The Relative Role of Public and Private Health Expenditure for Economic Growth: A Solow Growth Model Expansion

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Introduction

Determining the factors affecting economic growth for countries is of significant interest to the macroeconomist. In his classic article from 1956, Robert Solow proposed the model that has since become the modern standard for economic development models. His growth model, the *Solow growth model*, assumes a neoclassical production function with diminishing returns to capital, i.e. total income Y depends on physical capital K and effective labor AL, where effective labor is defined as the product of technology A and labor L. Solow proposed two exogenous factors, saving rates and population growth, to explain varying economic growth rates across countries. Solow argued that higher saving rates lead to capital accumulation, leading to economic growth, while population growth leads to lower economic growth as it means that capital is more spread out among labor.

The Solow model is not without caveats, and many improvements have been suggested since the model was first proposed. Most notably is the addition of human capital, which was called the *augmented Solow growth model (SGM)*. In 1992, Mankiw showed that human capital, as well as physical capital and labor, significantly contributed to economic growth. Human capital, physical capital, and labor together could explain the economic growth disparity across countries better than physical capital and labor alone. As an indicator of human capital, Mankiw used education. The higher the level of education, the higher the human capital. He used the fraction of the working population between ages 15 and 19 enrolled in school as the indicator of human capital, demonstrating that human capital is highly correlated with output, and that the entire regression fit better after its inclusion.

More independent variables can be added to Mankiw's version of SGM. Nonneman and Vanhoudt (1996) extended Mankiw's model to include $m > 2$ independent variables. Factors such as research and development (Nonneman and Vanhoudt, 1996), distance to the equator (Ram 1997), equipment investment (Temple 1998), and investment in informational technology (Yoo, 2003) have since been added, all showing a positive effect on output. (Yoo and Yang, 2004)

Health as a form of capital

Health capital is another important contributing factor to economic growth. Healthy individuals are more productive and earn higher wages. Intuitively, illness and disability negatively affect hourly wages, especially in developing countries where most of the work consists of manual labor. (Bloom 2001) Large amounts of microeconomic data also suggest a positive relationship between health and wages. (Strauss and Thomas 1998, Savedoff and Schultz 2000, Schultz 1999a, 1999b, Schultz and Tansel 1992) Considering health as another form of capital that contributes to the economic growth seems reasonable.

Commonly Used Indicators of Health Capital

Realizing the importance of health for economic growth, and responding to the increasing interest in medical care expenditure, a growing number of studies have attempted to find the precise relationship between health and economic output. (McCoskey and Seldon 1998) Some common indicators of health capital used in these studies are life expectancy and medical care expenditure. The intuition is that the longer an average person lives, or the more he spends on health care, the better his health must be. Knowles and Owen (1995) showed that higher life expectancy positively contributes to economic growth. The problem with using the life expectancy of the general population, however, is that it may not be an accurate measure of the health of the working population (labor), which is essentially what matters in output production. The last few years of life are beyond the working age (people are not likely to work at the age of 78), and thus unlikely to contribute significantly to output. For example, one could not conclude that the health status of the US population is worse off than that of the Maltan population because their life expectancies are 78 and 79.2, respectively (US Census Beaureau). It is even harder to conclude that Malta has more healthful labor than the US because the Maltan population lives longer on average. Using total medical expenditure has its own caveats as well. Although cross-country studies generally show a positive correlation between GDP and medical care expenditure (Hensen and King 1996, Blomqvist and Charter 1997, Barro 1998, Roberts 1999, Hitiris and Posnett 1992, Hesmatti), it may not be the best indicator for health capital because the causality of the relationship is unclear. For example, Devin and Hensen (2001) showed that a change in health care expenditure caused a GDP change in some countries, but the reverse in others. Also, total medical expenditures will include all kinds of medical care, including elective care that is not directly linked to health, such as cosmetic surgeries. These luxurious medical procedures may take up a large fraction of total medical expenditure because they are usually much more expensive than the basic care. Thus, the total medical expenditure may falsely represent how much the population really spends on the kind of medical care that is directly linked to their healthfulness (which determines health capital).

Public Versus Private Health Expenditure

What is of interest today is whether it is public or private health expenditure that contributes more to the health of the population and economic growth. Do government managed health care systems, such as the United Kingdom's National Health system, or privately managed health care systems, as is the case for the US, better contribute to economic growth? There is little literature on public and private health expenditure's impact on economic growth. Yoo and Yang (2004) and Aguayo-Rico (2005) are examples of the few studies that have dealt with public health expenditure. There seems to be no literature on the relative relationship of public and private health expenditure in the context of SGM. In other words, no literature has yet added simultaneously both public and private health expenditures to Mankiw's version of SGM.

A New Indicator of Health Capital

Including both private and governmental health in the SGM has a few advantages. First, the relative weights of each in determining economic growth could potentially be determined. Second, the two terms sum up to the total health expenditure (THE), thereby the regression would be controlling for the THE as well. The challenging part is how to include both in the framework of SGM. In this paper, we take advantage of the fact that private and public health expenditures add up to total health expenditure, and that the validity of THE as an indicator of health capital has already been demonstrated by other literature, by expressing THE as a function of private health expenditure (PHE) and government health expenditure (GHE). THE as represented as a function of GHE and PHE is introduced to Mankiw's version of SGM (equation 4). The hypothesis of this paper is that GHE (the amount the Government spends on the health care of its citizens, in the form of government paid medical care, public vaccination programs, the funding from WHO in the case of poorer countries, etc) matters more for economic growth because it has a more direct influence on economic growth than private expenditures, because most of what government programs cover is the medical care that is crucial for survival, healthfulness, and the well-being of the citizens and laborforce. Public health insurance, for example, does not cover cosmetic surgeries. Further, it is hypothesized that government health expenditures matter more for developing countries because citizens are less able to afford even basic medical care on their own, thus placing a larger burden on the government, whereas populations in more developed countries have access to quality or at least basic medical care with or without the help of the government.

Model

This paper will use an augmented Solow growth model that includes physical capital, human capital, health capital, labor and technology as determining factors of ouput. The augmented model is an extended form of the original Solow growth model which gave output ($Y(t)$) as a Cobb-Douglas function of physical capital ($K(t)$), labor ($L(t)$), and technology ($A(t)$). (Solow, 1952) The original Solow growth model looks as follows:

$$Y(t) = K(t)^{\alpha}(A(t)L(t))^{1-\alpha} \tag{1}$$

As mentioned before, Mankiw added human capital to equation 1 to account for the contribution of human capital ($H(t)$, represented by education) to economic growth:

$$Y(t) = K(t)^{\alpha}H(t)^{\beta}(A(t)L(t))^{1-\alpha-\beta} \tag{2}$$

Yoo and Yang (2004) and Heshmatti added health capital, $P(t)$, to (2) and showed that their model gave a better fit than when health capital was not included. The augmented Solow model used as the basis for this study looks as follows:

$$Y(t) = K(t)^{\alpha}H(t)^{\beta}P(t)^{\gamma}(A(t)L(t))^{1-\alpha-\beta-\gamma} \tag{3}$$

Yoo and Yang and Heshmatti used public health expenditure as percentage of GDP and per capita total health expenditure as indicators of the health capital $P(t)$. In this paper, $P(t)$ is represented by a function of two components of total health expenditure: government health expenditure $G(t)$ and private health expenditure $R(t)$:

$$P(t) = G(t)^{\theta}R(t)^{\phi} \tag{4}$$

Equation 3 was rewritten, subsituting the $P(t)$ from equation 4 into equation 3. Equation 5 is the novel expansion of SGM used in this paper, and forms the basis for Model 4 in Section 1 of this paper.

$$Y(t) = K(t)^{\alpha}H(t)^{\beta}(G(t)^{\theta}R(t)^{\phi})^{\gamma}(A(t)L(t))^{1-\alpha-\beta-\gamma} \tag{5}$$

Then, the following equations are derived using the same assumptions and manipulations as in Solow (1956) and Mankiw (1992). L and A are assumed to grow exogenously at rates n and g.

$$L(t) = L(0)e^{nt} \tag{6}$$

$$A(t) = A(0)e^{gt} \tag{7}$$

The effective labor is $A(t)L(t)$. We define k as the stock of physical capital per effective labor, $k = K/AL$; h as the stock of human capital per effective labor, H/AL; p as the stock of health capital per effective labor, P/AL; and y as the income per effective labor Y/AL. Model 3 assumes that a constant fraction of output, s, is invested to capital, and that all capitals depreciate at the same rate δ in every country. A fixed value of 0.05 was used for $n + g$ in Mankiw (1992), which we will follow. If we define s_k as the fraction of income invested in physical capital, s_h as the fraction of income invested in human capital, s_g as the fraction of income invested in health capital coming from governmental sources and s_r as the fraction of income invested in health capital coming from private sources, then the evolution of the economy (k^*, h^*, r^*, g^*) can be described as follows:

$$k^*(t) = s_k y(t) - (n + g + \delta)k(t) \tag{8}$$

$$h^*(t) = s_h y(t) - (n + g + \delta)h(t) \tag{9}$$

$$g^*(t) = s_g y(t) - (n + g + \delta)g(t) \tag{10}$$

$$r^*(t) = s_r y(t) - (n + g + \delta)r(t) \tag{11}$$

Equations 8, 9, 10, and 11 imply that the economy converges to a steady state (k^{**}, g^{**}, g^{**}), and r^{**}) by

$$k^{**} = \left(\frac{s_k^{1-\beta-\gamma} s_h^{\beta} (s_g^{\theta} s_r^{\phi})^{\gamma}}{n + g + \delta} \right)^{1-\alpha-\beta-\gamma} \tag{12}$$

$$k^{**} = \left(\frac{s_k^{\alpha} s_h^{1-\alpha-\gamma} (s_g^{\theta} s_r^{\phi})^{\gamma}}{n + g + \delta} \right)^{1-\alpha-\beta-\gamma} \tag{13}$$

$$g^{**} = \left(\frac{s_k^{\alpha} s_h^{\beta} s_G^{1-\alpha-\beta-\phi\gamma} s_r^{\phi\gamma}}{n + g + \delta} \right)^{1-\alpha-\beta-\gamma} \tag{14}$$

$$r^{**} = \left(\frac{s_k^{\alpha} s_h^{\beta} s_g^{\theta\gamma} s_r^{1-\alpha-\beta-\theta\gamma}}{n + g + \delta} \right)^{1-\alpha-\beta-\gamma} \tag{15}$$

Technology is defined as $A(t) = A(0) + gt$. Also note that $\ln A(0) = \alpha + \epsilon$, where α is a technology constant, which is based on the assumption that technology is the same across countries, and ϵ is a country specific shock, which allows for variations of resource endowments, institutions, etc. (Mankiw 1992) Mankiw included climate to the ϵ term, which we exclude.

Substituting equations 12, 13, 14, and 15 into equation 3, and taking the logarithm yields a linear regression formula for steady-steady income per capita Y/L:

$$\begin{aligned} \ln(Y/L) = \ln(A(0)) + gt + \frac{\alpha}{1-\alpha-\beta-\gamma} \ln(s_k) + \frac{\beta}{1-\alpha-\beta-\gamma} \ln(s_h) \\ + \frac{\gamma\theta}{1-\alpha-\beta-\gamma} \ln(s_g) + \frac{\gamma\phi}{1-\alpha-\beta-\gamma} \ln(s_r) \\ - \frac{\alpha+\beta+\gamma}{1-\alpha-\beta-\gamma} \ln(n + g + \delta) \end{aligned} \tag{16}$$

Equation 16 will be the final form of the linear regression formula used in this paper (as Model 4 in Section 1).

Finally, note several important assumptions made by Solow, Mankiw, and Yoo and Yang which I carry into this analysis. First, I assume diminishing returns to all capital, or $(\alpha + \beta + \gamma) < 1$. (Mankiw) This assumption allows for a steady state of the capital accumulation to be reached. Second, physical, human, and health capital depreciate at the same rate, δ. Third, production functions for all three capitals are similar enough for the purpose of this paper. (This is opposing Lucas (1988), who claimed them to be fundamentally different.) Fourth, as mentioned earlier, the value of 0.05 will be used for $n + g$ as in Mankiw (1992) and other SGM literature.

Research Concentration

Under the broad theme of the paper, studying the relative importance of GHE and PHE in explaining economic growth, four distinct studies are conducted. In Section 1, the new expansion of the SGM model (equation 5), called Model 4 and including THE as a function of GHE and PHE, is tested, and the results are compared to three different versions of SGM (model 1, 2, and 3). In Section 2, the coefficients from Section 1 are used to test for the fitness of the new expansion of SGM (Model 4) into the framework of SGM. This was done through an F-test to see if the restriction placed by SGM's framework was rejected. The restriction being unrejected would suggest that model 4 fits well into the structure of SGM. In this section, the values of the exponents in equation(5) are also determined, including θ and ϕ, which correspond to the relative weights of GHE and PHE, respectively. In Section 3, the causality relationship between GDP and THE, GHE, and PHE is studied. Previous studies explored causality relationships between GDP and THE, but not GDP and GHE or GDP and PHE. Even if GHE and PHE are shown as significant determinants of economic growth, they would not be meaningful indicators of economic growth if the direction of causation is from GDP to PHE or GDP to GHE. In Section 4, the underlying assumption of this paper, that GHE and PHE positively correlate with the health of the labor (thereby contributing to the economic growth), is tested by a free structured regression of adult mortality on GHE and PHE as well as other health variables. Here, the adult mortality rate of population aged between 15 and 60 is chosen rather than life expectancy or infant mortality rate as an indicator of the health of the labor because the majority of the labor population falls within this age group.

The Granger causality test was performed to test for the direction of causation between GDP and health expenditure. This further tests for the endogeneity of health expenditures with respect to GDP. If the Granger causality test shows that variance in health expenditure is explained (caused) by GDP, but variance in GDP is not explained by variance in health expenditure, it gives evidence that health expenditure is not merely an endogenous component of GDP; rather, health consumption actually contributes to the growth of GDP. This could serve as further evidence that healthfulness of the workers contributes to the economic growth.

Finally, estimated values for each exponent of the expanded SGM are determined. The coefficient for each variable in equation (16) represents an equation made up of α, β, δ, and γ, which are each exponents of physical capital, human capital (education), and health capital. Health capital is further divided into private and government health expenditure, which are represented by exponents ϕ and θ. This forms a linear system of equations, allowing the values to be calculated. The values for ϕ and θ are the weights for the government and private components of health expenditure. The values were calculated using Mathematica.

