The Effect of Health Status on Economic Growth

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1 Proposal

This paper will explore the effect of health status on economic growth. Over the past half century, economists and statisticians alike have estimated the effect of health status on economic growth through the use of a proxies, such as health indicators. A health indicator with which many are familiar, life expectancy, is a statistical measure of average lifespan based on birth year, sex, and other demographics. Economists like Bloom (2004) have reported the "positive, sizable, and statistically significant effect" of life expectancy on economic growth. Despite such findings, other economists, such as Pascale (2005), argue that life expectancy is an imperfect measurement of global health status. Such discrepancies between economists on the significance and magnitude of health indicators effect on economic growth are not unheard of. The debate over the efficacy of health indicators constitutes reason to investigate the validity of any measure of health status in its effects on economic growth.

Life expectancy is one measure of health of health status; however, there is a refined metric developed in the 1990s by the World Health Organization, disability adjusted life years (DALY). DALY is a measurement of health loss which effectively sums the years of life lost as a result of premature death and the years of life lived with a disability. The initial motivation behind DALY was to develop a health metric capable of providing "consistent estimates of the incidence, prevalence, duration, and case-fatality" for disabling diseases around the world (Murray, 1996). In our estimations of the effect of health status on economic growth, we focus on two health indicators, fertility rate, whose effect is well understood in economics, and a contemporary measure, disability adjusted life years (DALY), whose effect is inconclusive, and determining their impact on GDP growth rate.

Using DALY and fertility rate, we model the effect of health status on economic growth at five-year intervals for approximately 168 countries. Similar to research conducted by Bhargava et al. (2006), data from the World Development Indicators dataset (WDI) is analyzed on a panel of GDP series adjusting for purchasing power. We focus on the effect of DALY and fertility rate on economic growth and seek to generate consistent estimates for fertility and identify the statistical significance of the relationship between DALY and GDP growth rate.

2 Literature Review

The vast empirical literature on the effect of health status on economic growth focuses on issues regarding the legitimacy of distinct health indicators, the relationship between health status and economic growth, and the validity in using health status to direct public policy. Based on these questions, this literature review will consider the following: (1) the strengths and weaknesses of health indicators, (2) the main causes of economic growth, (3) the relationship between health indicators and economic growth, and (4) the implications of using disability adjusted life years as a proxy of health in measuring economic growth.

2.1 Strengths and Weaknesses of Health Indicators

Discrepancies among the validity of health indicators, even those seemingly akin, are not unheard of. In fact, health indicators have become more varied in terms of measurement since the 1980s. With various health indicators being introduced, accurately identifying representative and responsive indicators is critical to quantitatively describing the overall health of a population. Perhaps the most commonly known health indicator is life expectancy, a statistical measure of the average time one is expected to live (Engineer et at., 2010). Life expectancy is the only health indicator used in constructing the Human Development Index (HDI), a ranking of countries based on their achievement in human development. Other health indicators are infant mortality rate, adult survival rate (ASR), and age at menarche, to name a few. Though there can be different uses for different health indicators, the efficacy of specific health indicators in their use relating to economic growth remains under debate.

Unsurprisingly, several concerns have been cited about the strengths and weaknesses of particular health indicators. There is some evidence that there exist more efficacious indicators than life expectancy for quantifying the health status of a population. Research shows that there may be more suitable proxies for measuring health, for instance, indicators representative of both the living and the dying. Take Barton et al.'s (1981) study for example, suggesting that the occurrence of pressure sores would be a better parameter, as it is "relevant to the living and the dying, and reflects preventable morbidity caused by deficits in social, remedial, 'hotel,' nursing and medical care, whether acute or chronic." Furthermore, it has been claimed by Takano and Nakamura (2001) that mortality rate is perhaps a better indicator. While there lacks economic consensus on the efficacy of pressure sores as a proxy for health, in recent years there has become growing support of mortality rate as a strong health indicator. Investigating the influence of 35 health indicators, Takano and Nakamura (2001) found male and female mortality rate to be the most significant indicator, describing 50% of the variance in health in their study. Together with those findings, Jourmard et al. (2008) suggests there is evidence that among all health indicators, despite the shortcomings of mortality and longevity, male and female mortality "remain the best available proxies for health."

