Standards of living and health status: the socioeconomic determinants of life expectancy gain in sub-Saharan Africa

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June 2013

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(June 2013)

Abstract

Using a panel dataset on 45 sub-Saharan Africa countries (SSA), this study analyzes empirically the socioeconomic determinants of life expectancy gain (considered as an indicator of global health improvement at country level). In order to treat heterogeneity and endogeneity concerns, we use multiple estimation methods including pooling, fixed-effect, long difference and system GMM. Our analyses show that income is critical for health enhancement. Particularly, we find that GDP per capita is strongly and positively correlated with life expectancy gain. Furthermore, variables such as adult literacy, access to improved sanitation and safe water appear positively correlated health gain. In contrast the high incidence of extreme poverty is negatively correlated with heath gain while the impact of income inequality seems ambiguous.

Codes JEL: C12, C51, I11, I12
Key words: Standards of living, health, life expectancy at birth.
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I would like to thank to my thesis supervisors Catherine Araujo-Bonjean and Martine Audibert for their comments, criticisms and suggestions. I also thank Fousseni Traoré, Researcher at International Food Policy Research Institute (IFPRI) for his reading and precious comments.

1. Introduction

Since the second half of the last century, the life expectancy[1] has significantly increased in most of the developing countries, in particular, in Sub-Saharan Africa (SSA) where it went from 40.4 years in 1960 to 54.16 years in 2010 (World Bank, 2010). As the debate has long existed about the causes of the mortality decline, many studies that investigate some possible explanations concerning the levels and the variation of life expectancy show mixed results. Various answers were given to the question of what factors has been most associated with the increases in levels of life expectancy. For some authors, this has been the result of the success in the application of communicable disease control technologies through public health activities (Stolnitz, 1975). And for others, it has been mainly attributable to the global improvement in the economic situation, particularly the elimination of famines and improved nutrition available to the people of the less developed countries (Krishnan, 1975).

Despite these divergent views, these studies do not ignore the role that has been played by the conjunction of various socio-economic factors which resulted in an overall decrease in mortality risk over time. The improvement of health status observed in developing countries may have been also driven by the concomitant rises in economic levels, social well-being and health service investments through the increase in per capita income combined with higher health expenditure and progress in medical technologies. In this study, our analysis is focused essentially on those factors directly linked to the population living conditions such as income, poverty, inequality, education, social and environmental factors.

Regarding number of studies carried out on the health problematic in developing countries, our study can be considered as an update of some of them although we take a different methodological step. In fact, authors like Kabir (2008) which examines the socio-economic determinants of life expectancy for 91 developing countries, uses probit regressions to determine the probability for a country to be in one of the following countries groups: low, medium and high life expectancy. As many of his explanatory variables turned out to be

[1] Life expectancy at birth expresses the average length of time that an individual born in a given period would live if he experienced the mortality rates of that period throughout his lifetime. It indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth is considered the same throughout its life. Life expectancy at birth provides a useful snapshot of mortality and represents a more synthetic measure of health status that is comparable across populations and time.
In quantifying health status, life expectancy is, as for mortality rate, one of the most used traditional measures of global health. Although, recently other health indicators have been developed to represent not only death or living but also the condition of health. These indicators include the Disability Adjusted Life Year (DALY) and the Disability Adjusted Life Expectancy (DALE). But, these last indicators remain, in some respects, rarely used by researchers in large scales cross-country studies, given their very detailed data requirement.

statistically insignificant in most of his regressions, the author deduce that the relevant socio-economic factors like per capita income, education, health expenditure, access to safe water, and urbanization cannot always be considered to be influential in determining life expectancy in developing countries. Also, Fayissa and Gutema (2005) estimate a health production function for Sub-Saharan Africa based on the Grossman (1972) theoretical model that treats social, economic, and environmental factors as inputs of health production function. Socioeconomic and environmental factors such as income per capita, illiteracy rate, food availability, ratio of health expenditure to GDP, urbanization rate, and carbon dioxide emission per worker are specified as determinants of health status. The model is estimated by one-way and two-way panel data approaches. Their results suggest that an increase respectively in income per capita, food availability and literacy rate are well associated with improvement in life expectancy. These results lead authors to suggest that health policy that focus solely on provision of program excluding socioeconomic aspects, may do little toward improving the current health status.

But, the main criticism that could be addressed to these two previous studies is that, for the first, it does not exploits the temporal dimension allowing him to control for countries specificities by the use of panel methods. For the second study, the endogeneity issue of GDP per capita is not addressed. Hence, the accuracy of the estimations is seriously compromised.