Data

A total of 87 countries were considered. Former communist countries, whose GDP depends heavily on oil, and countries with less than 10,000,000 population were not included. Also, the countries for which data crucial to this study, such as net enrollment rate of secondary education, was missing were also excluded. The list of countries selected is identical to that of Yoo and Yang (2004), which serves as the basis of this study. Throughout the research, regressions were run under three different country groups; All, OECD or

Advanced, and Developing. All included all 87 countries. The OECD or Advanced group consisted of 34 countries that were either members of the OECD, or defined as advanced economies by the IMF and World Bank. The developing countries consisted of all the countries that were not a member of OECD. Data for SGM were the average of values from years 1990 to 2000. Y/L is the real GDP per working population (whose age is defined as 15 to 64) measured in 2005 international dollar, PPP. For s_k, we used the fraction of real investment in the physical capital (including the governmental investment) in real GDP, s_h as the net secondary school enrollment rate, and s_p as the fraction of real public health expenditure in real GDP, $g + \delta$ as 0.05, and n as the average rate of growth of working population. s_r was represented by per capita private heatlh expenditure and s_g by per capita private health expenditure measured in 2005 international dollar, PPP. The data on GDP, investment and population growth rate n came from the World Bank, secondary education net enrollment rate from Barro and Lee (2003), and data on private and government health expenditures in various forms (per capita, as percentage of GDP, as percentage of total health expenditure) and other health variables from the National Health Account data from the WHO.

All data, except for education and health expenditures and indicators, came from the National Accounts Statistics provided by the United Nations Statistics Division. Intersecretariat Working Group on National Accounts (ISWGNA) comprising United Nations Statistics Division, International Monetary Fund, World Bank, Organisation for Economic Cooperation and Development, Statistical Office of the European Communities and the United Nations regional commissions collects data for the National Accounts Statistics. For high income economies, the data is collected by the OECD. For most developing countries, data is collected from national statistical organizations and central banks by visiting and resident World Bank missions. The National Account Statistics are most reliable for the OECD countries. It is less reliable for the low income economies because many economic transactions go unrecorded. Informal economic activities sometimes pose a measurement problem, especially in developing countries, where much economic activity may go unrecorded. Obtaining a complete picture of the economy requires estimating household outputs produced for local sale and home use, barter exchanges, and illicit or deliberately unreported activity. Technical improvements and growth in the services sector are both particularly difficult to measure. How consistent and complete such estimates depends on the skill and methods of the compiling statisticians and the resources available to them. However, GDP and investment share data are two of the most frequently used statistics in literature, thus they are determined through a meticulous process, several statistic organizations cooperating to provide the most accurate estimate. The data for the OECD countries are likely to be highly reliable, while that for low income economies is less reliable, but acceptable.

Barro and Lee is the most widely used source for educational data, such as the net enrollment rate for secondary school, because it provides the most comprehensive and reliable data.

Data on health expenditures came from National Health Accounts consolidated by the WHO. This is an extension of what OECD has been doing with its member countries - OECD has been collecting and publishing data on health expenditures called the System of Health Accounts. The methodology and classification were adopted by the WHO in an effort to collect health account data from low income countries as well as the OECD countries. The data on the National Health Accounts for OECD countries come directly from OECD's System of Health accounts, but for low income economies, WHO itself collects and consolidates the data from "sources including national health accounts reports, public expenditure reports, statistical yearbooks and other periodicals, budgetary documents, national accounts reports, central bank reports, nongovernmental organization reports, academic studies, and reports and data provided by central statistical offices, ministries of health, ministries of finance and economic development, planning offices, and professional and trade associations, statistical data on official web sites, and household surveys." (Annex, WHO) When data were missing, WHO used typical statistical extrapolation and estimation. WHO worked closely with the ministries of health of each country to collect as accurate data as possible, and to increase the comparability of the data collected from each country.

The National Health Accounts reports various measures of health expenditure. This includes total health expenditure, government health expenditure, and private health expenditure, and their sub-components. Total expenditure on health (THE) comprises the funds mobilized by the system, being the sum of General Government and Private Expenditure on Health.

General government expenditure (GGE) corresponds to the consolidated outlays of all levels of government: territorial authorities (Central/Federal Government, Provincial/Regional/State/District authorities, Municipal/ Local governments), social security institutions and extrabudgetary funds, including capital outlays. It is provided by the Central Bank/Ministry of Finance to the International Monetary Fund or by the United Nations Statistics Department. It is subdivided into Social security funds, expenditure by the ministry of health, and the misc others. Social security funds (SSHE) comprise the expenditure on health by social security institutions. Social security or national health insurance schemes are imposed and controlled by government units for the purpose of providing social benefits to members of the community as a whole or to particular segments of the community. They include direct outlays to medical care providers and to suppliers of medical goods as well as reimbursements to households and the supply of services in kind to the enrollees.

Private expenditure on health (PvtHE) is the sum of outlays for health by private entities, such as commercial or mutual health insurance providers, non-profit institutions serving households, resident corporations and quasi-corporations not controlled by government with a health services delivery or financing, and direct household out-of-pocket payments. It is subdivided into Prepaid and risk-pooling plans, Firm's expenditure on heatlh, Non-profit organizations serving households, and Out of Pocket spending by the household. Only the estimates for Prepaid and risk pooling plans, Non-profit organizations serving households, and household out of pocket payments are reported in the NHA.

Prepaid and risk-pooling plans (PrepaidHE) are the expenditure on health by private insurance institutions. Private insurance enrollment may be contractual or voluntary, and conditions and benefits or basket of benefits are agreed on a voluntary basis between the insurance agent and the beneficiaries. They are thus not controlled by government units for the purpose of providing social benefits to members.

Firm's expenditure on health is the outlay by private enterprises for medical care and health-enhancing benefits other than payment to social security or other prepaid schemes.

Non-profit institutions (nongovernmental organizations) serving mainly households (NGOs) are the outlays of those entities whose status does not permit them to be a source of financial gain for the units that establish, control or finance them. This includes funding from internal and external sources.

Out-of-pocket spending by private households (OOPs) is the direct outlay of households, including gratuities and payments in kind, made to health practitioners and suppliers of pharmaceuticals, therapeutic appliances and other goods and services, whose primary intent is to contribute to the restoration or to the enhancement of the health status of individuals or population groups. It includes household payments to public services, non-profit institutions and nongovernmental organizations. It includes non-reimbursable cost sharing, deductibles, co-payments and fee-for-service, but excludes payments made by companies that deliver medical and paramedical benefits, whether required by law or not, to their employees. It excludes payments for overseas treatment.

The first year NHA was reported was in 1996, and yearly estimates are currently available for 1996-2006. A major update and revision of the data was made in 2005 as major improvements were made in methodologies, more data became available, new countries provided data, and previous data were refined since its beginning in 1996. NHA is a fairly new project, and the WHO describes it as an ongoing process of making improvements and updates, rather than set in stone. WHO seems to use a meticulous process to provide the most accurate and comparable estimates by "using several hundreds of sources", closely working with the ministries of health via a feedback correspondence system where they verify their estimates with each country's ministry of health for additional input, and publishing a detailed 200 page booklet designed to help lower income countries to complete their NHA. Policy reports using these data are already being produced by several countries and WHO. It is unclear whether the quality of data for all the countries included in NHA is acceptable. However, it is likely that the NHA data on OECD countries is reliable.

Lastly, the quality of the various health variables used in the free structured regression in section 4 is difficult to be determined. Unlike the National Accounts Statistics or National Health Accounts that are prepared by several major statistical organizations working together, different health variables are collected by smaller sub groups within WHO as part of smaller projects. For instance, data on fraction of population with access to improved sanitation is collected under Water, Sanitation, and Hygiene project of the WHO, which is a project of much smaller scale than the NHA. Therefore, the findings based on these health variables, especially for low income countries sample, should be taken with most caution out of all the findings in this study.

1 Different Expansions of the Original Solow Growth Model

1.1 The Models

In this paper, Model 1 through 4, each containing a different set of variables as part of the Solow Growth Model (SGM), are compared. The original SGM only contained labor, physical capital, and investment rate as the explanatory factors of economic growth. Model 1 is Mankiw's (1992) expansion of the SGM which added education to the original SGM. Model 2 contains total health expenditure as percentage of GDP in addition to all the variables of Model 1. Model 3 contains per capita total health expenditure in addition to all the variables of Model 1. Lastly, Model 4 divides the total health expenditure from Model 3 into private and government (equation 5), where government health expenditure is represented by per capita government health expenditure, and private health expenditure by per capita private health expenditure.

Model 1:

$$\ln(\mathrm{y/n}) = \ln(\mathrm{I/GDP}) + \ln(\mathrm{SEC}) + \ln(n + g + \delta) \tag{17}$$

Model 2:

$$\ln(\mathrm{y/n}) = \ln(\mathrm{I/GDP}) + \ln(\mathrm{SEC}) + \ln(\mathrm{THE/GDP}) + \ln(n + g + \delta) \tag{18}$$

Model 3:

$$\ln(\mathrm{y/n}) = \ln(\mathrm{I/GDP}) + \ln(\mathrm{SEC}) + \ln(\mathrm{PerCapTHE}) + \ln(n + g + \delta) \tag{19}$$

Model 4:

$$\begin{aligned}\ln(\mathrm{y/n}) = \ln(\mathrm{I/GDP}) + \ln(\mathrm{SEC}) + \ln(\mathrm{PerCapGHE}) \\ + \ln(\mathrm{PerCapPHE}) + \ln(n + g + \delta)\end{aligned} \tag{20}$$

Models 2, 3, and 4 are an expansion of Mankiw's (1992) model in that they all include health as another indicator of economic growth. It is called the health capital in this paper noting its similarity to the physical or human capital as an asset of investment. There are intuitive reasons behind this; healthier workers are generally more productive and efficient, thus contributing more to economic production per worker. If the health of the general population of the workers is less than optimal, which might be the case in developing countries where there is lack of resources for quality health care for broad population, the workers are more likely to perform poorly during work, or more frequently take a sick day.

Models 2 and 3 attempt to discern whether the percentage form or the per capita form of health expenditures is a better indicator of health capital. Yoo and Yang (2004) used percentage of GDP form whereas Heshmatti used per capita form. Here, total health expenditure as percentage of GDP was used for Model 2, and per capita total health expenditure for Model 3. Total health expenditure as percentage of GDP has the advantage of eliminating the differences in GDPs as an influencing factor, and allows one to compare simply what fraction of the total GDP each country spends on health. By using the percent GDP instead of the absolute value of total health expenditure, we control for the fact that costs of health care are drastically different across countries (Mattoo 2002). $300 spent on health care in Thailand can buy much more health care service than $300 in France. Health care costs are generally linearly correlated to GDP due to higher wages, administrative costs, and more expensive equipment and drugs, therefore dividing the health care expenditure by GDP eliminates the cost disparity to a certain degree. Also, the fact that physical capital is represented by investment as percentage of GDP gives grounds for using the percent GDP form of health expenditure for health capital to make the units consistent.

On the other hand, using per capita total health expenditure may be better because it has wider variance across countries. Whereas the percent GDP form will range between 5 to 10, per capita total health expenditure ranges from 10 to 4000 US dollars. Also, per capita form may represent the amount of health care received per worker better than the percentage form. One thing to note is that per capita rather than per labor form is used because health care service is consumed by even the non-working population, so per capita health expenditure would more adequately represent the amount of health care service consumed by a worker.

Model 4 further breaks down Model 3 in that per capita health expenditure is replaced by two different variables – per capita government health expenditure and per capita private health expenditure. As will be discussed in more detail later, Model 3 yielded a better fit than Model 2, which signifies that per capita health expenditure is better than the percent GDP form as an indicator of health capital in the context of the SGM. We break down total health expenditure into its components because what we want to know ultimately is whether government (public) or private health spending more influences economic growth. As was discussed earlier, the health variable can be expanded to accommodate two separate variables (equation 4), which becomes two separate linear variables in a logarithmic equation (equation 5). From the coefficients of each variable, the exponents of the government HE and private HE can be determined, which is further discussed in Section 2. The exponents could be considered as the weights of private and public health expenditure which could tell us what kind of role and significance each has towards the economic growth. Including both GHE and PHE controls for the endogeneity problem that could arise if only either GHE or PHE were included, as the two sum to total health expenditure (eliminating the endogeniety problem arising from the GHE or PHE solely affected by the THE), and by including both variables, the ratio of GHE and PHE is considered.

1.2 Results

1.2.1 Overall Trend

In earlier trials, the sign of the coefficient for the labor growth rate had been of concern when a larger sample of countries were considered; its sign was not only consistently positive, which is the opposite of what theory and previous studies show, but also statistically significant. It was hard to overlook the positive coefficient when it was often significant at 5% or even 1% confidence level. More importantly, this prevented estimation of the exponents using the restrictions of the SGM framework - therefore, it had to be concluded that the fit of Model 4 into the SGM framework was questionable at best, and that the exponents (the weights of each capital) no longer meaningful within the SGM context.

Under the belief that part of this was due to a liberal selection of countries, the total country sample was reduced down from 112 to 87 countries by eliminating former communist countries such as those that used to be part of the Soviet Union and extremely small countries such as Andorra. This list of countries is identical to that used by Yoo and Yang (2004). Also, Yoo was replicated as closely as possible in other aspects. The same data from the same time period and source as Yoo was used (World Bank Data for all data, 1990-2000 average, except for human capital data, which came from Barro and Lee (2003)). Yoo could not be replicated exactly, however, because the World Bank stopped providing GDP on the basis of 1995 int. dollar, PPP, which Yoo used. GDP on the basis of 2005 int. dollar, PPP, had to be used instead. The original data has been requested, and the author is currently waiting for the data.