The debate as to whether a health indicator constitutes a strong proxy for health is fueled by the health indicators' ability to characterize the overall health of a population and the indicators' level of responsiveness to the quality of health care mediations (Joumard et al., 2008). Deaths that are unrelated to the quality of health care mediations have been used to show that mortality is an imperfect measure (Joumard et al., 2008). Jourmard et al. (2008) notes other imperfections have risen from the fact that "cross-country comparisons of health care systems" are particularly difficult to make using mortality as a primary indicator. However, mortality is not the only imperfect measure. For instance, several concerns have been voiced about the valuable data lost when basing health status on life expectancy. Despite the HDI relying on life expectancy as its sole indicator, life expectancy too has drawbacks, as it "is only an indirect measure of healthy years lived" (Engineer, Roy, and Fink, 2010). There has been empirical work done by Engineer, Roy and Fink (2010) to remedy these flaws by introducing a new indicator into HDI's calculations, expected lost healthy years (LHE). Engineer, Roy and Fink (2010) suggest a different approach and construct HDI using LHE. The findings were similar to the findings when using only life expectancy. The lack of consensus on the strengths and weaknesses of health indicators suggest a health indicator representative of the overall population and sensitive to the quality of health intervention may allow for more meaningful comparisons of overall health status.

2.2 Causes and Reasons for Economic Growth

The determinants of economic development are a prevalent focus of both theoretical and empirical research. There are several philosophies of economic growth which researchers disagree upon, including the debates on the effect of decreased inflation, increased early education, and decreased government consumption on economic growth. Over the years, growth theory has evolved in stages revolving around government policies and technological progress, to encompassing broader issues such as "accumulation of human capital, fertility, and diffusion of technology" (Barro, 1997). As Barro suggests, accumulation of capital is among some of the major theories of economic growth. Solow (1956) developed a model, the Solow growth model, using a production function framework to describe exogenous growth in an economy in which output is produced with only two factors: labor and capital. The Solow (1956) model operates under the key assumption that "capital is subject to diminishing returns in a closed economy." Main conclusions from the model draw support for conditional convergence, articulating that poor countries grow at a faster rate than their rich counterparts and thus, poor countries will converge to the income level of rich countries if the savings rate for capital is the same. Among the large body of research, Barro (1997) and Mathus (2005) also offer robust support for the neoclassical idea of conditional convergence. In addition to capital, other determinants have been studied in their effect on economic growth. Barro (1997) compares seven conceivable determinants: initial schooling, life expectancy, fertility, government consumption, inflation, political freedom, and trade on real GDP per capita for 100 countries from 1960 − 1990 and finds that only trade has a significant effect on economic growth. Similar to Barro, Kohlmey (1996) concludes trade regulations are positively correlated with economic growth (Kohlmey,1996).

The assessment of economic growth is much more complex than summarizing the effect of an individual determinant. In addition to improvements in trade, economic growth has been demonstrated as a result of increased learning and innovation. Sørensen (1999) analyzes the role of learning and research and development (R & D), concluding that in the long run equilibrium, economic growth is stimulated exclusively by R&D. Another impediment in studying the causes of economic growth is that causality is difficult to prove. Heo and Tan (2001) use a Granger causality test to determine the relationship between political systems and economic growth. The study finds it is likely democracy that causes economic growth, although, it also finds economic growth causes democracy. Heo and Tan (2001) note that mixed results are indicative of contingent factors, possibly including the timing of development, geographical region, export promotion and import substitution. While such factors may very well be important for economic growth, they will not be the main focus of this paper which is focused on health determinants.

2.3 Connection Between Health Indicators and Economic Growth

The effect of health status on economic growth continues to demand attention, as there remains dissension in empirical studies. Myriad research papers have been published over the past half-century arguing the effect of health status on economic growth (Qureshi and Mohyuddin, 2006; Strauss and Thomas, 1998; Wang et al., 1999; Bhargava et al., 2006 ; and Weil, 2007). Even economists who find the relationship between human capital accumulation and economic growth to be weak, such as Mathus (2005), recognize certain measures of health status to be heavily correlated with growth. The work of Strauss and Thomas (1998), Wang et al. (1999), Bhargava et al. (2006), and Weil (2007) provides general accord on the significance of health status in economic growth. Though measured using different empirical models, Bhargava et al. (2006) and Weil (2007) both approximate the effect of health on GDP using ASR as their main indicator and find health status to be a significant determinant of economic growth. Strauss and Thomas (1998) produced studies using distinct health indicators and were able to state the significance of health status on economic growth. Strauss and Thomas (1998) demonstrated significance of health status on economic development using height and body mass index (BMI) as the key indicators whereas Bhargava et al. (2006) proved significance using a vastly different indicator, ASR. Despite variances in the health indicators chosen, it important to learn about different health measures because even if there is a positive correlation found, knowing the magnitude of the impact of a health indicator is critical for making any data driven decisions. Overall, there exists a wide body of research supporting the theory that health status has a significant effect on economic growth.