In this study, we use alternative approach to control potential estimation bias by exploiting both the temporal dimension and dealing with the endogeneity problem. Our dataset is a panel of 45 countries which coverage span the period 1960-2011[2]. For each variable, we have averaged over a five-year period the annual data to reduce annual fluctuations and measurement errors.
The work is organized as follow. In Section 2, we proceed to the literature on recent empirical studies focusing on the determinants of health status particularly in developing countries. The third section is devoted to the presentation of data and descriptive statistics. In the fourth section, we develop the econometric model by proposing multiples estimation methods. This section is then accompanied by a fifth one in which we conduct diagnostic tests to assess the quality of our estimation methods. In the sixth section, we proceed to the presentation and the discussion of the estimation results followed by a general conclusion.

[2] The list of the countries in the sample is presented in appendix.

2. Literature Review

Country wealth is one of the most discussed health causal factor in the literature. It has long been evidenced a strong relation between health and the absolute level of income (measured by per capita GDP). It's established that the lower per capita GDP, the lower life expectancy (World Bank, 1993). However, once countries attain some threshold level of income, the correlation between income and life expectancy become weak. Hence increases in per capita GDP no longer appear to be associated with life expectancy gains (Wilkinson, 1996). This author found that health of a population is directly related to its average income and no consistent relation is above that level. Rogers (1979) which provided a conceptual framework of the relation between income and life expectancy based on the observations from developed countries found that the relation is non-linear. He observed that life expectancy rises at a declining rate as income grows. Education is also considered as one major influential determinant of life expectancy. Many studies have empirically demonstrated the dominant role of education in explaining the differences in health status. They highlight that life expectancy differs considerably in relation to education (Grabauskas and Kalediene, 2002; Kalediene and Petrauskiene, 2000). But in general, few measures of education variables still be employed in the analyses of health status determinants. For example, Rogot et al (1992) revealed that life expectancy varies directly with years of schooling while Gulis (2000) which uses literacy rate shows statistically significant role of this variable in explaining life expectancy.

Access to health care is considered as the most direct way of improving health status essentially through curative and preventive treatments including the provision of medical goods and facilities such as clean water, nutrition, mosquito (Gertler and van der Gaag, 1990). In a multivariate linear regression analysis on data of 156 countries, Gulis (2000) found that, access to safe drinking water impacts significantly life expectancy. However, the most used variables to test the effects of health inputs are typically the health resources indicators. These resources include health expenditure, health workforce (physician, nurse, etc.) and health infrastructure (hospital, and hospital beds, etc). The total health expenditure is perceived to have significant influence on life expectancy because it directly helps reduce mortality and morbidity (Kabir, 2008). Using cross-country time series data, Hitiris and Posnet (1992) find negative correlation between health spending and mortality rates. Grubaugh and Santerre (1994) find positive and significant impact of number of doctors and number hospital beds on infant mortality rates.

In addition to the previously determinants, other general characteristics of the population are considered among health determinants. Gender is one of these components. There is well-known evidence that females live longer than males. Population behavior is another factor that affects heath status; for example, smoking, alcohol consumption, and daily activity. Phelps (1997) argued that the role of medical care is considerably small relative to the lifestyle. Urbanization also plays a crucial role in determining life expectancy. Although, Rogers and Wofford (1989) revealed that urbanization was less influential on life expectancy than anticipated, urban inhabitants of the developing countries generally enjoy improved medical care and means of life, better education, and other improved socio-economic facilities, which impact positively on health outcomes.

Regarding the particular specificities of Sub-Saharan Africa region, we notice that the population of this region has been living under serious life-threatening diseases (malaria, diarrhoeal diseases, respiratory infections, AIDS, etc.), which have important implications for reduction in life expectancy. The SSA region also suffers from violent conflicts. Davis and Kuritsky (1997) found that, in countries experiencing severe conflicts, life expectancy has been shortened by an average 2.35 years. Since these geographical specificities tend to show an unfavorable context in SSA, it may be important to include in the analysis some of the aspects related to country epidemiologic and socioeconomic environment.

3. Data and Sources

3.1. Sample

The sample used in this study consists of 45 of the 47 SSA countries reported by the World Bank[3] for which sufficient data are available over long period both for the life expectancy variable and the other interest variables. All the variables are extracted from the World Development Indicators database from which we compile a panel dataset covering the period 1960-2011. The choice of 1960 as the base year is guided, in particular, by the idea that 1960 is, for many SSA countries, a reference year marking their independence. Thus one may think that the observed evolution in life expectancy since this date can be considered as a good indicator of the progress realized by these countries in terms of health improvement.

