Robert J. (1997). *Determinants of Economic Growth: A Cross-Country Empirical Study*. Cambridge MA: The MIT Press.
3) Barro, Robert J., & Sala-I-Martin, Xavier (1995). *Economic Growth*. New York: McGraw-Hill, Inc.
4) Behrman, Jere R. (1993). The Economic Rationale for Investing in Nutrition in Developing Countries. *World Development* 21 (11).
5) Behrman, Jere R. (1996). The Impact of Health and Nutrition on Education. *The World Bank Research Observer* 11 (1).
6) Bouis, Howarth E., & Haddad, Lawrence J. (1992). Are Estimates of Calorie-Income Elasticities Too High?: A Recalibration of the Plausible Range. *Journal of Development Economics* 39 (2).
7) Dasgupta, Partha, & Ray, Debraj (1986). Inequality as a Determinant of Malnutrition and Uncertainty. *The Economic Journal* 96, December.
8) Deolalikar, Anil B. (1988). Nutrition and Labor Productivity in Agriculture: Estimates for Rural South India. *The Review of Economics and Statistics* 70 (3).
9) Grossman, Michael (1972). On the Concept of Health Capital and the Demand for Health. *The Journal of Political Economy* 80 (2).
10) Haddad, Lawrence J., & Bouis, Howarth E. (1991). The Impact of Nutritional Status on Agricultural Productivity: Wage Evidence from the Philippines. *Oxford Bulletin of Economics and Statistics* 53 (1).
11) Hertz, Erica, Herbert, James R., & Landon, Joan (1994). Social and Environmental Factors and Life Expectancy, Infant Mortality, and Maternal Mortality Rates: Results of a Cross-National Comparison. *Social Science & Medicine* 39.
12) Jamison, Dean T. (1986). Child Malnutrition and School Performance in China. *Journal of Development Economics* 20 (2).
13) Johnston, Francis E., Low, Setha M., Baessa, Yetilu de, & MacVean, Robert B. (1987). Interaction of Nutritional and Socioeconomic Status as Determinants of Cognitive Development in Disadvantaged Urban Guatemalan Children. *American Journal of Physical Anthropology* 73.
14) Leibenstein, Harvey (1957). *Economic Backwardness and Economic Growth: Studies in the Theory of Economic Development*. New York: Wiley & Sons.
15) Lena, Hugh F., & London, Bruce (1995). Dependency, Health Care Resources, and Basic Needs in Noncore Nations: A Cross-National Analysis. *Research in the Sociology of Health Care* 12.
16) Levine, Ross, & Renelt, David (1992a). Cross Country Studies of Growth and Policy: Some Methodological, Conceptual, and Statistical Problems. *World Bank Working Paper Series* 608.
17) Levine, Ross, & Renelt, David (1992b). A Sensitivity Analysis of Cross-Country Growth Regressions. *American Economic Review* 82 (4).
18) Mankiw, N. Gregory, Romer, David, & Weil, David (1992). A Contribution to the Empirics of Economic Growth. *The Quarterly Journal of Economics* 152, May.
19) Mazumdar, Dipak (1959). The Marginal Productivity Theory of Wages and Disguised Unemployment. *Review of Economic Studies* 26 (3).
20) Moock, Peter R., & Leslie, Joanne (1986). Childhood Malnutrition and Schooling in the Terai Region of Nepal. *Journal of Development Economics* 20 (1).
21) Mushkin, Selma J. (1962). Health as an Investment. *The Journal of Political Economy* 70 (5), Part 2.
22) Parsons, Donald O. (1982). The Male Labour Force Participation Decision: Health, Reported Health, and Economic Incentives. *Economica* 49 (193).
23) Rogers, Richard G., & Wofford, Sharon (1989). Life Expectancy in Less Developed Countries: Socioeconomic Development or Public Health? *Journal of Biosocial Science* 21.
24) Sahn, David E., & Alderman, Harold (1988). The Effect of

Human Capital on Wages, on the Determinants of Labor Supply in a developing country. *Journal of Development Economics* 29 (2).
25) Strauss, John (1986). Does Better Nutrition Raise Farm Productivity? *Journal of Political Economy* 94 (2).
26) Strauss, John, & Thomas, Duncan (1998). Health, Nutrition, and Economic Development. *Journal of Economic Literature* 36.
27) Strauss, John, Gertler, Paul J., Rahman, Omar, & Fox, Kristin (1993). Gender and Life-Cycle Differentials in the Patterns and Determinants of Adult Health. *The Journal of Human Resources* 28 (4).
28) Swamy, Anand V. (1997). A Simple Test of the Nutrition-Based Efficiency Wage Model. *Journal of Development Economics* 53.
29) Thomas, Duncan, & Strauss, John (1997). Health and Wages: Evidence on Men and Women in Urban Brazil. *Journal of Econometrics* 77.
30) White, H (1980). A Heteroscedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroscedasticity. *Econometrica* 48.
31) Williamson, John B., & Boehmer, Ulrike (1997). Female Life Expectancy, Gender Stratification, Health Status, and Level of Economic Development: A Cross-National Study of Less Developed Countries. *Social Science & Medicine* 45 (2).
32) Wolff, Edward N., & Gittleman, Maury (1993). The Role of Education in Productivity Convergence: Does Higher Education Matter? In Szirmai, Adam, Ark, Bart Van, & Pilat, Dirk (Ed.), *Explaining Economic Growth: Essays in Honour of Angus Maddison*. North-Holland: Elsevier Science Publishers B. V..
33) World Bank (1998). *World Development Indicators 1998 on CD-ROM*.