Not only is there wide array of health indicators that show positive correlation between health status and economic growth, there are also studies cited using prevalence of particular diseases to show a correlation between health status and economic growth. While Qureshi and Mohyuddin (2006) agree that the effect of health status on economic development is significant, their findings differ from Weil (2007) and Bargava et al.'s (2006) in a subtle, yet substantial way. Seemingly contradictory to the findings of Weil (2007) and Bargava et al. (2006), Qureshi and Mohyuddin (2006) report no significance in the effect of health indicators on economic growth, as measured using under five mortality rate and life expectancy at birth. While several studies investigate the influence of health status on economic growth using health indicators as a proxy, Qureshi and Mohyuddin (2006) use diseases prevalence rates, particularly for malaria and hepatitis, to explore the effect of heath status on economic growth. Their findings show that both malaria and hepatitis have a statistically significant negative impact on both GDP and GDP growth rate, where malaria is significant at the 5 percent level and hepatitis is significant at the 10 percent level.

Over the past half-century, sufficient evidence of positive correlation between health status and economic growth has emerged. Perhaps policy makers are unaware of such findings, or it may be the case that they are aware of the research yet they find competing interests preclude them from implementing the policies. Nonetheless, policy makers are not effectively utilizing objective health indicators in developing public health policies to reduce the effect of the given health problems on GDP. Revisiting the aforementioned work from Qureshi and Mohyuddin (2006), their study provides a distinct instance where implementing policy "aimed at lowering the prevalence of malaria and hepatitis [would] have a positive impact on GDP growth in developing countries." If their interest is positive GDP growth, this tool is a beneficial device. However, if their objective includes corruption or wealth building for themselves, then that objective is the true source of the failure rather than inability to utilize findings proving the effect of health status on economic growth. Accompanied in their stance, Weil (2007) acknowledges the impact public health policy could have if it took into consideration the significance of health status on economic development, highlighting that, all else held constant, eliminating the health differentials caused by differing ASR among countries "would reduce the variance of log GDP per worker by 9.9 percent." Initiating economic growth through evidence based health policy remains a viable option, primarily for countries deficient in quality health systems.

2.4 DALY as a Measure of Health Status

Developed in the early 1990s by the World Health Organization (WHO), disability adjusted life years (DALY) is a metric of health loss. Mathematically, it is calculated as the sum of years of life lost as a result of premature death and the years of life lived with a disability. DALYs count the years of healthy life lost (YLL) due to premature mortality and non-fatal impediments.

The initial motivation behind constructing DALY was for policy makers to be able to make more informed decisions to improve systems and to eliminate health disparities. In an early study by Anand and Hanson (1997), a review of the DALY concluded the theoretical and mechanical basis for the method is flawed, in particular the "age weighting and discounting" involved in constructing DALY. Such flaws have led Anand and Hanson (1997) to consider all conclusions from the data inappropriate as an incentive for public health policies. Though some recognize deficiencies in the DALY, others, such as Murray and Lopez (1996) appreciate it for its ability to provide objective information on the extent of health problems across countries, time, gender and causes. Murray and Lopez (1996) conclude that in 1990, among the top causes of burden was unipolar major depression. They forecasted that the incidence of unipolar major depression would increase in the 21st century and rise to the second largest contributor of health burden in the world in 2020 (Murray and Lopez, 1996). Recalling the economic body in support of health status' effect on GDP, it follows that such an event could potentially be debilitating for the labor force and effectively economic development. The discussion as to whether or not DALY is a sufficient measure of health status constitutes a noteworthy reason to examine its aptitude in functioning as a stand-in for health status and measuring the overall effect of health status on economic growth.

3 Model

3.1 Exposition

Before discussing the econometric model this paper will be employing, it is important to first visit the underlying economic model through which the general relationship between health and economic growth can be considered. The Solow (1956) Growth Model was the first paper in economic literature providing a direct relationship between the labor force and economic growth. The model uses capital accumulation to describe economic growth. Solow assumes $Y(t)$ is the rate of production, $sY(t)$ is the rate of saving, $K(t)$ is stock of capital, and $\frac{dK}{dt}$ is net investment. Solow constrains production and assumes output is produced with the help of only two factors: labor and capital, where $L(t)$ is the rate of input of production factors. This yields

$$\hat{K} = sF(K, L), \tag{1}$$

a differential equation determining the "time path of capital accumulation" (Solow, 1956). Equation 1 establishes a connection between inputs on the micro level and economic growth in the economy.