After these revisions were made, the coefficients of all variables in all four models had expected signs; physical, human, and health capitals coefficients were positive, and the labor growth rate $ln(n + 0.05)$ were consistently negative whenever it was statistically significant. The only time this term was positive was when it was statistically insignificant, which only happened in Model 3. The coefficient for labor growth

Table 1. The Four Expansions of the Solow Growth Model

		All	OECD and Advanced	Developing
Model 1	ln(I/GDP)	0.163	0.9812656****	0.0924502
		(0.432)	(0.617)	(0.404)
	ln(SEC)	0.624*	0.5680266*	0.4880051*
		(0.097)	(0.159)	(0.098)
	$\ln(n+g+\delta)$	-2.451*	-1.049266**	0.0320754
		(0.528)	(0.567)	(0.640)
	C	-4.734*	0.7743957	-1.798544
		(1.533)	(1.914)	(1.652)
	R^2	0.6825	0.6639	0.4289
Model 2	ln(I/GDP)	0.441581	1.352367*	0.2371184
		(0.377)	(0.460)	(0.385)
	ln(SEC)	0.2936052*	2.053542*	0.4860434*
		(0.082)	(0.122)	(0.095)
	ln(THE/GDP)	0.9710711*	1.241073*	0.6322391*
		(0.193)	(0.369)	(0.216)
	$\ln(n+g+\delta)$	-1.652879*	-0.166725	-0.8233869
		(0.458)	(0.464)	(0.592)
	C	0.4127514	6.520858*	0.907672
		(1.51)	(1.737)	(1.727)
	R^2	0.7510	0.8243	0.4885
Model 3	ln(I/GDP)	0.1192838	0.5168232*	0.0403599
		(0.188)	(0.231)	(0.223)
	ln(SEC)	0.1492747*	0.0309317	0.1841245*
		(0.048)	(0.069)	(0.058)
	ln(PerCapTHE)	0.6907733*	0.664504*	0.6506929*
		(0.050)	(0.043)	(0.069)
	$\ln(n+g+\delta)$	0.1232885	0.2209922	0.3606156
		(0.341)	(0.274)	(0.593)
	C	-3.109278*	-2.186574*	-2.346841
		(0.858)	(0.901)	(1.600)
	R^2	0.9280	0.9673	0.8100
Model 4	ln(I/GDP)	0.3092645	0.8826759*	0.2518024
		(0.359)	(0.0.363)	(0.388)
	ln(SEC)	0.5220591*	0.460829*	0.4304395*
		(0.098)	(0.150)	(0.106)
	ln(PerCapGHE)	0.1478029	0.1265307	0.1069072
		(0.097)	(0.138)	(0.123)
	ln(PerCapPHE)	0.0985844	0.0908673	0.0.0867221
		(0.124)	(0.0.131)	(0.160)
	$\ln(n+g+\delta)$	-1.586655*	-0.2621724	-0.5630095
		(0.570)	(0.387)	(0.694)
	C	-3.681272*	1.311418	-1.313345
		(1.362)	(1.024)	(1.682)
	R^2	0.7470	0.8342	0.4876
	F-test ($GHE = PHE = 0$)	5.75*	5.26*	4.86*
Model 5	ln(I/GDP)	0.619**	0.830**	0.454
		(0.281)	(0.387)	(0.275)
	ln(SEC)	0.647*	0.827*	0.494*
		(0.160)	(0.207)	(0.163)
	ln(GHE/GDP)	0.455*	0.785*	0.285**
		(0.130)	(0.172)	(0.120)
	$\ln(n+g+\delta)$	-2.53*	1.234**	-1.953*
		(0.620)	(0.461)	(0.693)
	C	-3.21	9.230*	-2.967
		(1.97)	(1.746)	(2.071)
	R^2	0.7750	0.899	0.5825
Model 6	ln(I/GDP)	0.435	-0.255	0.504***
		(0.317)	(0.456)	(0.276)
	ln(SEC)	0.796*	1.464*	0.499*
		(0.168)	(0.292)	(0.171)
	ln(PHE/GDP)	0.079	-0.001	0.169
		(0.171)	(0.200)	(0.188)
	$\ln(n+g+\delta)$	-2.98*	-0.084	-2.302*
		(0.682)	(0.598)	(0.704)
	C	-5.77*	2.280	-4.283**
		(1.92)	(1.623)	(1.856)
	R^2	0.7227	0.8048	0.5553

P-values: *<1%; **<5%; *** <10%; **** <15%

rate was negative in all three samples groups in Model 1, 2, and 4. The correct signs allowed for estimation of the exponents using the SGM restrictions in section 2. F-test for the SGM restriction that the sum of coefficients equal zero showed that the restriction was not rejected in Model 4, which suggested that Model 4 fits into the SGM framework to a degree.

It should be noted that the variables were not always statistically consistent. For instance, investment was significant in the Model 1 OECD sample, but not in the Model 2 Developing sample. There was no pattern of when it was or was not statistically significant - however, an F-test for every sample in all four models showed that all variables were jointly significant at close to 0% statistical confidence. However, the variables were statistically significant more often than not, especially for the OECD sample.

The coefficients and the standard errors reported are heteroskedasticity robust. This controls for the potential problem that the dependent variables are correlated to each other. Standard errors are reported under coefficients in parentheses.

1.2.2 Model 1

Model 1 is Mankiw's version of SGM. The signs of coefficients were as expected: positive coefficients for physical investment (I/GDP), human capital (SEC), and a negative coefficient for population growth rate ($n + g + d$, where $g + d$ equals 0.05.) The R^2 value for Model 1 was 0.6825.

1.2.3 Model 2 and 3: Model 3 yields the best fit

Adding a health capital variable (model 2 and 3) increased the R^2 value in general compared to model 1. In Model 2, adding the total health expenditure as percentage of GDP (THE/GDP) increased the R squared value to 0.7510 from 0.6825 in Model 1. In model 3, using per capita total health expenditure (PerCapTHE) instead yields the best fit at the R^2 value of 0.9280, having about 17% more explanatory power than model 2. This suggests that the per capita form of health expenditure is a better indicator of health capita than the percent GDP form of health expenditure.

The positive coefficient for the population growth term ($\ln(n + g + \delta)$), which was expected to be negative, raised concern in choosing per capita form of health expenditure as the indicator of the health capital to be used in Model 4 (they were positive, but not statistically significant). This problem was solved when per capital form of GHE and PHE in Model 4 actually yielded negative coefficients for labor growth rate term in Model 4.

1.2.4 Model 4

The signs of the coefficients for all the variables were as expected, and the F-test for all three samples suggested that the variables were jointly significant.

Breaking down per capita total health expenditure into per capita public and private health expenditures yielded a lower R^2, at 0.7470, compared to 0.92 in model 3. This was surprising because normally inclusion of additional variables raise the R^2 value since more variables usually means a greater explanatory power. A possible explanation for the lowered R^2 is that there is synergistic relationship between GHE and PHE. If there was a synergistic relationship between the two, then when they are considered together as THE such as in Model 3, it would have a higher effect on the economic growth, than if they were considered separate such as in Model 4. This would result in higher R^2 value for Model 3 than Model 4.

1.2.5 Model 5 and 6

Model 5 and 6 were tested to see the effect of GHE and PHE on economic output separately. Thus, model 5 includes capital, education, labor, and G(t) or GHE, and model 6 capital, education, labor and P(t). All the coefficients were significant for all three country groups, and the signs were as expected, which indicates the importance of government health expenditure in explaining economic output, and justifies adding GHE as an indicator of health in the Solow Growth Model. In Model 6, however, P(t) or PHE was often insignificant at 10% confidence level, indicating that private health expenditure alone is perhaps not a good indicator of economic output. This may also help understanding why the PHE term was insignificant in Model 4. This may also serve as supporting evidence that GHE rather than PHE is more important in increasing worker's health, and thus worker productivity and economic output.

1.2.6 Health Stock vs. Flow

The data used for PHE and GHE are both flow observations, meaning they are quantitive measurements of new PHE and GHE being consumed or added overtime (over a period of year). Health stock would the amount of health (if measurable) that has accumulated overtime, and is retained even after time passes. Thus, health stock would be the amount of health that one possess at a given point in time.

In labor economics, the concept of wage stock is often used, specifically in micerian equations where the years of schooling serves as the wage stock. The logic is that the number of years in school reflects the accumulated wage potential, and represents a person's wage earning potential at a given point in time (it is not flow because it does not change from year to year).

It is perhaps better to use health stock type data rather than flow (which GHE and PHE are) especially for a growth model such as SGM. However, it is difficult to gauge the health stock from macroeconomic data. Health stock concept can be used and possibly be configured for each individual from microeconomic data (mincerian equation and labor economics is largely microeconomics). In addition, the author could not find literature of mincerian equation applied to estimate health stock - the only time health variables were used was part of a mincerian equation estimating wage stock. Therefore, we assume in this study that GHE and PHE approximately represent the health stock of the population in that consumption of health care approximately represent health stock of the population.

1.3 Conclusion

Adding health capital as an additional variable to Mankiw's version of SGM generally increased the explanatory power of the model. Using per capita health expenditure as an indicator of health capital increased the explanatory power of the model by much more (about 30% increase from model 1) than using health capital as a percentage of GDP. This result led the author to use per capita form of the government and private health expenditures as indicators of $G(t)$ and $R(t)$ to construct model 4 to ultimately determine the exponents of government and private health expenditures terms in section 2. Not all variables were always statistically significant, but there were similar problems found in other papers as well. For instance, in Heshmatti's paper there were several instances where investment or labor growth rate was not statistically significant. Indeed, the F-test consistently indicated that all the variables are jointly significant. This combined with the high R^2 value, and correct coefficient signs justified the testing of SGM framework restriction to see how Model 4 fit into the SGM framework, and also to estimate from it the exponents $\alpha, \beta, \gamma, \theta$ and ϕ in Section 2.

2 Exponential Terms

2.1 The Fit of Model 4 In The SGM Framework: Initial Restriction

From equation 16, one can see that the coefficient in front of each variable is a term made up of exponents from equation 5: α, β, γ, θ and ϕ. These are the exponents for investment in physical capital, human capital (education), health capital (total health expenditure), and the exponents for the two sub-variables of health capital (government health expenditure, and private health expenditure) respectively.

If the data fit Model 4 perfectly in the way that SGM predicted, the sum of coefficients for investment, education, per capita GHE, per capita PHE, and population growth rate should be close to zero.

$$\frac{\alpha}{1-\alpha-\beta-\gamma} + \frac{\beta}{1-\alpha-\beta-\gamma} + \frac{\gamma}{1-\alpha-\beta-\gamma}(\theta+\phi) - \frac{\alpha+\beta+\gamma}{1-\alpha-\beta-\gamma} = 0 \tag{21}$$

The F-test applying this restriction (that the sum of coefficients of all the variables equals to zero) could test for whether this condition holds true for Model 4. The null hypothesis is that the coefficients sum up to zero, and a high F-statistic would allow us to reject the null and suggest that the constraint placed by the SGM format does not hold. If the null is not rejected due to a low F-statistic, it would suggest the restriction holds, meaning that the new expanded model containing extra variables fit into the framework of SGM. This gives further evidence that equation 5 is an adequate expansion of SGM, and that per capita form of GHE and PHE were proper indicators for $G(t)$ and $R(t)$.

The F-tests for all three groups of countries showed that equation 21 was not rejected at less than 1% confidence level. This means that there is some evidence that Model 4 fits into the SGM framework to a degree. The fact that Model 4 holds the initial restriction of SGM gives ground for estimating the exponent values using the restrictions imposed by the SGM.

2.2 Exponential Terms

Recall equation 16. An important new assumption when introducing $G(t)$, government health capital, and $R(t)$, private health capital, as components of $P(t)$, total health capital, was that the exponents of $G(t)$ and $R(t)$, θ and ϕ, respectively, add to one. Under this assumption, equation 16 can be re-written as follows:

$$\begin{aligned}\ln(Y/L) = \ln(A(0)) + gt + &\frac{\alpha}{1-\alpha-\beta-\gamma}\ln(s_k) + \frac{\beta}{1-\alpha-\beta-\gamma}\ln(s_h) \\ &+\frac{\gamma\theta}{1-\alpha-\beta-\gamma}\ln(s_g) + \frac{\gamma\phi}{1-\alpha-\beta-\gamma}\ln(s_r) \\ &-\frac{\alpha+\beta+\gamma(\theta+\phi)}{1-\alpha-\beta-\gamma}\ln(n+g+\delta)\end{aligned} \tag{22}$$

It can then be re-arranged to yield the following:

$$\begin{aligned}\ln(Y/L) = \ln(A(0)) + gt + &\frac{\alpha}{1-\alpha-\beta-\gamma}(\ln(s_k) - \ln(n+g+\delta)) + \frac{\beta}{1-\alpha-\beta-\gamma}(\ln(s_h) - \ln(n+g+\delta)) \\ &+\frac{\gamma\theta}{1-\alpha-\beta-\gamma}(\ln(s_g) - \ln(n+g+\delta)) + \frac{\gamma\phi}{1-\alpha-\beta-\gamma}(\ln(s_r) - \ln(n+g+\delta))\end{aligned} \tag{23}$$

Each coefficient is a function consisting of exponents α, β, γ, θ and ϕ. There are four equations: equation 24 through equation 27. As mentioned earlier, there is one additional restriction, equation 28. Therefore, there are five equations, and variables, which allows for estimation of values for α through ϕ.

$$\frac{\alpha}{1-\alpha-\beta-\gamma} \quad \text{coefficient for } \ln(s_k)-\ln(n+g+\delta) \tag{24}$$

$$\frac{\beta}{1-\alpha-\beta-\gamma} \quad \text{coefficient for } \ln(s_h)-\ln(n+g+\delta) \tag{25}$$

$$\frac{\gamma\theta}{1-\alpha-\beta-\gamma} \quad \text{coefficient for } \ln(s_g)-\ln(n+g+\delta) \tag{26}$$

$$\frac{\gamma\phi}{1-\alpha-\beta-\gamma} \quad \text{coefficient for } \ln(s_r)-\ln(n+g+\delta) \tag{27}$$

$$\theta+\phi=1 \quad \text{Model Constraint} \tag{28}$$

The estimates for the exponents would allow us to compare relative values for the exponents of public health expenditure (θ) and private health expenditure (ϕ) – which would tell us the relative weights of each in explaining the economic growth. One of the objectives of this study was to determine whether government or private component of health expenditure matters more with respect to economic growth.

2.3 Results

The values of exponents were determined using equations (24), (25), (26), and (27), and are shown in Table 2.

The relative magnitudes of θ and ϕ for All, OECD, and Developing countries suggest that government health expenditure's relative importance is larger than private health expenditure's. The ratio of GHE to PHE's weights are around 6:4 for all country samples. The difference in the weights for the OECD countries are similar to that for the developing countries. The difference is slightly larger for developing countries - 60:40 in OECD sample, and 62:38 in developing countries.

GHE matters more for economic growth in both OECD and developing countries, but the reason behind each is likely to be different - for the developing countries, government's efforts to provide basic health care and to improve the health state of the population (such as improving water and sanitation), and for the OECD countries, the difference in efficiency in publicly and privately managed health care expenditure, are likely to be the reasons.

For the developing countries, the finding is in accordance with the hypothesis and the intuition that GHE matters more than PHE for the health, and thus for economic growth. Because the general population is less able to afford health care on their own, and the quality of health care is poor due to lack of trained medical

Table 2. Solved Coefficients for Model 4

	All	OECD and Advanced	Developing
α	0.171427	0.30749	0.116814
β	0.248779	0.190287	0.232523
γ	0.122597	0.083508	0.0997854
θ	0.575057	0.59704	0.615511
ϕ	0.424943	0.40296	0.384489

professionals and facilities, the task of maintaining and improving the health of the population would largely be left to the government. The fact that θ is greater than ϕ supports this argument.

For the OECD countries, there was a less clear hypothesis - it is easier to postulate an hypothesis for the developing countries where the health care consumption is low, so that the variance in health of workers can be explained by more primary, necessary health care consumptions such as a treatment for a cold, or a broken bone. It is less clear whether GHE or PHE would matter more for the health of the population, hence economic growth, for the OECD countries because the level of health care consumption in these countries is generally above the minimal level required to maintain one's health. It would be hard to imagine a worker being unable to afford treatment for a broken bone or to purchase cold medicine. Therefore, the variance in the health level of workers is likely to be smaller, and this variance cannot be explained by a straightforward difference in the availability of basic health care as in developing countries, but must be explained by more subtle factors such as how the health care system is run, how effective and efficient such health care system is in improving the health of its people, and whether the difference in government or private share of the health care system matters. The exponent estimates show that GHE matters more for economic growth in OECD countries as well.