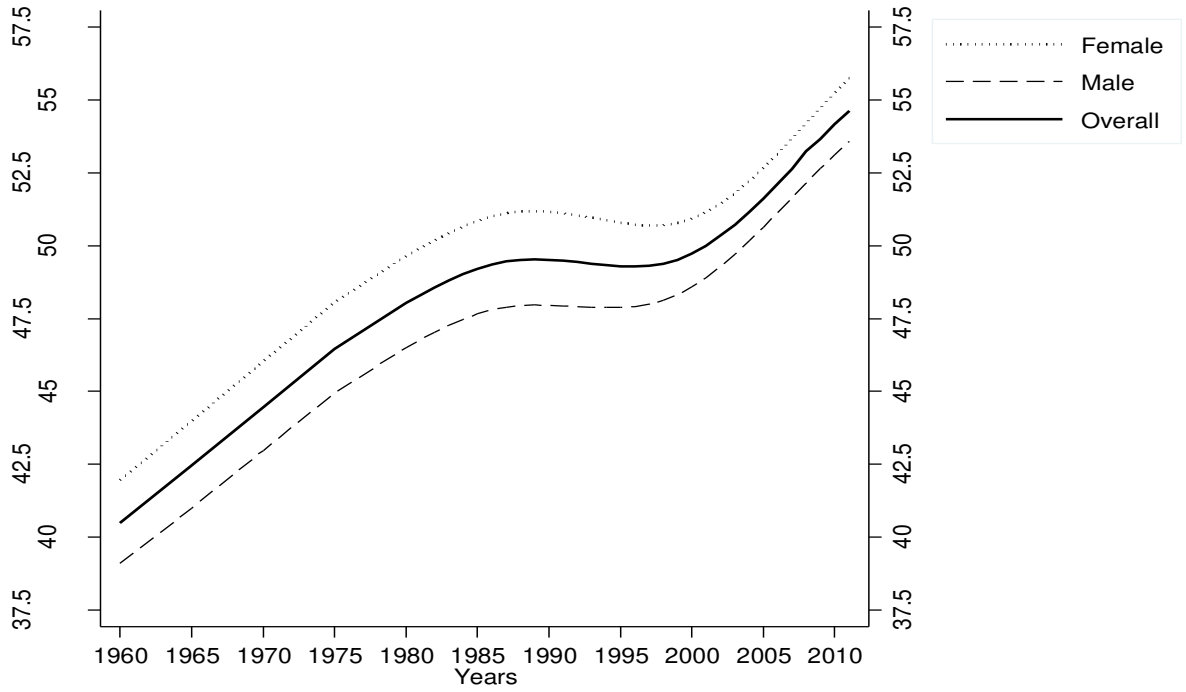
[3] http://go.worldbank.org/JRVQH9W970

3.2. Evolution of Life expectancy in SSA

Since the second half of the last century, it has been observed a significant increase in life expectancy in the world. According to WPP (2010)[4], over the five year-period 1950-1955, the average life expectancy at the world level was 48 years and it had reached 68 years by 2005-2010. In 1950-55, the more developed regions already had a high expectation of life (66 years) and have since experienced further gains in longevity (76.9 years), 11 years higher than in the less developed regions where the expectation of life at birth is 65.9 years in 2005-10.

When focusing on SSA countries where life expectancies are found to be among the lowest in the world, analysis of the dynamic of life expectancy in this region shows three major episodes in the evolution (Figure 1). Indeed, until the start of the 1990s, life expectancy has steadily increased from 40.49 years in 1960 to 49.53 years in 1989. From this year until 1996, it was observed a noticeable stagnation of the evolution of life expectancy. It was even observed a slight decrease until reaching almost 49.2 in 1996 (World Bank, WDI).

Figure 1: Evolution of Life expectancy in SSA region from 1960 to 2010



Sources: Based on data from World Bank WDI

One of the main causes of life expectancy stagnation pointed out by numbers of studies has been of the explosion of HIV/AIDS epidemic. According to United Nation' World Population Prospects (2010), life expectancy showed dramatic declines in the countries most affected by

[4] United Nations, World Population prospects,2010 Revision

HIV/AIDS. In Botswana, for example, where HIV prevalence was estimated at 24.8 percent in 2009 (among the aged 15-49 years), life expectancy has fallen from 64 years in 1985-90 to 49 years in 2000-05. And for Southern Africa as a whole, where most of the worst affected countries are, life expectancy has fallen from 61 to 51 years over the last 20 years. In addition to impact due to the AIDS epidemic, other factors have been identified as having contributed to the stagnation of life expectancy. These factors include armed conflict, economic stagnation, and resurgent infectious diseases such as tuberculosis and malaria.