We focus on labor from the health perspective and do only an application of Solow's growth model. As claimed by Bhargava (2001), aspects of health such as "disease prevalence rates and cognitive functioning" are important for economic growth because of their effect on productivity. The theoretical mechanism we consider depicting the effect of health on economic growth begins by assuming individuals' health affects productivity, as more salubrious persons are more capable of producing. Then, it follows that a healthier labor force results in a more productive labor force.

As economic literature suggests, a more productive labor force consequently results in increased economic growth. Thus, we employ an adapted Solow growth model framework with health instead of labor. That is, we amend Solow's assumption that output is produced with labor and capital and suppose, instead, that output is produced with only health and capital. We use Solow's growth model framework as a basis for modeling the impact of the contribution of heath on economic growth.

3.2 Data

The majority of the data come from two sources−the World Bank's World Development Indicators (WDI) data set and the Institute of Health Metrics and Evaluation at the University of Washington (IHME). In the model put forth by Bhargava et al. (2006), the primary variable of interest is adult survival rate (ASR). However, in this case we estimate the effect of health status on economic growth using two health indicators fertility rate, whose effect is well understood in economics, and the contemporary measure, disability adjusted life years (DALY), whose effect remains under debate. Thus, we continue to use fertility rate and replace ASR with DALY throughout. Consequently, the time varying regressors included in our adaptation of Bhargava et al.'s model are total fertility rate, the ratio of investment to GDP level, DALY, interaction between DALY and GDP level, and GDP level. The ratio of investment to GDP data are collected from WDI as Gross Capital Formation and is interpreted as investment as a percent of GDP. The interaction between DALY and GDP is merely the product; that is, $DALY \cdot GDP$. Total fertility rate data and GDP data, including real GDP and the ratio of investment to GDP are from WDI. Total fertility rate gives the average number of births women would have if they lived through all their childbearing years. Meanwhile, DALY is calculated as the sum of years of life lost as a result of premature death (YLL) and the years of life lived with a disability (YLD). Mathematically, that is

$$DALY = YLL + YLD, \tag{2}$$

where YLL is the product of the number of deaths, n, and the standard life expectancy at the age of death, ℓ, computed as

$$YLL = d \cdot \ell, \tag{3}$$

and YLD is the product of the number of incidence cases, i, the disability weight,w, and the "average duration of the case until remission or death," r, computed as

$$YLD = i \cdot w \cdot r \tag{4}$$

(World Health Organization, 2016). Moreover, our sample of interest includes 168 countries, all of which are analyzed at five year intervals over the period $1990 - 2015$. It should be noted that some countries are excluded as a result of incomplete data. Following the work of Bhargava et al (2006) our specification tests are run using modifications of the aforementioned variables, as described explicitly in Table 1.

Variable	Source
Logarithm of fertility rate	WDI
Logarithm of investment to GDP ratio	WDI
Logarithm of DALY	WDI
Interaction between DALY and GDP	WDI, UW
Logarithm of GDP	WDI

Table 1: Variable and Source

The modeling strategy we use is a direct adaptation of Bhargava et al.'s (2006). Hence, where Bhargava et al. (2006) makes assumptions regarding ASR, we make similar assumptions regarding DALY. We assume only "country-specific random effects are correlated" with DALY and fertility in time t" in order to "allow for countries to possess unobserved permanent characteristics that in turn could influence the levels of explanatory variables"(Bhargava, 2001). Bhargava et al. (2006) classifies such variables under this assumption as "special endogenous," for instance, DALY. Further, we assume lagged GDP is fully endogenous, meaning it may be correlated with the errors. This allows for GDP to be "treated as a different variable in each time period" (Bhargava, 2001). Additionally, we include common assumptions, such as the error terms being independently distributed random variables.

Descriptive statistics for the variables described in Table 1 are reported below in traditional form, with the number of observations, mean, standard deviation, minimum, and maximum.

Variable	Obs	Mean	Std. Dev.	Min	Max
Logarithm of fertility rate	912	1.081	.5263	.1044	2.1526
Logarithm of investment to GDP ratio	946	3.076	.4004	.0924	5.066
Logarithm of DALY	1128	14.747	2.200	9.325	20.225
Interaction between DALY and GDP	1046	118.159	26.111	61.796	207.043
Logarithm of GDP	1046	8.012	1.604	4.171	11.545
GDP Rate	1021	2.343	5.120	−50.236	53.9326

Table 2: Descriptive Statistics

Additionally, we generate lagged variations of the variables in Table 1. Descriptive statistics for the lagged variables are reported below in Table 3.