However, the same rationale used to explain such finding in the developing countries sample cannot be used here because the population in OECD countries are wealthy enough to afford basic health care on their own, and the private health care sector is well developed, and health care is widely available so that most people are not dependent on the government for most basic health care. A possible explanation for why GHE is more important in OECD countries may be that the government is more efficient in promoting the health of the working age population per dollar because they reduce the problem of redundant costs that the private system has, cover procedures that are more necessary to the state of well-being rather than unnecessary elective procedures, and make more cost containment efforts. PHE in the developed countries, on the other hand, may matter less for the economic growth because at the level of health care consumption of the developed countries, which is very high, a large fraction of PHE may be spent on elective procedures that are not significantly beneficial to health in the way that promotes one's productivity. As already mentioned, elective plastic surgeries, or rather superfluous number of tests run may not contribute much to the economic performance of the labor. These are a few possible reasons why GHE may contribute to economic growth more than PHE in the developed nations. The efficiency of GHE and PHE for the worker's health is further discussed in section 4 where different health indicators, including various government and private health expenditure measures are considered in a free structured regression.

3 Direction of Causation and Endogeneity Problem

3.1 Granger Causality Test

The Granger Causality Test tests for the causal relationship between variables Y and X by regressing Y with the lagged values of Y as well as X. The reverse regression is performed as well; X is regressed with lagged values of Y and X. If the lagged values of X are jointly significant (F-test) in the first regression, and if the lagged values of Y are not jointly significant for the second regression, X is found to *granger cause* Y (Y does not granger cause X.) If either X is jointly significant in the first regression, and Y is also jointly significant in the second regression, or if the X's or Y's are found to be not significant in the first and second regressions respectively, no conclusion can be drawn as to whether X causes Y or the reverse is true.

Three sets of causality test was performed, between:

1. GDP and per capita total health expenditure
2. GDP and per capita private health expenditure

3. GDP and per capita government health expenditure

Tables 3, 4, and 5 show the results of the tests.

3.2 Results

3.2.1 GDP and Per Capita Total Health Expenditure

GDP (year 2004) was regressed on three lags of GDP and three lags (year 2001 through 2003) of per capita total health expenditure (29), and the reverse regression was performed as well (30). All lags came from the same period of time. The top half of table 3 shows the results for (29), while the bottom half (30).

$$\begin{aligned}\mathrm{GDP}_{2004} = B_0 + B_1\mathrm{GDP}_2003 + B_2\mathrm{GDP}_{2002} + B_3\mathrm{GDP}_{2001} \\ + B_4\mathrm{PerCapTHE}_{2003} + B_5\mathrm{PerCapTHE}_{2002} + B_6\mathrm{PerCapTHE}_{2001}\end{aligned} \tag{29}$$

$$\begin{aligned}\mathrm{PerCapTHE}_{2004} = B_0 + B_1\mathrm{GDP}_2003 + B_2\mathrm{GDP}_{2002} + B_3\mathrm{GDP}_{2001} \\ + B_4\mathrm{PerCapTHE}_{2003} + B_5\mathrm{PerCapTHE}_{2002} + B_6\mathrm{PerCapTHE}_{2001}\end{aligned} \tag{30}$$

The null hypothesis for the F-test was as following:

$$B_4 = B_5 = B_6 = 0 \tag{31}$$

$$B_1 = B_2 = B_3 = 0 \tag{32}$$

For the All country sample, the F-statistic for equation 31 was 3.54 and significant at 5% confidence level, and that for equation 32 was 0.61 and insignificant at least 10% confidence level. This tells us that the lags of per capita total health expenditures were jointly significant in explaining the variance of GDP, but the lags of GDP were not so in explaining the variance of total health expenditure. This indicates that variance in total health expenditure granger caused the variance in GDP, not the other way around, and that total health expenditure is not an endogenous component of GDP.

For the OECD country sample, the results were less clear. Both null hypotheses were rejected at 10% significance level, leading to an inconclusive interpretation that GDP caused total health expenditure, while total health expenditure also caused GDP.

For Developing countries, neither of the hypotheses were rejected; neither GDP caused total health expenditure, nor THE caused GDP.

3.2.2 GDP and Per Capita Private Health Expenditure (PHE)

The causality relationship between GDP and PHE was studied. GDP was regressed with three lags of GDP and PHE (33), and PHE was regressed with three lags of GDP and PHE (34). Null hypotheses for (33) and 34) are shown in (35) and (36).

$$\begin{aligned}\mathrm{GDP}_{2004} = B_0 + B_1\mathrm{GDP}_2003 + B_2\mathrm{GDP}_{2002} + B_3\mathrm{GDP}_{2001} \\ + B_4\mathrm{PerCapPHE}_{2003} + B_5\mathrm{PerCapPHE}_{2002} + B_6\mathrm{PerCapPHE}_{2001}\end{aligned} \tag{33}$$

Table 3. Causality test: GDP and Total Health Expenditures

		All	OECD and Advanced	Developing
GDP Test	GDP_{t-1}	1.162912* (0.177266)	1.36374* (0.4267011)	1.718012 (0.2404834)
	GDP_{t-2}	0.237563 (0.293195)	-0.3834218 (0.9072334)	-0.1964482 (0.9051006)
	GDP_{t-3}	-0.3865612 (0.2526412)	0.05228 (0.5152046)	-0.5585222 (0.9188033)
	$PerCapTotHE_{t-1}$	-0.0162588 (1.06421)	-0.3597214 (0.8982644)	-3.939945 (3.018401)
	$PerCapTotHE_{t-2}$	-2.26275 (1.789174)	-0.9298799 (1.45735)	2.544573 (3.396205)
	$PerCapTotHE_{t-3}$	2.53356** (1.112266)	1.14224 (0.8065714)	3.66734 (4.766719)
	C	77.55818*** (44.6099)	1.704956 (339.9831)	58.66961 (40.27785)
	R^2	0.992	0.9988	0.9969
	F-Test	3.54** (0.0166)	3.03*** (0.0522)	1.67 (0.1787)
TotHE Test	GDP_{t-1}	-0.0059685 (0.0102802)	-0.0747494** (0.0283898)	0.0018185 (0.0149278)
	GDP_{t-2}	0.013552 (0.0145299)	0.1306157** (0.0529547)	0.0070118 (0.0359939)
	GDP_{t-3}	-0.0063712 (0.0115172)	-0.0543846** (0.0276841)	-0.0088822 (0.0285796)
	$PerCapTotHE_{t-1}$	1.627808* (0.0765927)	1.566767* (0.1133825)	1.546622* (0.1404903)
	$PerCapTotHE_{t-2}$	-0.6620246* (0.1614293)	-0.5539197** (0.2602278)	-0.5926399* (0.2019916)
	$PerCapTotHE_{t-3}$	0.0398311 (0.1074822)	-.0032313 (0.1788791)	0.1079543 (0.1674247)
	C	6.399326*** (3.270481)	14.95484 (16.63675)	5.455401* (2.083286)
	R^2	0.9990	0.9983	0.9956
	F-Test	0.61 (0.6082)	2.72** (0.0703)	0.08 (0.9724)

Table 4. Causality test: GDP and Private Health Expenditures

		All	OECD and Advanced	Developing
GDP Test	GDP_{t-1}	1.056161* (0.1387148)	1.280368* (0.4279139)	1.267225* (0.3568575)
	GDP_{t-2}	0.471397 (0.341633)	-0.2132028 (0.9702473)	0.7612327 (0.9331522)
	GDP_{t-3}	-0.5109801 (0.315227)	-0.0476007 (0.5803915)	-1.063272 (0.7564678)
	$PerCapPrvHE_{t-1}$	-0.7218968 (1.569005)	-1.796351 (1.903557)	1.507852 (3.853933)
	$PerCapPrvHE_{t-2}$	-7.638042** (3.131278)	-4.318543 (3.997845)	-12.19653 (7.378347)
	$PerCapPrvHE_{t-3}$	9.111683* (2.949404)	6.610628** (3.099101)	15.02339*** (8.488969)
	C	56.88543 (37.35001)	140.5622 (297.5707)	43.1694 (41.56255)
	R^2	0.9993	0.9988	0.9973
	F-Test	3.36** (0.0209)	2.59*** (0.0801)	761.06* (0.000)
PrvHE Test	GDP_{t-1}	0.0014284 (0.0042338)	-0.0153608 (0.0140278)	0.0087401 (0.0113095)
	GDP_{t-2}	-0.0126914 (0.008426)	0.0095154 (0.0235547)	-0.273291 (0.0210443)
	GDP_{t-3}	0.0116207** (0.0058532)	0.0059871 (0.0106912)	0.0197841*** (0.0109051)
	$PerCapPrvHE_{t-1}$	1.611673* (0.0643531)	1.505893* (0.1084516)	1.689836* (0.1416495)
	$PerCapPrvHE_{t-2}$	-0.4928508* (0.1847955)	-0.2974892 (0.2964817)	-0.5146947** (0.2107586)
	$PerCapPrvHE_{t-3}$	-0.1192203 (0.1541241)	-0.2013432 (0.2225345)	-0.2235912 (0.170678)
	C	5.060046* (1.274003)	20.84201** (9.587018)	2.884601** (1.218119)
	R^2	0.9984	0.9988	0.9827
	F-Test	1.90 (0.1331)	2.37*** (0.0997)	1.80 (0.1520)

Table 5. Causality test: GDP and Government Health Expenditures

		All	OECD and Advanced	Developing
GDP Test	GDP_{t-1}	1.214598* (0.203103)	1.378016* (0.4256908)	2.158379* (0.3337081)
	GDP_{t-2}	0.1025975 (0.3267647)	-0.3814638 (0.9073988)	-1.624137* (0.5845853)
	GDP_{t-3}	-0.305216 (0.2504245)	0.033221 (0.5186998)	0.4483452 (0.5609519)
	$PerCapGovHE_{t-1}$	-0.3449875 (1.504264)	0.5315797 (1.260149)	-8.729389 (6.181789)
	$PerCapGovHE_{t-2}$	-1.976681 (2.726857)	-2.71927 (2.359818)	17.48261*** (9.125168)
	$PerCapGovHE_{t-3}$	2.745242 (1.883969)	1.908354 (2.039994)	-5.780573 (5.691681)
	C	91.71101 (56.42652)	-63.55376 (417.0954)	44.38679 (47.59501)
	R^2	0.9992	0.9988	0.9971
	F-Test	2.41 (0.0701)***	2.01 (0.1438)	1.83 (0.1468)
GovHE Test	GDP_{t-1}	1.553922* (0.0741069)	-0.0482106 (0.0372105)	0.0156742 (0.0125589)
	GDP_{t-2}	-0.5385144* (0.1680988)	0.0942844 (0.0700698)	-0.0363962 (0.0241796)
	GDP_{t-3}	-0.0156715 (0.129931)	-0.0449351 (0.0378175)	0.0207913 (0.0148597)
	$PerCapGovHE_{t-1}$	-0.0059694 (0.0095958)	1.545096* (0.0985954)	1.250652* (0.1955142)
	$PerCapGovHE_{t-2}$	0.0149686 (0.0122774)	-0.5537787** (0.235659)	0.0908321 (0.2653346)
	$PerCapGovHE_{t-3}$	-0.0077132 (0.0103857)	0.0210529 (0.2170003)	-0.2443659 (0.1514201)
	C	1.685091 (3.64567)	1.623746 (24.375)	1.581461 (1.498644)
	R^2	0.9983	0.9988	0.9952
	F-Test	0.63 (0.5960)	2.37*** (0.0997)	0.79 (0.5035)

$$\begin{aligned} \text{PerCapPHE}_{2004} = B_0 + B_1\text{GDP}_2003 + B_2\text{GDP}_{2002} + B_3\text{GDP}_{2001} \\ + B_4\text{PerCapPHE}_{2003} + B_5\text{PerCapPHE}_{2002} + B_6\text{PerCapPHE}_{2001} \end{aligned} \quad (34)$$

$$B_4 = B_5 = B_6 = 0 \quad (35)$$

$$B_1 = B_2 = B_3 = 0 \quad (36)$$

The results indicate that PHE granger caused GDP in both the All country and Developing country samples. Equation 35 was rejected at 5% and 1% significance level, respectively, while equation 36 was not rejected at the minimum of 10% significance level.

The results for the OECD and Advanced country sample was inconclusive as both equation 35 and equation 36 were rejected at 10% significance level.

3.2.3 GDP and Per Capita Government Health Expenditure (GHE)

The causality relationship between GDP and GHE was also studied, and GDP was regressed with lags of GDP and GHE, and GHE was regressed with lags of GDP and GHE. The null hypotheses are shown in equation 39 and equation 40.

$$\begin{aligned} \text{GDP}_{2004} = B_0 + B_1\text{GDP}_2003 + B_2\text{GDP}_{2002} + B_3\text{GDP}_{2001} \\ + B_4\text{PerCapGHE}_{2003} + B_5\text{PerCapGHE}_{2002} + B_6\text{PerCapGHE}_{2001} \end{aligned} \quad (37)$$

$$\begin{aligned} \text{PerCapGHE}_{2004} = B_0 + B_1\text{GDP}_2003 + B_2\text{GDP}_{2002} + B_3\text{GDP}_{2001} \\ + B_4\text{PerCapGHE}_{2003} + B_5\text{PerCapGHE}_{2002} + B_6\text{PerCapGHE}_{2001} \end{aligned} \quad (38)$$

$$B_4 = B_5 = B_6 = 0 \quad (39)$$

$$B_1 = B_2 = B_3 = 0 \quad (40)$$

The results indicate that GHE granger caused GDP in the All countries sample. Equation 39 was rejected at 10% confidence level for the All country sample while equation 40 was not rejected. The results were the opposite for the OECD and Advanced country sample, however, as equation 40 was rejected while equation 39 was not rejected. This suggests that GDP caused variance in GHE, which suggests that GHE is an endogenous component of GDP for this group of countries. For the Developing country group, neither null hypotheses were rejected.

3.3 Conclusion

For the All country sample, it was shown that THE, PHE, and GHE granger caused GDP. This gives further evidence that THE, PHE, and GHE are not endogenous components of GDP. For OECD and Advanced country group and Developing country group, the findings were less clear. Either both nulls were rejected, or neither nulls were rejected, making unclear the direction of causation. However, no test led to the conclusion that GDP granger caused THE, PHE or GHE for any country group except for in one occasion where GDP was shown to granger cause GHE at 10% significance level for the OECD and Advanced country group.

4 Free Structured Regression on Adult Mortality and Health Life Expectancy (HALE)

4.1 Model

The exponents of GHE and PHE indicated that government spending on health generally contributes to economic growth more than private spending on health does (about 60:40 ratio for All countries combined).