However, despite this significant stagnation, one can observe again, from the second half of 1990, an increase of life expectancy which has reached 54.16 years in 2010. This recovery was mainly driven in part by the reduction of the magnitude of AIDS virus propagation in many countries, also due to the roles played by public health policies, which, for the most, are part of the MDG launched since the early 2000s.

On gender aspects, it is widely recognized that female life expectancy at birth is higher than that of males in nearly all countries around the world. According to WPP (2010), females have a life expectancy of 70 years, compared to 66 years for males in 2010. The female advantage in the more developed regions is around 7 years while in the less developed regions, it's almost 3.5 years.

In terms of longevity gain in Sub-Saharan Africa, despite non-monotonic evolution of life expectancy, the region has still made significant progress in terms of improvement in health status. Over the period 1960-2010, it recorded an absolute gain of 14 years (an increase of life expectancy of 33.8 percent compared to 1960 level). This represents an average of 2.7 years of longevity gain every 10 years (see table 1).

Table 1: Life expectancy gain in SSA compared to others regions (1960-2010)

Region	1960	2010	Absolute gain (years)	Relative gain (%)	Average decadal gain (years)
By Geographic Area					
Sub-Saharan Africa	**40.5**	**54.2**	**13.7**	**33.8**	**2.7**
East Asia and Pacific	47.6	73.2	25.7	54.0	5.1
Europe and Central Asia	67.5	75.7	8.2	12.1	1.6
European Union	69.4	79.7	10.3	14.8	2.1
Latin America and Caribbean	56.1	74.1	18.0	32.1	3.6
Middle East and North Africa	46.4	72.5	26.0	56.1	5.2
North America	69.9	78.8	8.9	12.7	1.8
South Asia	43.3	65.3	22.0	50.9	4.4
By Income Level					
Low income	42.3	58.8	16.6	39.2	3.3
Lower middle income	45.5	65.5	20.0	43.9	4.0
Upper middle income	49.9	72.6	22.8	45.6	4.6
OECD countries	67.5	79.4	11.9	17.7	2.4

Sources: Calculations based on data from World Bank WDI

Although Sub-Saharan Africa has experienced a significant gain in life expectancy over time, it has remained relatively less performing compared to other regions of the world such as Middle East and North Africa sub-region, East Asia and Pacific sub-region and South Asia, which have made respectively the gains of 56.1%, 54.0% and 50.9% compared to their initial level (see Table 1).

4. Empirical Model

Our empirical model departs from the following Cobb-Douglas health production function:

$$LEXP_{it} = (SELC_{it})^{\beta} * (HI_{it})^{\gamma} * (e)^{\alpha+\mu_i+\lambda_t+\varepsilon_{it}} \qquad (1.a)$$

Where $LEXP_{it}$ denotes the level of life expectancy in country i at the time t. $SELC_{it}$ stands for all of socioeconomic factors related to living condition and HI_{it} captures the vector direct health inputs and any component of health system. The coefficients α, β and γ represent the parameters to be estimated. μ_i, λ_t and ε_{it} represent respectively the country-specific effect, time-specific effect and the error term. Taking the logarithm in equation (1.a) will yield the following Log-log functional form:

$$ln(LEXP_{it}) = \alpha + \beta ln(SELC_{it}) + \gamma ln(HI_{it}) + \mu_i + \lambda_t + \varepsilon_{it} \qquad (1.b)$$

Where the coefficients β and γ can now be interpret as elasticities of life expectancy with respect of socioeconomics factors ($SELC_{it}$) and direct health inputs (HI_{it}).

The variables incorporated in the analysis are the per capita GDP in purchasing power parity (PPP) dollar representing the per capita income. Although the per capita health expenditure is recognized as one of the key variable of health inputs, we have not included it in the regressions because of the acute problem of collinearity with income. Nevertheless, we used the share of public health spending in total health expenditures. Since the major part of the health expenditures are endorsed by the government in developing countries, this indicator, representing, in fact, the public effort in health production, could serve to measure the impact and the effectiveness public spending on life expectancy. Still based on literature, we have also included the adult literacy, fertility rate, access to safe water and sanitation, number of physicians per thousand people. We control for country epidemiologic environment such as the prevalence of HIV (percentage of people living with HIV) and we also include variables related to socioeconomic environment such as incidence of extreme poverty (poverty headcount ratio at $1.25 PPP a day in % of population) and level of inequality represented by the gini index.