Variable	Obs	Mean	Std. Dev.	Min	Max
Lag logarithm of fertility rate	912	1.081	.5263	.1044	2.153
Lag logarithm of investment to GDP ratio	821	3.071	.409	.092	5.066
Lag logarithm of DALY	940	14.734	2.207	9.325	20.225
Lag logarithm of Interaction between DALY and GDP	882	116.137	25.956	61.797	206.208
Lag logarithm of GDP	882	7.904	1.612	4.171	11.545
GDP Rate	1021	2.343	5.120	−50.236	53.93

Table 3: Descriptive Statistics

While many of the descriptive statistics are only slightly changed when we adjust to lagged variables, it should be noted that the sample size of 3 of our independent variables decreases. The number of observations decreases by 10.96% for ratio investment to GDP, by 16.67% for DALY, and by 15.67% for interaction between DALY and GDP.

Further, we compute the correlations between the independent variables from Table 1.

Variable	$lfert$	$lItoGDP$	$lDALY$	$lDALYGDP$	$lGDP$
logarithm of fertility rate	1.0000				
logarithm of investment to GDP ratio	−0.2266	1.0000			
logarithm of DALY	0.0995	−0.0853	1.0000		
logarithm of Interaction between $DALY \cdot GDP$	−0.6232	0.1137	0.3829	1.0000	
logarithm of GDP	−0.7146	0.1635	−0.2465	0.7942	1.0000

Table 4: Correlations between the independent variables

Table 4 suggests there is multicollinearity among some of the independent variables; particularly between $lDALYGDP$ and $lfert$, $lGDP$ and $lDALYGDP$, and $lDALY$ and $lDALYGDP$. Among the correlations, the most concerning is the correlation between $lGDP$ and $lDALYGDP$, as it is nearly an 80% correlation. To examine the distributions of the variables, histograms are provided in the Appendix.

3.3 Econometric Model

An early publication of Bhargava (2002) provides an econometric framework with which we can produce estimates of GDP growth rates for different countries at different time periods. The econometric model is given by

$$y_{it} = \sum_{j=1}^{m} z_{ij}\gamma_j + \sum_{j=1}^{n_1} x_{1ijt}\beta_j + \sum_{j=n_1+1}^{n} x_{2ijt}\beta_j + u_{it}, \tag{5}$$

where the parameters are defined below in Table 3 (Bhargava, 1991).

Parameter	Definition	
Z	Time invariant variables X_1	Exogenous time invariant variables
X_2	Endogenous time invariant variables	
$t = 1, 2, \ldots, T$	Time periods	
$i = 1, 2, \ldots, N$	Country	
β, γ	Slope coefficients	

Table 5: Parameters Defined

The assumptions from section 3.2 yield several important limitations for the model. Recall, we consider fully endogenous variables, X_2, different variables in different time intervals. Following the model assumptions of Bhargava et al. (2006), we let X_1 be the vector $n_1 \times 1$ and let X_2 be the vector $n_2 \times 2$, such that $n_1 + n_2 = N$. Next, we let Z be the vector $m \times 1$ of time invariant variables. Then, we can describe endogeneity for variables such as DALY as

$$X_{2it} = \sum_{j=1}^{T} F_{tj} X_{1ij} + F_t^* Z_i + U_{2it}. \tag{6}$$

Equation 6 gives way to the assumption that"only country specific random effects δ_i are correlated with endogenous variables x_{2ijt}" (Bhargava et al., 2001). Further, equation 6 provides the "correlation between time varying variables and errors U_{it}" present in the model (Bhargava et al., 2001). Lastly, we represent the assumption that error terms are independently distributed random variables mathematically by

$$u_{it} = \delta_i + v_{it}. \tag{7}$$

Expected coefficients are as follows. Based on Bhargava's 2003 paper, *Family Planning, Gender Differences, and Infant Mortality*, we expect the coefficient on fertility rate to be negative, as "high fertility rates in developing countries often reflect unwanted fertility that adversely affects households' resource allocation decisions"(Bharvaga, 2003). We expect the coefficient on the interaction between DALY and GDP to be negative since an increase in disease incidence, resulting in healthy years of life lost, most likely leads to a less productive labor force, and thus a decrease in GDP growth rate.

Likely econometric problems expected to arise in the estimation are issues of heteroskedasticity and autocorrelation because of correlation in variables from one year to another year. We incorporate a Hausman test to determine whether the appropriate specifications are affecting residuals in a systematic way or not. We run distinct specification tests using the same time variables and using lagged variables.

3.4 Results

3.4.1 Same-time Variable Results

We first observe regression results using the same time variables where all x_i are in the same time as y_i, meaning we are regressing y_{it} on x_{it}. We run both a fixed effects and random effects specification test on the panel data. Table 6 presents the empirical results from our same-time fixed effects and random-effects GLS regressions.