To explore this issue further, two entirely new regressions were run. For the first regression, Adult mortality rate (mortality rate in a population of age between 15 and 60, per 1000 people) was the dependent variable, and independent variables includes numerous factors that affect health. For the second regression, health life expectancy (HALE) ("Average number of years that a person can expect to live in "full health" by taking into account years lived in less than full health due to disease and/or injury", WHO) was the dependent variable, and the independent variables included the same health factors used in the first regression. Both regressions were run separately for the Developing country group, and the OECD and Advanced country group.

The goal of this section is to identify possible channels through which GHE affect health in OECD and developing countries, and to study the importance of GHE and PHE in determining health. The health status of labor population can be proxied several potential health indicators such as life expectancy, adult mortality, or the healthy life expectancy (HALE). Adult mortality between ages 15 and 60 was chosen because the majority of the working population fall in the age group of between 15 and 60. Adult mortality seemed an adequate indicator of the general health of the population in that age group. Life expectancy, widely used as a health indicator in literature, might not be the best representation of the health of the working population. For instance, for a country where infant mortality rate is high, it significantly reduces the life expectancy of the total population for that country, but that does not say much about the health status of the working population (although high infant mortality rate is an indication of the generally poor health of the general population, it is too broad an assumption.) HALE shares a similar problem. Still, HALE has a unique advantage; it offers an insight into the true healthiness of the population by not only taking into consideration mortality, but also morbidity of 170 different diseases that may not result in mortality yet negatively affect the health state of the population. Life expectancy only takes into account mortality, thereby, neglecting other health impacting factors. For instance, a condition requiring dialysis does not result in mortality as long as the person has a dialysis three to four times a week, for three to four hours at a time. Although not resulting in death, this is extremely time consuming and must negatively affect one's economic activity.

In this regression, we can learn if government and private health expenditures are indeed significant in determining adult mortality rate and HALE, and if so, whether government or private health spending has a larger effect, and whether the relative weights would coincide with the results from section 2. If the results show that GHE is more important than PHE for adult mortality, this, combined with the findings from section 2 could have important policy implications as government managed health expenditure may indeed be more effective in producing healthier and more productive working population.

Further, several other health factors besides government and private health expenditures affecting adult mortality and HALE were included in the regressions. This is useful for several reasons: leaving out relevant variables that ought to be included in the regression yields biased coefficients, and it is likely that adult mortality rate is affected by more than government and private health expenditures. Also, this lets us examine what factors are important in determining health, proxied by adult mortality and child mortality, which is meaningful in its own right.

4.2 Results

Table 6 shows the results.

4.3 Health Expenditures

4.3.1 Total Health Expenditure As Percentage of GDP

In the unrefined regression, total health expenditure as percentage of GDP was significant for adult mortality (AM) for OECD and Advanced countries at 10% confidence level, but not significant for AM for developing countries, or HALE in either groups. The coefficient is -7.35, which means that for each additional percent of GDP spent on health care, 7.35 fewer deaths per 1000 people aged between 15 and 60. This means 7350 fewer deaths per 1,000,000 population in OECD countries, which is a significant number.

The fact that Total HE as percent GDP is statistically insignificant in explaining HALE or AM in most cases indicates that the fraction of GDP spent on health is not an important factor determining the health of labor.

4.3.2 Per Capita Government and Private Health Expenditure

Per capita total health expenditure (PCTHE) was not included as a variable; instead, per capita government and private health expenditures (PCGHE and PCPHE respectively) were used, which sum up to PCTHE. PCGHE and PCPHE were used for developing countries only (Social Security, Private pre-paid insurance, and Out of Pocket expenditure were used instead of PCTHE and PCGHE in OECD countries.) Neither PCPHE nor PCGHE were statistically significant at 10% confidence level.

4.3.3 General Government Health Expenditures as a Percentage of Total Health Expenditure

Government health expenditure as percent total health expenditure (GHE/THE) was not statistically significant at 10% level confidence level for either AM or HALE in any of the samples.

Although the numbers may not be taken as face value, there is a significant positive relationship between OOP/THE and AM in OECD countries. This suggests that OOP/THE may not be efficient, and thus the increase in its share correlates with poor health state of the working population.

4.4 Other Health Variables

4.4.1 Gross Domestic Product

Surprisingly, GDP was not significant (p-values ranging from .236 to .967) in determining either adult mortality rate, nor HALE in either OECD or Developing country samples. This is counter intuitive because higher GDP is generally accompanied by higher living standards, and intuition tells us that the population would be healthier. But higher GDP may also mean more industrialized and thus a more polluted environment, stressful lifestyle, and more demanding and competitive work environment, which can all bring additional stress to workers.

Table 6. Free Structured Regression - Unrefined

	OECD and Advanced		Developing	
	Healthy Life Expectancy (HALE)	Adult Mortality	Healthy Life Expectancy (HALE)	Adult Mortality
PerCapGDP	0.0003638 (0.000)	-0.0031193 (0.007)	-3.84e-06 (0.000)	-0.0021424 (0.0068212)
NetPrimEnrlMale	0.3795018 (0.280)	-3.805** (1.180)		
PopGrwthRate2005				
UrbanPop2006				
FertilityRate	0.2050588 (3.353)	-11.56714 (9.946)	-1.744148* (0.659)	24.25188*** (12.7429)
MCVImmunized	-0.2093136 (0.257)	2.888025 (1.191)	0.2088125** (0.104)	-3.034377*** (1.751293)
GenGovHlthExp	-0.4831132 (0.545)	6.039936 (2.333)	0.0477104 (0.051)	-0.1174928 (0.9118901)
HepImmunized			0.0416714 (0.037)	-0.6162766 (0.6571166)
SHPPresent			-0.0239665 (0.042)	0.1498433 (0.6175239)
ExtHealthResc			0.0856891 (0.113)	-2.642677 (1.788527)
NumNurses	-0.3752948 (0.708)	3.042685 (3.282)	-0.0900604 (1.436)	-2.151528 (8.123862)
NumPhysicians	-0.7149192 (1.483)	16.22394 (6.150)	0.9527867 (0.817)	-18.2053 (16.57417)
Sanitation			0.0938642*** (0.056)	-1.269752 (0.8248871)
CleanWater			0.0542017 (0.060)	-0.2580861 (0.9131094)
HospBeds	0.0583565 (0.054)	-0.8243395*** (0.254)	0.0073678 (0.090)	1.617744 (1.93508)
DentDensity				
PharmDensity	-1.083441 (1.720)	40.75827*** (10.113)		
PerCapGovHE			0.0046599 (0.007)	-0.1765648 (0.1205356)
PerCapPrivHE			0.0026247 (0.008)	0.0407545 (0.1275678)
OOPHealthExp				
PrivHealthExp				
NursePhysRat	0.1924711 (1.675)	-5.184918 (6.881)	-0.4723398* (0.109)	7.778757* (1.920872)
TotHealthExp	0.3033125 (0.3544282)	-7.352242*** (1.876)	-0.5523168 (0.368)	7.999049 (7.436119)
DeathsCancer	-0.2120866 (0.235)	2.194231 (1.045)	-0.0173687 (0.014)	0.1594438 (0.2652917)
DeathsCardio	-0.0869769 (0.108)	0.9346361 (0.449)	-0.0146135 (0.013)	0.1203848 (0.2263184)
DeathsInjury	-0.1684793 (0.139)	1.844061*** (0.650)	-0.058684* (0.011)	0.6545191* (0.2322607)
DeathsNCDisease	0.0867207 (0.126)	-1.040262 (0.549)	0.0063112 (0.014)	-0.1226746 (0.2595187)
TobaccoUse	-0.2226784 (0.225)	1.738233 (0.876)		
AlcoholUse	0.5309273 (0.423)	-4.664664 (1.990)	-0.030699 (0.168)	3.47683 (2.905483)
SocialSecurity	-0.002059 (0.031)	0.1123658 (0.130)		
PrvInsurance	-0.5305251 (0.683)	5.792311 (2.784)		
OutOfPocket	-0.8204745 (0.817)	10.64417 (3.684)		
cons	75.85087 (65.02071)	114.5301 (195.2648)		
R^2	0.9421	0.9592	0.7689	0.7812

Table 7. Free Structured Regression - Refined

	OECD and Advanced		Developing	
	Health Life Expectancy (HALE)	Adult Mortality	Healthy Life Expectancy (HALE)	Adult Mortality
PerCapGDP	0.001141 (0.000)	-0.0008003 (0.001)	0.000246 (0.000)	-0.0025875 (0.007)
NetPrimEnrlMale	0.1350966** (0.062)	-2.230775** (1.011)		
FertilityRate	-7.877632 (1.758)	-5.313248 (10.018)	-1.396302** (0.635)	8.277794 (12.1)
MCVImmunized	-0.0215755 (0.053)	0.398317*** (0.206)	0.0418296 (0.040)	-0.3188588 (0.665)
GenGovHlthExp			0.0492673** (0.022)	-0.5293139 (0.372)
NumPhysicians	-0.1652816 (0.728)	3.023602 (4.703)	0.2877401 (0.510)	-2.793249 (9.107)
Sanitation			0.0764147** (0.032)	-0.838525*** (0.490)
PerCapTotHE			-0.0011607 (0.004)	-0.0081499 (0.072)
NursePhysRat	-0.2246799 (0.483)	-0.7308883 (2.120)	-0.5421096* (0.077)	8.507218* (1.307)
DeathsInjury	-0.0751372 (0.048)	0.9570877* (0.221)	-0.066713* (0.012)	2.488546* (0.249)
TobaccoUse	-0.1132921 (0.077)	0.5403873 (0.430)		
AlcoholUse	0.0278578 (0.292)	-0.0588039 (1.392)	-0.022976 (0.132)	3.977486**** (2.491)
SocialSecurity	0.01416 (0.015)	-0.0965446 (0.081)		
PrvInsurance	-0.0641574 (0.043)	0.4827184*** (0.0.245)		
OutOfPocket	-0.0213621 (0.087)	-0.6725547 (0.467)		
cons	56.22669* (23.120)	251.151*** (126.119)	55.64* (3.99)	220.2056** (70.960)
adjusted R^2	0.5703	0.7421	0.7431	0.5332

Table 8. Free Structured Regression - Further Refined

	OECD and Advanced		Developing	
	Health Life Expectancy (HALE)	Adult Mortality	Healthy Life Expectancy (HALE)	Adult Mortality
NetPrimEnrlMale	0.1350966** (0.062)	-0.6355853*** (0.376)		
FertilityRate			-1.748836* (0.543)	12.3682 (9.599)
GenGovHlthExp			0.0593952* (0.023)	-0.659374** (0.375)
Sanitation			0.0942704* (0.027)	-1.048126* (0.459)
NursePhysRat			-0.5569679* (0.077)	8.649005* (1.268)
DeathsInjury	-0.0616383** (0.024)	0.7617658* (0.119)	-0.0666817* (0.011)	0.9041086* (0.222)
TobaccoUse	-0.0615934*** (0.031)	0.3561708**** (0.225)		
AlcoholUse	-0.180615 (0.122)	0.9988744 (0.771)	0.0174974 (0.118)	2.946859 (2.121)
PrvInsurance	-0.0530475** (0.025)	0.4861801** (0.201)		
PerCapGovHE	0.001012*** (0.001)	-0.0011124 (0.003)		
cons	61.35419*** (4.742)	95.266* (30.153)	59.751* (3.683)	184.6675* (65.853)
adjusted R^2	0.4311	0.6477	0.7299	0.5621

Table 9. Explanation of Model Parameters

Variable	Definition
PerCapGDP	Gross Domestic income per capita (PPP international $), 2005
AdultMort	Mortality rate of population aged between 15 and 60 Rate
ChildMort	Mortality rate of population aged 5 or younger 2005 Rate
NetPrimEnrlMale	Net primary school enrollment ratio male (%), combined
PopGrwthRate2005	Population annual growth rate (%), 2005
UrbanPop2006	Population in urban areas (%), 2006
FertilityRate	Total fertility rate (per woman), 2006
MCVImmunized	One-year-olds immunized with MCV, 2005
DTTImmunized	One-year-olds immunized with three doses of diptheria tetanus toxoid and pertus
HepImmunized	One-year-olds immunized with three doses of Hepatitis B (HepB3) (%), combined
SHPPresent	Births attended by skilled health personnel (%), combined
GenGovHlthExp	General government expenditure on health (% of TotHE)
NumNurses	Number of nursing and midwifery personnel per 1000, combined
ExtHealthResc	External resources for health as percentage of total expenditure on health, combined
NumPhysicians	Number of physicians per 1000, combined
Sanitation	Population with sustainable access to improved sanitation (%) total , combined
CleanWater	Population with sustainable access to improved drinking water sources (%) total, combined
HospBeds	Hospital beds (per 10,000 population), combined
PerCapGovHE	Per capita government expenditure on health (PPP int. $), combined
PerCapPrivHE	Per capital private expenditure on health (PPP int. $), combined
PrivHealthExp	Private expenditure on health as percentage of total health expenditure, combined
TotHealthExp	Total expenditure on health as a percentage of gross domestic product, combined
OutOfPocket	Out-of-pocket health expenditures
PrePaidCosts	Prepaid cost health expenditures
NursePhysRat	Ratio of nurses and midwives to physicians, combined
DeathsCancer	Age-standardized mortality rate for cancer (per 100,000 population), 2002
DeathsInjury	Age-standardized mortality rate for injuries (per 100,000 population), 2002
DeathsNCDisease	Age-standardized mortality rate for non-communicable diseases (per 100,000 population), 2002
DeathsCardio	Age-standardized mortality rate for cardiovascular diseases (per 100,000 population), 2002
DeathsTuber	Age-standardized mortality rate for tuberculosis (per 100,000 population), 2002
TobaccoUse	Prevalance of current tobacco use among adults (¿= 15 years) (%) both sexes, 2005
AlcoholUse	Per capita recorded alcohol consumption (liters of pure alcohol) among adults
PharmDensity	Density of pharmaceutical personnel per 1000, combined
DentDensity	Density of dentistry personnel per 1000, combined

4.4.2 Vaccinations

Vaccinations are important in reducing mortality, especially for the developing countries where the potential for contraction of contagious diseases is high. Three different vaccinations were chosen based on the availability of information on them. The hypothesis was that vaccination would matter more for reducing AM and increasing HALE for developing countries than in OECD countries. The results generally showed this trend - the percentage of population immunized with MCV positively correlated with HALE, and negatively with AM at 5% and 10% confidence level. HepImmunized was not statistically significant, but this may be due to the correlation between population MCV immunization and Hep immunization. They are both vaccinations, and a higher MCV immunization rate would correlate with higher Hep immunization. In the refined regression, only MCV immunization was used as a representative indicator of vaccination prevalence.

4.4.3 Sanitation and Water

Data on percent population with access to sanitation and clean water was 100% for all OECD countries except for a few (very little variance), therefore, these variables were used only for Developing countries.