4. Estimation Strategy

4.1. Pooling and Fixed Effect Estimations

Using equation (1.b), we first adopt the pooled cross-sectional regression model as our basic specification. In this estimation, all the individual observations on country and time period are pooled using five-year period average for life expectancy and explanatory variables. Assuming that the error term ε is stochastic and normally distributed with mean zero and constant variance, we first estimate equation (1.b) by Ordinary Least Squares (OLS). In this pooling estimation, one could control for country specific effect by including dummy variable for each country. But, given the high number of countries (45), introducing dummies variable would lead to a dummy variable trap, so we chose to control only for the time-effect by introducing time dummies which capture effects associated five-year periods we have constituted. The results obtained from this first estimation are presented in column 1 of Table 2.

Although this OLS estimator remains unbiased and consistent if the error term does not contain any components that are correlated with explanatory, it may suffers from endogeneity problem of some explanatory variables. For instance, as there may be a strong reverse causality between health status and income, this will arise to the endogeneity problem that must be corrected using instrumental variable procedure. For that, we instrument GDP per capita following Pritchett and summers (1996). These authors, using results from Levine and Renelt (1992) and Easterly et al. (1993), used as instruments the terms-of-trade shocks and the ratio of investment to GDP.

Levine and Renelt (1992) showed that the ratio of investment to GDP is robustly related to growth. Easterly, Kremer, Pritchett, and summers (1993) have shown that the growth rates of income over five-year periods are explained in part by terms-of-trade shocks. This finding suggests us to use terms of trade shocks[5] as an instrument, since the five-year changes in terms of trade are convincingly exogenous, both in the sense of not having a direct relation to health and not being determined by any other country-level variable that jointly affect income growth rates (Pritchett and Summers,1996). Smith and Haddad (1999) also suggest the use of country economic openness as potential candidate for income instrumentation, as economic openness may improve national income but not otherwise directly affect health. Therefore, in complement of terms-of-trade shocks and ratio of investment to GDP, we use country openness measured as the ratio of trade volume (sum of imports and exports) to GDP. Results obtained from the 2SLS pooling estimations are presented in column 2 of Table 2.

Trying to control for countries specific effects, we estimate fixed-effects model (Baltaji, 1995) which allows us to captures country-specific unobservables that may affect life expectancy and which do not vary over time. Time-invariant factors may be climatic conditions, countries' physical environments and deeply-embedded cultural and social norms which can be controlled by μ_i in the estimations. The fixed-effects approach, in addition to removing bias, can serve to control for measurement errors and non comparabilities in the data due to definitional and measurement differences at the country level (Ravallion and Chen 1996). Hence, in addition to previous time dummies (capturing time-specific effect), we introduce a single time-trend variable which can capture the long run effects of time such as those related to technological progress and innovations in medicine. The model is then estimated par the within approach whose results are summarized in column 3 and 4 of Table 2.

[5] The terms of trade index measures the relative prices of a country's exports and imports. We use Net barter terms of trade index as term of trade indicator calculated as the percentage ratio of the export unit value indexes to the import unit value indexes (World Bank, WDI).. For each country, we estimate a deterministic trend, which is then extracted from the original series to get the cycle. This cyclical component (considered a deviation of the series compared to long-run equilibrium) is retained as our shock indicator since it's highly affected by regular shocks (Perron, 1989).