GDP rate	(b) fixed	(B) random
Logarithm of DALY	−2.725(1.799)	−.1824 (.5506)
Logarithm of $DALY \cdot GDP$	.3931(.1789)**	.0343(.0658)
Logarithm of GDP	−6.941(2.739)**	−1.014(1.006)
Logarithm of fertility rate	−3.941(1.364)***	−2.1353(.5388)***
Logarithm of Investment to GDP	1.945(.5914)***	2.195(.4361)***
Constant	45.48(27.94)	4.824(8.816)

Table 6: Same-time fixed and random effects GLS regression

When observing regression results, we look for significance in fertility rate as well as in the interaction between DALY and GDP. Both the fixed effects and random effects results match our estimated sign for the coefficient on fertility rate. Fixed effects results show that a 1 percentage point increase in fertility rate is associate with a .0394 percent decrease in GDP rate while random effects results show a 1 percentage point increase in fertility rate is associated with a .0214 percent decrease in GDP. It is found in both regressions that the effect of fertility on GDP rate is statistically significant at the 1 percent level.

Further, as a result of interacting DALY and GDP, we cannot interpret the coefficients of DALY and GDP independently, we must only interpret the change in GDP rate with respect to DALY. It follows that the change in GDP with respect to DALY is given as $-2.725 + .3931(8.012) = .4245$ at the mean value of log GDP,8.012. For fixed effects, our results indicate that a 1 percent increase in DALY is associated with a .0042 percent increase in GDP rate. The interaction between DALY and GDP is statistically significant at the 5 percent level. Last, we observe one of our control variables, the ratio of investment to GDP, is statistically significant at the 1 percent level in both fixed effects and random effects regressions.

The results of the random-effects GLS regression do not vary a great deal from the results of our fixed-effects regression. The results of the fixed effects regression suggest that all the explanatory variables are at least significant at the 5 percent level and the only primary variable that is significant at the 1 percent level is fertility rate in both the fixed effects and random effects model.

Analyzing the magnitude of the coefficients of our primary variables, we see that the effect of the DALY, as measured using the interaction between DALY and GDP, and fertility rate are smaller in the random effects model than the fixed effects model. To determine whether to use the fixed effects or the random effects model we use the Hausman test.

	(b) fixed	(B) random	$(b-B)$ difference	$\sqrt{(V_b - V_B)}$ S.E.
$lDALY$	-2.7254	$-.1824$	-2.5429	1.7123
$lfert$	-3.94101	$-.2.1353$	-1.8057	1.2534
$lGDP$	-6.3476	-1.0144	-5.3332	2.5482
$lItoGDP$	1.9448	2.1946	$-.2499$	.39959
$lDALYGDP$	.39312	.03429	.35887	.16644

Table 7: Hausman test results

In interpreting these results, we let b mean consistent under the null hypothesis and the alternate hypothesis and B means inconsistent under the alternate hypothesis while efficient under the null hypothesis. The Hausman test uses the null hypothesis that the difference in coefficients is not systematic.

$$\begin{aligned} chi^2(5) &= (b-B)'[V_b - V_B]^{-1}(b-B) \\ &= \quad 7.77 \\ prob > chi^2 &= 0.1695 \end{aligned}$$

Based on the results, the $p - value$ of .1695 suggests we cannot reject the null hypotheses to use the random effects model. Thus, we conclude the difference in the coefficients is not systematic so we choose the random effects model. Then, using only the random effects regression results, we observe that the estimated effect of DALY on GDP growth rate is insignificant while the effect of fertility rate on economic growth is significant and consistent with current literature, as an increase in fertility rate is associated with a decrease in GDP growth rate.

As a result of regressing all x_i in the same time period as y_i, it is possible that there are issues of endogeneity. To illustrate, using the same-time regression results, it is unclear whether fertility rate is determining GDP growth rate, or rather, GDP growth rate is determining fertility rate. To correct for such issues of endogeneity, we run lagged regressions where y_{it} is being regressed on the x_{it-1} .

3.4.2 Lagged Variable Results

To correct for possible issues of endogeneity, we run regressions lagged variables. We run both a fixed effects and random effects specification test on the panel data using 792 observations and 174 groups. Table 8 presents the empirical results from our lagged variable fixed effects and random-effects GLS regressions.