Between sanitation and water, sanitation consistently showed higher correlation with both HALE and AM in almost any combination of variables that were regressed. Sanitation was positively correlated with HALE at 10% significance level, and its coefficient 0.0938. It was negatively correlated with AM, but not at 10% significance level. The general theme from numerous regressions involving different combinations of variables is that sanitation matters more for health than water (sanitation is consistently significant statistically, whereas water was not.)

4.4.4 Health Care Professionals and Facilities

The density of physicians, nurses, dentists, pharmaceutical professionals, the ratio of nurses over physicians, and the number of hospital beds per 10,000 population were considered. For Developing countries, the physician and nurses densities were not significant, hospital beds was not significant. Interestingly, the ratio of nurses over physicians was highly significant for both HALE and AM (p-value 0.00 for both) and had a positive coefficients of -0.473 and 7.79, respectively. This is an interesting result: higher the ratio of nurse/physician, the higher AM and lower HALE. 10% increase in the ratio correlates with 4.7 reduction in HALE, and 78 more deaths per 1000 working population.

What this tells us is that the higher the ratio of nurses versus physicians, the higher the AM and HALE in developing countries. One of the problems in developing countries is that most health care professionals are nurses or nurses' assistants, and very few are physicians. Nurses and nurses' assistants have limited capabilities compared to physicians, and thus as the ratio increases, the quality of health care received is likely to decrease.

For OECD countries, ratio of nurse/phys did not matter. Number of hospital beds per 1000 population negatively correlated with AM at 10% significance level. Surprisingly, pharmaceutical density correlated with AM positively (the more pharmaceutical workers, the higher AM) at 10% significance level.

4.4.5 Lifestyle: Alcohol and Tobacco Use

Data on prevalence of tobacco use was only available for OECD countries, but per capita recorded amount of alcohol consumption (unit: liters) was available for both developing and OECD countries. Neither of them was significant for either HALE or AM for both country samples.

4.4.6 Causes of Deaths

Aged standardized deaths due to cancer, cardiovascular diseases, injuries, and non-communicable diseases were tested for their correlation with AM and HALE. Death due to injury is statistically significant for all samples except for HALE for OECD countries. In all the other regressions of different combinations of variables, death due to injury persistently showed statistical significance at around 5% level. Death due to cancer, cardiovascular disease, and non-communicable disease were not statistically significant for any sample.

4.4.7 Fertility Rate

Total fertility mattered only for developing countries. It was correlated negatively with HALE and and positively with AM at 1% and 10% level respecitvely.Possible explanation could be that higher the fertility rate is correlated with higher population growth rate, and more population for the country, both of which are characteristic of less developed countries. The higher population combined with scarce health care resources in most of the countries in the Developing country group could lead to poorer health state of the general population.

4.4.8 Education

Data on net primary school enrollment rate was complete only for OECD countries. However, when developing countries with the data available were regressed, net primary school enrollment rate did not have statistically significance for neither HALE nor AM. It was negatively correlated with AM at 5% confidence level. Net primary school enrollment rate represents the education level of the general population, and the hypothesis was that higher the education level, the healthier the general population because they will better take care of their health, thus lower the AM. However, it would have made more sense if the basic education level mattered more for developing countries as education is less widely available compared in OECD and more developed countries, so the basic skills and knowledge learned in primary school would prove more beneficial to the population in the developing countries. However, results (not reported for developing countries, but estimated with smaller sample size, whose results are unreported in the table) showed that the enrollment rate mattered more for OECD countries than developing countries.

4.5 Free Structured Regression - Refined

4.5.1 Representative Variable for Each Category

Based on the results in table 6, one or two variables from each category was chosen as a representative variable. For instance, physician, nurse, pharmaceutical workers density, ratio of nurses/physican, hospital bed density were all used in the unrefined free structured regression. Because they all fall under health care professionals and facilities category, and they are likely to be correlated with each other, thus including such similar variables likely biased upward the standard errors of the variables, reducing the statistical significance of each of the variables, because their explanatory power is shared by many several similar variables. Using only one or two of from each category is likely to eliminate the problem.

Per capita GDP, net primary school enrollment rate, fertility rate, MCV immunization rate, physician density, ratio of nurse and physicians, sanitation, death due to injury, tobacco use and alcohol use were chosen for health indicator representative variables from each category of health variables. GHE per THE and per capita THE were used for developing countries, and where as the prepaid private insurance, social security, and out of pocket health expenditures as percents of THE were used for OECD countries as health expenditure representative variables. Social security, private insurance, and out of pocket expenditures per THE were all included even though they all represented the health expenditure category in order to study the relative importance of each in determining the health state of the general population.

4.5.2 Results for OECD Countries

After the initial refining (see table Free Structured Regression - Refined), at least one variable from each category was included in the regression; however, none of the variables were significant for HALE, and only a handful of variables were significant for AM at 10% significance level. The fact that non of the variables were significant for HALE compelled for further refining of the list of variables. Therefore, the regression was refined once more (see table Free Structured Regression - Further Refined). In the second round of refining, only the variables that were significant at minimum 20% confidence level for both HALE and AM were chosen. The last remaining variables, which were chosen because they showed persistent statistical significance in explaining HALE and AM, were net primary school enrollment rate, death due to injury, tobacco use and alcohol use, private pre-paid insurance plan.

Even though many categories were unrepresented in the second refined sample, the second round of refining was justified in that the adjusted R^2 decreased by only 15% for both HALE and AM and that every variable was significant at at least 10% significance level for both HALE and AM in the final regression.

4.5.3 Results for Devleoping Countries

Initially, at least one variable from each category was included in the regression; then, as for the OECD countries, the list of variables were further refined. This was justified in that the adjusted R^2 decreased only by less than 3%, and that all the variables were significant at 10% confidence level, except for per capita recorded alcohol consumption for both HALE and AM, and total fertility rate for AM.

4.5.4 Conclusion: Why Government Health Expenditure May Matter More For Health

The results for the free structured regression suggests a possible explanation for why public health expenditure may matter more for the health of the (working age) population. For OECD countries, it can be explained through the negative relationship between private pre-paid insurance with health. For developing countries, it can be explained through the positive relationship between general health expenditure, sanitation and health, and the negative relationship between the ratio of nurse/physician and health.

For developing countries, the results show that government health expenditure as percent THE is highly significant. When private health expenditure as percent GDP was included instead of GHE per THE, its relationship with HALE and AM was exactly the opposite - it negatively correlated with HALE, and positively with AM. This means that higher the GHE per GDP is linked to better health, whereas higher PHE per GDP is linked to worse health state of the population. Another important thing to note is the fact that expenditure on improving the access to sanitation is not included when calculating government health expenditure.(WHO) This may suggest that the importance of the government's expenditure on improving the health is not fully represented by the GHE. The fraction of population with access to sanitation facility has persistently been positively correlated with HALE and negatively correlated with AM in numerous regressions of involving different combination of the variables. Access to sanitation includes "connection to a public sewers, connection to septic systems, pour-flush latrines, simple pit latrines and ventilated improved pit latrines. Not considered as improved sanitation are service or bucket latrines (where excreta is manually removed), public latrines and open latrines." (WHO) These facilities are usually maintained by the government, thus it serves as a proxy for the government's effort to maintain public heatlh, especially in developing countries, yet is not classified under the government health expenditure under WHO and OECD guidelines. Therefore, the inclusion expenditure on sanitation in the GHE may be a better measure of the government's total expenditure on improving the health of the working population, and is likely to give a greater importance to the GHE in explaining the variance of HALE and AM. Taking this into account, if GHE included the expenditure spent on other non-medically related health promoting factors such as sanitation, and this new GHE were used for the study in section 2, it would likely yield a higher value for θ as the relative importance of the GHE in determining health, thus economic growth, would increase compared to the ϕ, the private expenditure. In other words, the θ for developing countries may have been underestimated due to the fact that a large fraction of government's expenditure on improving health is not represented by the GHE, despite the fact that these non-medically related health promoting factors such as sanitation are extremely important factors determining health in developing countries. This could explain why θ was not larger for developing countries contrary to the belief that government expenditure on health should matter more for the developing countries than for OECD countries. Perhaps the problem lies in the fact that the NHA (National Health Accounts) adopted its guidelines from the OECD's System of Health Accounts - measures such as sanitation can hardly explain the variance in health in these developing countries because they are close to 100% for all the countries in OECD.

For the OECD countries, neither GHE per THE nor THE per GDP was significant in explaining the variance of HALE and AM. What is interesting instead is the private pre-paid insurance per THE persistently showed statistical significance in explaining HALE and AM. Three components of the THE (the fractions of Social security, private pre-paid insurance, and out of pocket in THE) were included in the OECD sample to examine their relative importance in explaining HALE and AM. Social security expenditure on health (SSHE) "includes outlays for purchases of health goods and services by schemes that are mandatory and controlled by government. Such social-security schemes that apply only to a selected group of the population, such as public sector employees only, are also included here." Private pre-paid insurance (prepaidHE) is "the outlays of private insurance schemes and private social insurance schemes (with no government control over payment rates and participating providers but with broad guidelines from government)." The house hold out of pocket expenditure is "the direct outlays of households, including gratuities and in-kind payments made to health practitioners and to suppliers of pharmaceuticals, therapeutic appliances and other goods and services. This includes household direct payments to public and private providers of health-care services, non-profit institutions, and non-reimbursable cost-sharing, such as deductibles, copayments and fees for services." When these three fractions were included in the regression along with other health variables, prepaidHE was the only variable statistically significant in explaning HALE and AM. In fact, prepaidHE alone could explain up to 25% of the variance in HALE and AM (i.e. R^2 was around .25 when prepaidHE was regressed against HALE and AM.) The other two either showed no significance, or had little explanatory power, even when each were considered alone. This interesting finding suggests that the variance in HALE and AM are determined by how much of the country's total health expenditure is channeled through a form of private insurance than any other measures of health expenditures. Per capita government health expenditure was also positively correlated with HALE at 10% significance level. When it was replaced with per capita total health expenditure, per cap THE was not statistically significant for neither HALE nor AM, which suggests that per cap GHE's statistical significance in explaining HALE did not merely stem from its correlation with absolute amount of total health consumption; rather, it came from how much the government managed health expenditure is spent per capita.

Even more interesting is the sign of the coefficient for the prepaidHE term. It is negatively correlated with HALE and positively with AM. This indicates that higher fraction of THE spent through private insurance, the higher the adult mortality rate, and lower the HALE. This is a powerful finding in that it may mean that private insurance is the least efficient channel of health care consumption out of the three channels of health care consumption considered. The fact that prepaidHE's statistical significance, and the signs of its coefficients suggests indirectly that a channel other than private insurance is more efficient in improving the health, perhaps a government managed channel. It is important to note that SSHE does not seem to represent all types of government mediated insurance schemes, and is not equal to what we normally think of as government managed insurance, therefore, SSHE's statistical insignificance in explaining HALE and AM does not discredit or say anything about the importance of government health expenditure. For instance, the National Health Accounts for Canada reports only less than 2% of GHE as SSHE on its NHA.

On the contrary, the publicly funded insurance plans are required to pay for medically necessary care, as mandated by the Canada Health Act, thus the primary channel for health care obviously is a government managed insurance scheme. Similarly, UK reports 0% for social security, when National Health System, a government managed health insurance, is the largest insurance scheme in the country . This all suggests that such government managed insurances (that of Canada, or National Health System of UK) are not included in the Social Security category of the NHA, nor are they classified separately the current National Health Accounts provided by WHO (WHO only reports estimates for social security fund, and expenditure through the ministry of health under the government health expenditure.) What can be concluded here, instead, is that private insurance is likely the least efficient channel through which health care is consumed, and other channels, perhaps a government managed one, or perhaps out of pocket expenditure (which is not likely, and showed no significant relationship with health) is likely to be more efficient than the private insurance plans. This finding combined with the statistical significance of per cap GHE for HALE suggests that government health expenditure is actually what matters more for the health, and is the more efficient channel of health care consumption in OECD countries. This bolsters the finding that GHE matters more for economic growth in that less money is spent through private insurance, better the health state of the population, hence higher economic growth, indirectly explains why GHE has relatively more important for economic growth - in efficiency terms, a dollar spent on health through private insurance brings less health compared to a dollar spent through other means (such as the government), and thus results in less accumulation in the health capital, which translates to less economic growth.

5 Principal Component Analysis

First invented by Karl Pearson in 1901, principal component analysis reduces the number of possibly correlated variables by selecting a small group of uncorrelated factors (called components) that are later used as independent variables in a regression against the original dependent variable. Each component consists of all the variables, with differing weights. The first component accounts for the the most in the variables, then the second component explains as much as possible of the variance that is left over, and so on. Aside from reducing the number of variables, it also helps uncover major sources of variation underlying independent variables.

5.1 Results

Principal component analysis was performed using STATA. Table 5 and 6 show the results.

A total of 12 components were generated. This means that 12 components were needed to explain the variability in totality ($R^2 = 1$). Eigenvalue is the amount of variance in the data described by each factor (component). Generally only the factors with eigenvalues of 1 or greater are used because an eigenvalue of less than 1 means the component can account for less variance than the original variable did, thus of little use. Once factors to be used are selected, they are "rotated," which is a process redefining the factors to spread the variability more evenly among components, to make each factor more sharply distinct by configuring the loadings to be either very high (close to -1 or 1) or very low (close to 0). Then, these four rotated factors were regressed against Adult Mortality and HALE.

5.2 Interpretation of Data

For Developing countries, the first four components had eigenvalues greater than 1. The factors were varimax rotated. The following tables show the result. An insight into what each component means can be gained from looking at the variables that has a high coefficient for each factor. Variables of coefficients greater than 0.32 were considered important contributors to each component.

5.2.1 Developing Countries

- Component 1: NursPhysRatio, incidence tuberculosis, population with access to sanitation (-), total fertility, (-) number of physicians (Poor National Health Maintenance Effort)
- Component 2: HospitalBed, Alcohol, Nurse Density, (Unclear)
- Component 3: NetPrimary, Immunization, Water, GHE/THE (Infrastructure/Government Involvement)
- Component 4: THE/GDP (Total Spending on Health)

Component 1 is likely to represent poor national health maintenance, component 2 is unclear because Alcohol and HospitalBed and NurseDensity are seemingly unrelated, component 3 Infrastructure/Government Involvement), and component 4 total sending on health.

All components were significant at 1 or 5% confidence level. Component 1, 2, and 4 are positively correlated with adult mortality and HALE. Component 3 is negatively correlated with adult mortality and HALE. This suggests that poor national health maintenance effort, and total spending on health are negatively correlated with health. The first makes intuitive sense, whereas latter does not. It may be that the developing countries with higher adult mortality and HALE spend a large fraction of their total resources (GDP) on health care to prevent the national health from getting worse.

Component 3's positive correlation with health suggests that the infrastructure of the country and governmental involvement matter in its people's health state. (High primary school enrollment rate, immunization rate, and access to clean water, GHE/THE all represent positive infrastructure and government's developmental effort.)

Numerical interpretations are difficult because each factor is a combination of variables that are weighted differently for each factor, and there is no obvious unit.

5.2.2 Developed Countries

Five components had eigenvalues of greater than 1, thus were retained. They were then varimax rotated. Table 12, Table 13, and Table 14 summarize the results.

- Component 1: Net primary enrollment rate, out of pocket spending per total health expenditure (-), GHE/THE (Government Involvement / Large Government / Active Government) – negative out of pocket health care spending and positive GHE/THE may indicate that the (active) government rescue those who have to buy health care out of pocket otherwise
- Component 2: THE/GDP, Prepaid Insurance per total private health expenditure (Private Health Care Infrastructure / Private Insurance Industry)
- Component 3: GDP, Net primary enrollment rate (-), Ratio of Nurses and Physicians, Tobacco use (-) (Unclear)
- Component 4: Tobacco use (-), HepB Immunization, Hospital Bed (Health Consciousness)
- Component 5: Fertility (-), Hospital Bed, Alcohol use. (Large Old Population)

Not all factors were significant for adult mortality or HALE. Component 2 was significant at 5% confidence level for adult mortality, and component 1 for HALE at 5% confidence level. Component 1 seems to represent active government involvement or large government. This would then be negatively correlated with out of

Table 10. Developing Country PCA - Rotated Components

Variable	Comp1	Comp2	Comp3	Comp4	Unexplained
PerCapGDP	-0.2224	0.2718	0.0841	0.0662	.1438
NetPrimEnrlMale	-0.0795	-0.1506	0.4791	0.1263	.2734
FertilityRate	0.3746	-0.0271	-0.1572	0.0112	.1193
MCVImmunized	0.0036	0.0231	0.5072	0.0296	.2057
HospBeds	0.0250	0.5500	0.0374	-0.0303	.1081
NursePhysRat	0.5272	0.0848	0.1491	0.1124	.1654
TotHealthExp	0.0226	-0.0536	0.0320	0.6177	.2607
DeathsTuber	0.3285	0.1430	-0.2859	0.1884	.2696
AlcoholUse	-0.1135	0.3906	-0.1558	0.3008	.1643
TobaccoUse	-0.3954	0.0404	0.0119	0.0369	.2736
Sanitation	-0.1911	0.0814	0.3186	0.0309	.1707
NumNurses	0.0705	0.5944	0.0239	-0.1549	.1553
NumPhysicians	-0.3244	0.1723	-0.0514	0.1740	.217
GenGovHlthExp	0.3154	0.1475	0.4954	-0.0503	.3546
OutOfPocket	-0.0380	0.0602	-0.0209	-0.6312	.2464

Table 11. Developing Country Linear Regression.

Country	Adult Mortality Rate	HALE
pc7	56.37* (6.42)	-4.02* (0.23)
pc8	20.30* (6.15)	-0.66* (0.23)
pc9	-19.65* (5.07)	1.66* (0.33)
pc10	15.72** (6.48)	-0.83** 0.37
Constant	252.10* (7.94)	54.95* (0.44)
R^2	0.859	0.924

Table 12. Developed Country PCA Analysis

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	3.16579	.640211	0.2638	0.2638
Comp2	2.52558	.702297	0.2105	0.4743
Comp3	1.82328	.646697	0.1519	0.6262
Comp4	1.17659	.131129	0.0980	0.7243
Comp5	1.04546	.292439	0.0871	0.8114
Comp6	0.75302	.048651	0.0628	0.8741
Comp7	0.70437	.309122	0.0587	0.9328
Comp8	0.39525	.156859	0.0329	0.9658
Comp9	0.23839	.141472	0.0199	0.9856
Comp10	0.09691	.028200	0.0081	0.9937
Comp11	0.06871	.062052	0.0057	0.9994
Comp12	0.00666		0.0006	1.0000

Table 13. Developed Country PCA - Rotated Components

Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Unexplained
PerCapGDP	-0.1434	0.1323	0.5527	-0.1698	0.0201	0.293
NetPrimEnrlMale	0.4466	0.0096	-0.3112	0.0651	0.0677	0.185
FertilityRate	0.2292	0.0766	-0.0542	0.0929	-0.6618	0.213
MCVImmunized	0.0115	0.0877	-0.0572	0.7533	0.0479	0.207
HospBeds	0.1803	-0.0212	-0.0146	0.3146	0.5823	0.382
NursePhysRat	0.1950	-0.0409	0.6598	0.0409	0.0674	0.160
TotHealthExp	0.1031	0.5761	-0.0618	-0.1320	-0.1063	0.159
AlcoholUse	0.2008	0.2253	0.0501	-0.2518	0.3869	0.318
TobaccoUse	0.1061	0.1111	-0.3331	-0.4182	0.1968	0.147
PrePaidCosts	-0.1049	0.6732	0.0583	0.1790	0.0065	0.075
OutOfPocket	-0.5147	-0.2185	-0.1197	-0.0128	0.0699	0.032
GenGovHlthExp	0.5646	-0.2663	0.1442	-0.0484	-0.0802	0.093

Table 14. OECD Country Linear Regression.

Country	Adult Mortality Rate	HALE
pc1	-0.44 (1.34)	0.40** (0.18)
pc2	4.39** (1.88)	-0.22 (0.18)
pc3	-2.63 (1.81)	0.31 (0.32)
pc4	0.40 (2.04)	0.22 (0.29)
pc5	0.98 (1.87)	0.21 (0.29)
Constant	82.8* (2.45)	71.4* (0.32)
R^2	0.281	0.252

pocket spending on health care (the government will actively cover those who cannot afford private insurance) and positively correlated with GHE/THE, which is the case. Also, high net primary enrollment is indicative of an active government as primary school education is largely a responsibility of the government in most countries, rather than private sectors. Component 1 is positively correlated with HALE, which means that the more active involvement of the government (in health) is correlated with a longer healthy life expectancy.

What is interesting and in accordance with the findings from the earlier free structured regression is that private insurance seems to negatively affect health. Component 2 is interpreted as representing the private health care insurance (and its size) because it is correlated with THE/GDP (the size of the total health care industry) and fraction of private insurance per total health care expenditure. Component 2 is negatively with HALE, which means, if the assumed interpretations are right, that the larger the private insurance industry or the larger fraction of total health care that is channeled through private insurance, the higher adult mortality rate. This resounds and support the finding from free structured regression earlier that the fraction of private health insurance was negatively correlated with HALE and positively with adult mortality. Further, this is along the same line of logic that government health care is more important in economic output, as the results (theta is greater than phi) from section 2 showed.

6 Constant Elasticity Substitution (CES) Production Function

A CES production function was proposed by American economists Kenneth Arrow (1921-), Hollis Chenery (1918-), Bagicha S. Minhas (1929–2005), and Robert Solow (1924-) in their 1961 paper on capital-labor substitution and economic efficiency. Its unique feature is that it assigns a constant value to the substitutability of the factors of production included. Substitutability of factors tells us whether they are perfect subsitutes, perfect complements, or in between. The most commonly used CES production involves capital and labor as factors of production.

$$Y = A(\omega K(t)^{-\rho} + (1-\omega)L(t)^{-\rho})^{-1/\rho} \tag{41}$$

A is the scale parameter, ω is the relative weight of capital (thus, $1-\omega$ the relative weight of labor), and ρ is the parameter that yields the elasticity of substitution, σ.

$$\sigma = \frac{1}{1+\rho} \tag{42}$$

If $-1 < \rho < 0$, then $1 < \sigma < \infty$, labor and capital are substitutes, and it approaches perfect substitution as ρ nears -1. If $0 < \rho < \infty$, then $0 < \sigma < 1$, and they are complements. It approaches perfect complementation as σ approaches 1.

6.1 Application to Health Expenditures

An important question that can be answered is whether government and private health expenditures are substitutes or complements. In the first section where Model 1 through 4 were considered, it was assumed that GHE and PHE were perfect substitutes, or having unit elasticity. In layman's term, this meant that one dollar spent as GHE is perfectly substituted by one dollar spent as PHE in terms of bringing economic output.

The CES production function can then be applied to study the substitutability of GHE and PHE.

$$Y = (\omega {H_p}^{-\rho} + (1-\omega){H_g}^{-\rho})^{-1/\rho} \tag{43}$$

Linearizing the equation yields

$$\ln Y = \frac{-1}{\rho} \ln \omega {H_p}^{-\rho} + (1-\omega){H_g}^{-\rho} \tag{44}$$

We can also insert this function into the augmented Solow Growth Model that was constructed in section 1.

$$Y(t) = A(t)L(t)K(t)^{\alpha}H(t)^{\beta}\left(\omega {H_p}^{\rho} + (1-\omega){H_g}^{\rho}\right)^{\gamma(1-\rho)} \tag{45}$$

$$\begin{aligned} \ln Y = \frac{\alpha}{1-\alpha-\beta-\gamma} \ln K &+ \frac{\beta}{1-\alpha-\beta-\gamma} \ln H \\ &+ \frac{\gamma(1-\rho)}{1-\alpha-\beta-\gamma} \ln\left(\omega {H_p}^{\rho} + (1-\omega){H_g}^{\rho}\right) \\ &- \frac{\alpha+\beta+\gamma}{1-\alpha-\beta-\gamma} \ln\left(n+g+\delta\right) \end{aligned} \tag{46}$$

Because the expression still holds a non-linear term, and cannot be linearized by taking a log in the usual manner, the non-linear (nl) function of STATA was used to estimate the values for α, β, γ, ρ, and ω.

6.2 Results

Table 15 and Table 16 summarize the results.

6.3 Discussion

α, β, γ, exponents for capital, education, and health terms respectively, consistently significant at close to 0% confidence level, except for the developed country sample where α was not significant at 10% level. This can be perhaps attributed to the very small sample size (only 26 observations). Overall, this shows that capital, education and health are important for economic output. The coefficients for α, β, γ are around 0.25, 0.27, and 0.11 respectively for the all country sample. The α value remains relatively the same throughout different sample groups considered. However, β value drops down to 0.18 for developing countries, where as it dramatically increases to 0.54, whereas γ increases to 0.14 for developing countries, but drops to 0.09 for developed countries. These differences suggest that education becomes much more important in explaining the variance of income among developed countries, and health less, whereas health becomes more important and education less in explaining the income variance among developing countries. This makes intuitive sense in that economic activity in more developed nations is less hindered by their general health condition, because with exception of cancer or other debilitating diseases, workers maintain healthy enough state to perform productively (the productivity is increased dramatically as health increases from zero, but marginal productivity per health is likely to be diminishing, and approaches a horizontal asymptote placed at some value of health that is considered "‘enough"’ to perform most economic tasks. Healthiness beyond that point may yield marginal productivity, but may not be significant, and vary on each individual.) Rather, it is the education that should matter more in economic output because a much larger fraction of the their economy consist of jobs requiring higher education or expert knowledge - where a college degree is becoming a must. On the contrary, the health of workers at below the saturation point, marginal productivity per health is likely to be still high. Education is still important, but higher education is perhaps less than in developed

Table 15. CES Solow Growth Model

	All	Developing	OECD and Advanced
α	0.26* (0.08)	0.25** (0.10)	-0.07 (0.13)
β	0.27* (0.06)	0.18** (0.08)	0.55* (0.09)
γ	0.11* (0.02)	0.14* (0.05)	0.09* (0.02)
ρ	-103 (10123)	-77.3 (64018)	32.4 (1150)
ω	0.97 (10.3)	1.00* (0.01)	0 (0)
b_0	-1.29* (0.26)	-0.91** (0.42)	-0.25 (0.42)
$\overline{R^2}$	0.785	0.576	0.287

Table 16. CES Health Expenditures Alone

	All	Developing	Developed
ρ	0.20* (0.02)	0.21* (0.03)	0.21* (0.04)
ω	0.53* (0.02)	0.54* (0.02)	0.47* (0.06)
$\overline{R^2}$	0.306	0.354	0.702

countries because a large fraction of the economy consists of primary industry such as manufacturing, textile, and natural resources.

The estimates for ω and ρ are mostly insignificant in all groups (their confidence level is over 90%), which makes any meaningful interpretation of the coefficients difficult. However, the results from CES production function consisting of PHE and GHE are significant and gives an insight into the substitutability of PHE and GHE. ρ and ω values are significant at 0% confidence level in all three country groups. The average coefficients for ρ is around 0.2 and for ω around 0.50.

The positive coefficient for ρ indicates that GHE and PHE are in fact complements rather than substitutes. This finding is interesting because it suggests that consumption of GHE gives rise to consumption of PHE, not less of it, and vice versa. If what the results suggest is true, like a purchase of ground coffee incentivizes one to buy a coffee pot (complements), consuming health care through private means encourages consuming health care through public means also, and vice versa. Is this the case in the health care industry? It is plausible. A person who sees a psychologist, and has costs covered by the government, may seek additional counseling sessions on her own because she likes it so much, even though the government only pays up to two session per week. In this case GHE gave rise to PHE. Another example may be a surge in a particular health care consumption in the private sector giving rise to a demand for such health care even among those who are covered by the government, so that the government adopts and begins to cover for it, i.e. a new health care trend in the private sector spreads to the public sector. For instance, anti-depressant or psychological counseling used to be considered elective and thus only covered by private insurance. But as it became extremely common to take such drugs and seek counseling - a new trend has been created - the public insurance covers most of what private insurance does today. Also, bariatric surgeries such as gastric bypass is covered mostly by private insurance only, but it may become more common for the government to cover for such procedures as the demand for it will rise even among those covered by public as insurance as they learn more and more about it as it become popular in the private sector.

Free structured regression was conducted in two ways. In the first method, all health indicators were run in a regression to see the effect of each on adult mortality and HALE in the presence of all other variables, and subsequent reductions in variables were made based on how consistently the variables were significant. The final regression consisted of fewer than 10 variables that were consistently significant throughout the reduction process.

In the second method, Principal Component Analysis was used to find a pattern among the variables themselves, and construct new variables based on such patterns, and run them in a regression against the dependent variables, adult mortality and HALE.

Both have advantages and disadvantages; the first method shows the significance and coefficients of each variable against adult mortality and HALE, thus each variable remains a separate entity, explaining the variance of the dependent variable independently. Interesting and direct interpretation can be made from the results because each coefficient belongs to a different variable. The disadvantage is that it is extremely difficult to narrow down the list of variables especially when there are more than 20 variables to be considered, and there are thousands of different combinations of variables that can be tested. Furthermore, significance of variables change as more variables are added and subtracted to the regression, making it difficult to decide whether to retain such variables or not.

Principal component analysis is a type of factor analysis that is used to narrow down a wide range of variables, therefore, it is well suited for this kind of regression where there are more than 20 variables involved with no pattern among them. The downside of this technique is that individual variables lose their own place in the regression, and becomes part of a newly constructed variable instead. Because it is these new variables that are regressed against the dependent variables in question, direct interpretations about individual variables are often hard.