GDPrate	(b) fixed	(B) random
Lagged logarithm of DALY	−.3126(1.488)	.1293(.4792)
Lagged logarithm of $DALY \cdot GDP$	.3090(.1483)**	−.0153(7.653)
Lagged logarithm of GDP	−7.753(2.269)***	−.8466(.8824)
Lagged logarithm of fertility rate	−6.322(1.099)***	−3.538(.4537)***
Lagged logarithm of investment to GDP	−.7146(.4898)**	−.1028(.3379)
cons	45.48(27.94)	4.824(8.816)

Table 8: Lagged fixed and random effects GLS regression

The lagged regressions provide more statistically significant variables than the same-time regressions. In particular, fertility rate, the ratio of investment to GDP, and the interaction between DALY and GDP have a statistically significant effect on GDP rate in the fixed effects results using lagged variables. Fixed effects results for fertility rate suggest that all else held constant, a 1 percentage point increase in fertility rate is associated with a .0632 percent decrease in GDP rate while random effects suggest an associated decrease in GDP rate of only .0356 percent. Further, it is found in both regressions that the effect of fertility on GDP rate is statistically significant at the

1 percent level. We determine the change in GDP growth rate with respect to a change in DALY as $-.3126 + .3090(8.012) = 2.163$, meaning that a 1 percent increase in DALY is associated with a .02163 percent increase in GDP rate. The interaction between DALY and GDP is significant only in the fixed effects model and it is significant at the 5 percent level. Again, similar the the same-time random effects regression results, the ratio of investment to GDP is statistically significant.

To determine whether to use the fixed effects or the random effects model we use the Hausman test.

	(b) fixed	(B) random.	$(b-B)$ difference	$\sqrt{(V_b - V_B)}$ S.E.
$lDALY$	$-.312602$	.129327	$-.4419287$	1.40824
$lfert$	-6.32233	$-.3.53821$	-2.784124	1.00133
$lGDP$	-7.75294	$-.846603$	-6.9063	2.09005
$lItoGDP$	$-.714638$	.102765	$-.817403$	.311446
$lDALYGDP$	.309297	$-.015337$	.324634	.136684

Table 9: Hausman test results- lagged variables

Using the same definitions as the previous Hausman test, we test the null hypothesis that the difference in coefficients is not systematic. The results for the Hausman test are as follows

$$\begin{aligned} chi^2(5) &= (b-B)'[V_b - V_B]^{-1}(b-B) \\ &= \quad 77.33 \\ prob > chi^2 &= 0.0000 \end{aligned}$$

Based on the results, the small probability provides evidence against the the null hypothesis. Thus, we conclude the difference in the coefficients is systematic and choose the fixed effects model. Using the fixed effects regression results, we observe an increase in DALY, at a log GDP level of 8.012, is associated with an increase in GDP growth rate and this is statistically significant. Moreover, we observe the estimated effect of fertility rate is consistent with current literature in that an increase in fertility rate is associated with a decrease in GDP growth rate, all else held constant.

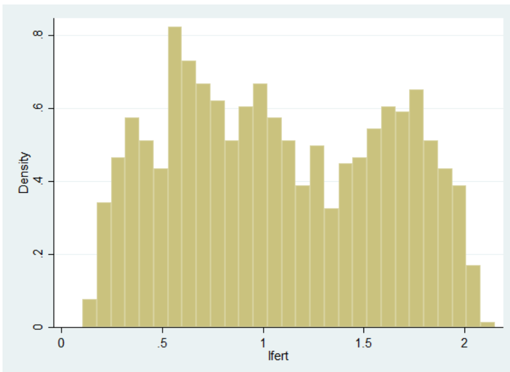
4 Conclusions

In determining the effect of health status one economic growth, we used two primary health indicators; fertility rate, whose effect is known, and DALY, whose effect is inconclusive. Due to the issue of endogeneity exhibited in the same-time regressions, we use the lagged variable regression results in our final estimation of the effect of health status on economic growth. Of the lagged variable regressions, we draw our final conclusions based on the estimated from the fixed effects regression, as the Hausman test described the coefficients as being systematically correlated.

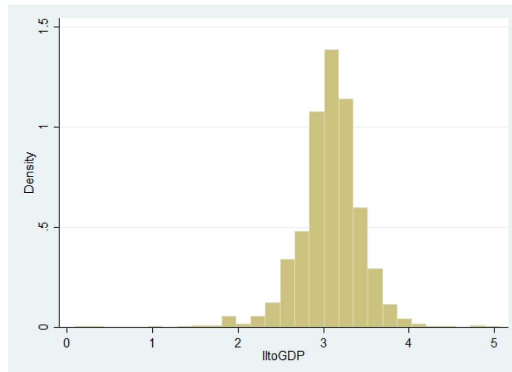
Ultimately, our results are consistent with current literature on the effect of fertility rate on economic growth, as we find an increase in fertility rate is associated with a decrease in economic growth. In terms of the effect of DALY on economic growth, we find an increase in DALY is associated with an increase in GDP rate at all practical levels of GDP. Consequently, we conclude when DALY is used as a proxy for measuring health, decreased health status has a positive effect on economic growth at certain GDP levels. However, this result is perplexing as it is counterintuitive that a decrease in health status is associated with an increase in economic growth.