Conclusion

The intention of this study was to determine how much government and private expenditure on health care mattered for economic growth, and the overall health state of the working population. The logic behind the study was that the health of the labor is translated to economic performance of the labor, and thus, can affect economic growth. Learning which type of health expenditure matters more for economic growth would give some guidance to whether a government managed health care system (ex. United Kingdom) or a privately managed health care system consisting of numerous private insurance companies (ex. United States) is better. This is a widely debated topic of today, and the author hoped to find further evidence supporting one way or the other.

The first part of the study was centered around the Solow Growth Model. Health capital was introduced as another variable into Mankiw's version of SGM (Model 1). Total health expenditure as percentage of GDP (Model 2) and Per capita total health expenditure (Model 3) were used as indicators of the health capital, and the results were compared to see whether per capita or percentage form performed better. Per capita total health expenditure yielded much better R^2 value, so the author decided to use the per capita form of health expenditure as the indicator for the health capital in model 4. To study the relative weights of government and private health expenditures, per capita total health expenditure was broken down into two separate variables; per capita government and private health expenditures. All the variables had coefficients of expected signs whenever they were statistically significant. (physical, human, health (comprising of GHE and PHE) capitals had positive coefficients, while labor growth term had a negative value, which was expected according the theory of SGM and previous empirical studies on SGM). There were cases where not all term were statistically significant at 10% confidence level, but the F-tests in such cases showed that the variables were jointly significant at close to 0% confidence level.

The next step was to test the fit of Model 4 in SGM framework. Model 4 included physical, human, and health capital broken down into to Government and Private components, and the labor growth term. In previous literature such as Mankiw (1992), in order to test for the validity of SGM as an economic growth model, the values for the exponents of each term in SGM equation were determined. Then, the estimated exponents, or the shares, were compared with the real shares of those terms determined from many years of empirical data. For instance, the historically determined shares of investment (α) is 1/3, and the estimated values for α from Solow's paper and Mankiw's paper (1992) was close to 1/3, ranging around 0.35-0.45, thereby supporting the validity of the SGM as an economic model. First, the restriction(21) was tested using the F-statistic. The restriction is derived from the SGM framework, and the restriction holding true would indicate that model 4 fits into the framework. The F-test showed that the null hypothesis that the sum of the coefficients equals zero was not rejected, which indicated that the restriction held true for Model 4. The initial evidence that Model 4 generally fit into the SGM framework allowed for the rearrangement of (22) into (23). An additional restriction that $\theta + \phi = 0$ was imposed as was assumed when breaking down total health expenditure into private and public components in Model 4. New regressions were run, and the coefficients for each term in (23) were matched with the corresponding equation made up of exponents as in (24) through (28), and the values for exponents α through ϕ were estimated.

The estimated values for α, β and γ were similar to those of Yoo and Yang (2004), which suggests model 4 is an acceptable expansion of SGM. α, β and γ for Yoo and Yang were 0.201, 0.252, and 0.187, respectively, and 0.17, 0.25, and 0.12 for Model 4, respectively. The values for α and β are similar, especially for β, where as the value for γ is smaller in model 4 than in Yoo. A possible explanation for this is that breaking up the total health expenditure into GHE and PHE components in Model 4 eliminated the synergistic effect between GHE and PHE when they were represented together as THE (this is a speculation rather than a conclusion). The θ and ϕ shows the relative weights of GHE and PHE in determining economic growth. The value for θ and ϕ were around .6 and .4, respectively for all three sample groups, All, OECD, and Developing countries. The θ was slightly higher for the developing countries (0.62:0.38) compared to the OECD countries (0.6:0.4), but the difference was rather small. In summary, the important conclusion of section 2 was that GHE mattered more than PHE for economic growth for all country samples.

In section 3, the potential problem of endogeneity that arises from introducing health expenditures as a health indicator into SGM in Model 4 was discussed. First, both PHE and GHE, instead of just one of the two were included partially to address the issue of THE affecting the economic growth through PHE or GHE. In other words, PHE or GHE alone could be shown to be a significant factor determining economic growth while they may merely be the proxy for the THE. Other studies that included a health indicator into SGM widely used THE as the indicator, and it was shown repeatedly that THE is a significant factor determining economic growth. Presenting PHE and GHE in the context of THE would have counted for the THEs effect on economic growth, all the while allowing for the relative ratio of PHE and GHE to be examined as the sub-variables of THE. The author constructed equation (16) as the final model. Second, there was a problem of endogeneity with respect to GDP. Economic growth was represented by the $\ln \text{GDP}$, and even if the regression results showed the GHE and PHE to be significant at 5% confidence level, and have positive coefficients, there was still the question of direction of causation. If GHE and PHE were endogenous components of GDP (variation in GDP causes variation in GHE and PHE, not the reverse), the significance of the coefficients do not mean much. They would only be of interest if GHE and PHE caused variation in GDP. To test for the causality, the Granger causality test was performed between 1) GDP and THE, 2) GDP and GHE, and 3) GDP and PHE. Heshmatti performed the granger causality test between GDP and THE, but the author could not find the studies that performed 2) and 3) in literature. All three tests were performed for three different country groups (All, OECD, Developing) as well. The causality test results were all promising. For All country sample, for instance, PHE, GHE, and THE were all shown to cause GDP, not the other way around.

The goal of section 4 of this study was to see how various measures of GHE, PHE, or THE actually affects the health of the working age population by running a free structured regression of adult mortality and health life expectancy (HALE) on GHE and PHE, and other various health determining factors such as vaccination, physician density, and population access to water and sanitation. This last section was to test the primary assumption of my study, which was that GHE and PHE contributes to the economic growth by affecting the health of the labor. Adult mortality rate of population of age between 15 and 60 was chosen as the indicator of the health of the labor force. HALE, the average number of years that a person can expect to live in "full health", was also chosen because it offers an insight into the true healthiness of the population by not only taking into consideration mortality, but also morbidity of 170 different diseases that may not result in mortality yet negatively affect the health state of the population. It is better than life expectancy because life expectancy only takes mortality into account. For instance, a condition requiring dialysis does not result in mortality as long as the person has a dialysis three to four times a week, for three to four hours at a time. Although not resulting in death, this is extremely time consuming and must negatively affect one's economic activity.

Initially, a total of 28 health variables were regressed against HALE and adult mortality (AM) using OLS. It was difficult to interpret the results because most of the variables were often statistically insignificant. This was most likely due to the fact that too many similar variables, that are probably correlated to each other, were included at the same time - for instance, density of physician, nurse, pharmaceutical workers, and hospital beds were all included, despite that they are likely to be highly correlated with one another. Such inclusion of similar variables would bias upward the standard errors, and lower the overall fit of the regression. The list of variables was refined twice. First, one or two representative variables from each category of health factor (categories such as health expenditure, health personnel, health facility, vaccination, etc). This reduced the number variables from 28 down to around 10. Many variables were still statistically insignificant in the first refined regression. It seemed like some categories just did not matter for HALE or AM, or the available variables were not good representative of the specific category. The list was refined the second time - it was reduced down from around 10 to around 6. This was a significant reduction from the initial list of variables, and many of the categories were simply left out, such as the economic status of the country (which was represented by the GDP per capita). Yet, this reduction was justified for two reasons: first, the R^2 was not reduced by no more than 12% for OECD countries, and by less than 1% for developing countries as a result of further refining, and second, almost all of the variables in the second refined regression were statistically significant.

The results of section 4 of this study provided supporting evidence for the the results of section 2 (that GHE mattered more than PHE for economic growth), and also provided a possible explanation as to why GHE matters more than PHE in both OECD and developing countries. For developing countries, government health expenditure as percent total health expenditure (GHE/THE), sanitation, and ratio of nurse/physician were statistically significant factors determining HALE and AM. GHE/THE represents the government's effort to improve the health of its people by medically related means, whereas sanitation represents government's effort to improve the health of its people by non-medical means (government health expenditure does not include factors such as sanitation although it promotes the health of the population significantly, especially in developing countries). Ratio of nurse/physician indicated that higher the ratio the poorer the health was. The fact that GHE/THE and sanitation mattered for HALE and AM, and that none of the variables of private health expenditure were significant shows that government's effort for health promotion matters more for the health of the population, and which ultimately affects economic growth.

For OECD countries, the most interesting finding was that private insurance is negatively related to HALE, and positively to AM at 5% confidence level. Private insurance was consistently statistically significant for both HALE and AM. Even when it regressed along with two other variables, Social security insurance and out of pocket expenditure, private insurance was the only one that was statistically significant. Also, when other variables of health expenditures such as PHE/THE, GHE/THE, per capita THE, and many others, were used instead of the private insurance variable, none of them were statistically significant, and it reduced the R^2 value by a significant amount. Private insurance alone accounted for about 25% of the variance in HALE and AM, and all the other health expenditure variables were either statistically insignificant, or had a minimal explanatory power. What was concluded from this finding was that higher the fraction of THE was spent through private insurance, the lower the health state of the population was. This suggests that private insurance is less efficient in improving health than other channels of health care consumption (in OECD countries, it is a matter of efficiency, rather than the physical availability of basic medical care because basic medical care immediately linked to survival are readily available in these countries, and the level general health care consumption is very high that the marginal health care consumption (the last dollar spent on health care) is not on basic health care, but more elective care), such as a government managed plan. The only other health care expenditure that mattered was per capita GHE, and it was positively correlated with HALE at 10% significance level. These two findings combined leads to the conclusion that private insurance is less efficient than government managed health consumption, which coincides with the finding that PHE is less important in determining economic growth. This may be because privately managed insurance is less efficient in improving and maintaining the health of the working population (possibly due to redundant administrative costs, poor management, or little cost containment efforts), thus matters less for economic growth.

In section 5, we used principal component analysis to narrow down the variables, and find a pattern underlying the variables. The consistent theme for both developing and developed country sample was that general government health expenditure, or government's involvement or infrastructure was important in determining adult mortality and HALE. Most interesting finding was that private insurance industry (the size of) is negatively correlated with health, which is similar to the finding from Section 4.

Lastly, in section 6, Constant Elasticity Substitution production was used to for estimating the substitutability of GHE and PHE. The finding was that GHE and PHE are complements, rather than substitutes. This complementarity may have contributed to somewhat of an insignificance of PHE in SGM alone, and made the free structured regression's interpretation more difficult. The relationship PHE and GHE may be more complex than originally thought.

In this study, the relative role of PHE and GHE was studied in the SGM framework. The finding suggests that GHE matters more than PHE in economic growth by more than 30% regardless of the income level of the country. Results also showed that per capita THE, GHE, or PHE granger caused difference in GDP per capita, not the other way around. In other words, per capita THE, GHE, and PHE are not mere endogenous components of the GDP per capita. The study also showed that government health expenditure and other health factors largely controlled by the government, such as access to improved sanitation, were statistically significant in explaining the variance in the healthy life expectancy and adult mortality for the developing countries. The fraction of total health expenditure through privately managed insurance was what mattered the most in determining the healthy life expectancy and adult mortality for the OECD countries. Interestingly, the higher the fraction of total health consumption was channeled through private insurance, the higher the adult mortality and lower the healthy life expectancy was, and higher the per capita GHE, the higher HALE was. This suggests private insurance is less efficient than government managed health consumption a improving and maintaining the health of the general population per every dollar spent. Lastly, many of seemingly important health factors such as the national average income, physician density, vaccination, or even alcohol use were shown to statistically insignificant in determining the adult mortality or healthy life expectancy.

Works Cited

Aguayo-Rico, Guerra-Turrubiates, and de Oca. "Empirical Evidence of the Impact of Health on Economic Growth." Issues in Political Economy, Vol. 14. August, 2005.

Barro, Robert J., "Economic Growth in a Cross Section of Countries," NBER Working Paper 3120, September 1989.

Bloom and Canning. "Health and Economic Growth: Reconciling the Micro and Macro Evidence," CDDRL Working Papers, Stanford University. February 2005.

Bloom, Canning, and Sevilla. "The Effect of Health on Economic Growth: Theory And Evidence," NBER Working Paper 8587, November 2001.

Devin and Hansen, "Health Care Spending and Economic Output: Granger Causality," Applied Economics Letters, Vol.8, 2001, pp.561-564.

Hesmati, Almas. "On the Causality between GDP and Health Care Expenditure in Augmented Solow Growth Model," SSE/EFI Working Paper Series in Economics and Finance 423, Stockholm School of Economics. 2001.

Hitiris and Posnett, "The Determinants and Effects of Health Expenditure in Developed Countries," Journal of Health Economics, Vol.11, 1992, pp.173-181.

Jamison, Lau, and Wang. "Health's Contribution to Economic Growth in an Environment of Partially Endogenous Technical Progress," Forthcoming in G. Lopez-Casasnovas, B. Rivera and L. Currais (eds.), *Health and Economic Growth: Findings and Policy Implications*. Cambridge, MA: MIT Press. Currently Available as Working Paper No. 10, Disease Control Priorities Project, Bethesda, Maryland: Fogarty International Center, National Institutes of Health, February 2004.

Knowles and Owen, "Health Capital and Cross-country Variation in Income per Captia in the Mankiw-Romer-Weil Model," Economics Letters, Vol. 48, 1995, pp.99-106

Lucas, Roberts E. Jr., "On the Mechanics of Economic Development," Journal of Monetary Economics, XXII (1988), 3-42.

Mankiw, Romer, and Weil, "A Contribution to the Empirics of Economic Growth," Quarterly Journal of Economics, Vol.107, 1992, pp.407-437.

McCoskey and Seldon, "Health Care Expenditures and GDP: Panel Data Unit Root Test Results," Journal of Health Economics, Vol.17, 1998, pp.369-377.

Nonneman and Vanhoudt, "A Further Augmentation of the Solow Model and the Empirics of Economic Growth for OECD Countries," Quarterly Journal of Economics, Vol.110, 1996, pp.943-953

Ram, R., "Tropics and Economic Development: an Empirical Investigation," World Development, Vol.25, 1997, pp.1443-1452.

Roberts, J. "Sensitivity of Elasticity Estimates for OECD Health Care Spending Analysis of a Dynamic Heterogeneous Data Field," Health Economics, Vol.8, 1999, pp.459-472.

Solow, Robert M., "A Contribution to the Theory of Economic Growth," Quarterly Journal of Economics, LXX (1956), 65-94.

Temple, J. "Equipment Investment and the Solow Model," Oxford Economic Papers, Vol. 50, 1998, pp39-62.

Weil, D. "Accounting for the Effect of Health on Economic Growth," NBER Working Papers 11455, National Bureau of Economic Research, Inc. 1995.

Yoo, S. H., "Does Information Technology Contribute to Economic Growth in Developing Countries? A Cross-country Analysis," Applied Economics Letters, Vol.10, 2003, pp.679-682.

Yoo and Yang, "Public Health Expenditures and Economic Output: A Cross-Country Analysis," Korean Journal of Public Finance, Vol.19-1, 2004, pp30-62.