One way to justify the perplexing result of DALY's effect on economic growth is to draw on the construction of DALY. Recall, DALY is calculated as the sum of years of life lost due to premature mortality and the years of life lived with disability. If we look at the United States, the three main contributing factors of DALY are ischemic heart disease, back and neck pain, and arthritis. Thinking about the nature of these diseases, it is clear that these diseases often effect individuals in their later years. As an illustration, consider just arthritis. It is reasonable to assume that despite the DALY generated as a result of arthritis during one's production bearing years, the majority of the toll arthritis takes on an individual is garnered in an individuals later years, particularly as individuals are exiting the labor force, meaning once an individual is generally no longer an active participant in the labor force (GBD, 2016). Consequently, it follows that an increase in DALY as a result of an increase in arthritis is not reflective of the effect of decreased health status on productivity. Thus, drawing cross country comparisons using DALY as a measure of health status on economic growth is problematic, as only some DALYs hinder one's ability to contribute a country's productivity and overall GDP. All in all, DALY is a useful measure and unique in that it is accounts for much more than the common health indicators used today. However, because of the fact that different countries are home to different diseases and such diseases effect productivity levels in different ways, DALY is an imperfect measure for describing the effect of health status on economic growth.

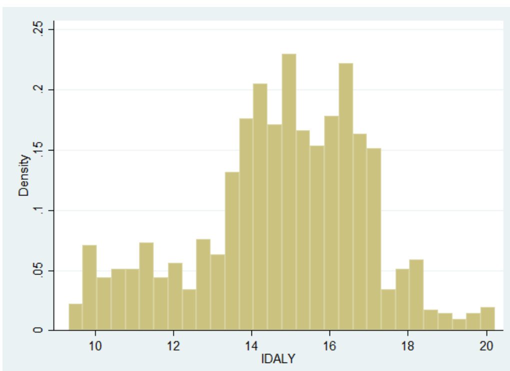
5 Appendix



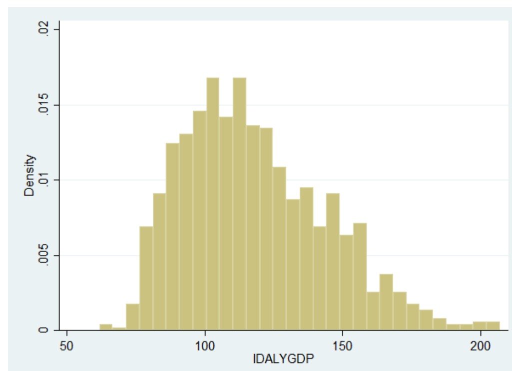
Logarithm of total fertility rate



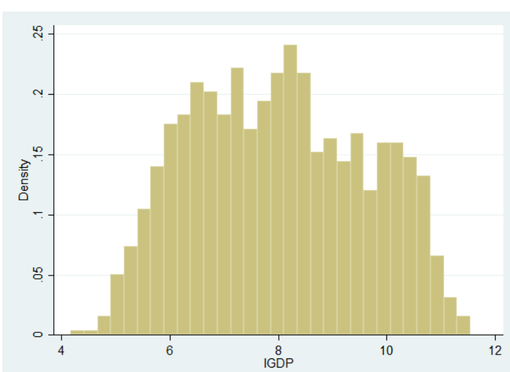
Logarithm of investment to GDP ration



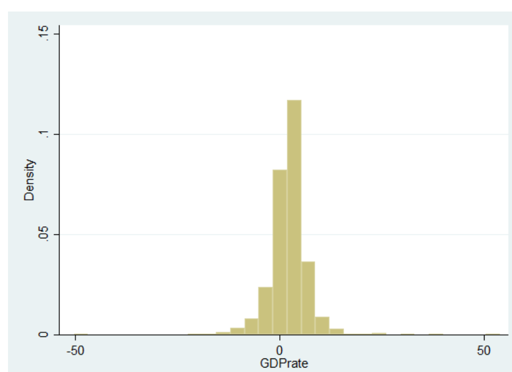
Logarithm of $DALY$



Logarithm of $lDALYGDP$



Logarithm of GDP



GDP rate

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