Table 2: Pooling and fixed-effects estimations results

	POOLED		WITHIN	
VARIABLES	**OLS**	**2SLS**	**OLS**	**2SLS**
Gdp_pcapita	2.3e-06**	1.8e-05***	1.2e-06**	3.7e-07
	(0.021)	*(0.000)*	*(0.037)*	*(0.812)*
Share_Public_health_expenditure	0.008**	0.010**	0.018***	0.019***
	(0.030)	*(0.036)*	*(0.006)*	*(0.007)*
Sanitary_access_rate	0.026***	0.057*	0.015*	-0.017
	(0.003)	*(0.063)*	*(0.090)*	*(0.121)*
Safe_water_access_rate	0.070***	0.134***	0.047**	0.019**
	(8.3e-04)	*(1.7e-04)*	*(0.042)*	*(0.047)*
Adult_literacy_rate	0.031**	0.022**	0.0018*	3.1e-05*
	(0.048)	*(0.030)*	*(0.089)*	*(0.099)*
Fertility_rate	0.026	0.153**	-0.229***	-0.243***
	(0.541)	*(0.0353)*	*(4.7e-05)*	*(2.1e-04)*
Urbanization _rate	-0.015	-0.027**	0.051	0.089
	(0.106)	*(0.0458)*	*(0.143)*	*(0.139)*
Physician_per_1000inhabt	0.012***	0.007**	0.007**	0.003**
	(0.001)	*(0.020)*	*(0.028)*	*(0.039)*
Prevalence_HIV	-0.015***	-0.013**	-0.014***	-0.008*
	(1.3e-04)	*(0.0298)*	*(3.6e-04)*	*(0.058)*
Extreme_Poverty_headcount_ratio	-0.079***	-0.074***	-0.050***	-0.041***
	(0.001)	*(1.9e-07)*	*(1.7e-06)*	*(2.0e-04)*
Gini_index	0.091	0.139*	0.059	0.027
	(0.130)	*(0.0975)*	*(0.213)*	*(0.590)*
Constant	3.972***	3.333***	3.450***	3.485***
	(8.1e-04)	*(6.9e-04)*	*(2.3e-04)*	*(8.1e-03)*
Time_trend	no	no	yes	yes
Time dummies	yes	yes	yes	yes
Sub-regions dummies	yes	yes	yes	yes
Observations	**271**	**271**	**271**	**225**
R-squared	**0.718**	**0.432**	**0.547**	**0.539**
Prob F test that all u_i=0			**0.000**	**0.000**
Prob Wald test corr(u_i, Xb)=0			**0.000**	**0.000**

Pvalue in parentheses *** p<0.01, ** p<0.05, * p<0.1
Sample: 1980-2010, Cf. section 5 for first stage regressions results

4.3. Long-Difference Estimation

As the annual or five-year change in life expectancy is very low, it seems more interesting to examine its evolution over a relatively long period in order to be able to identify the factors that can significantly contribute to the long-term variation. The aim of the long-difference estimation is to exploit the long-run changes in health status with respect to long-run changes in explanatory variables. In this approach, one suppose that the full effect of some of the explanatory variables can go beyond the just yearly or five-years changes in life expectancy. For example, health expenditure which is realized in a given year will continues to have effects

even in the subsequent years. In that case, rather than only associate expenditures with the corresponding life expectancy, one could analyze changes in life expectancy over a given period in relation to the absolute change in the interest variable over the same period. Thus, we estimate equation (1.b) in *long differences (LD)* approach following Acemoglu and Johnson (2005).

The *LD* approaches make interpretation easier as they directly measure the effect of change in economic variables between two dates on the change in life expectancy between the same dates. This approach may be useful because it is less vulnerable to serial correlation problems in the error terms (Acemoglu and Johnson, 2005). This method may be just limited to two dates panel. For examples, the difference observed between 1980 and 1989, between 1990 and 2000 or between 2000 and 2010. Since we consider only two dates, this estimation procedure is equivalent to the first-differenced specification. Hence using equation (1.b), one can write the *LD* specification as follows:

$$\Delta_{t_0 t_1} ln(LEXP_{it}) = \beta \Delta_{t_0 t_1} ln(SELC_{it}) + \gamma \Delta_{t_0 t_1} ln(HI_{it}) + \Delta_{t_0 t_1} \lambda_t + \Delta_{t_0 t_1} \varepsilon_{it} \qquad (2.a)$$

Where $\Delta_{t_0 t_1} ln(LEXP_{it})$ denotes the life expectancy gain in country i determined as the absolute variation of the level of life expectancy between the two dates t_0 and t_1. $\Delta_{t_0 t_1} ln(SELC_{it})$ is the variation all of socioeconomic factors over the same period and $\Delta_{t_0 t_1} ln(HI_{it})$ the variation of the direct health inputs and others health system components. $\Delta_{t_0 t_1} \lambda_t$ and $\Delta_{t_0 t_1} \varepsilon_{it}$ represent respectively, time-varying factors and the error term. Note that in this specification, the country-specific effect and the intercept term are just eliminated by the difference operator Δ since these factors are supposed to be constants over time. But this is not necessarily the case for time-specific since $\Delta_{t_0 t_1} \lambda_t$ can be different from zero. To control for this issue, we introduce the constant term in the difference equation[6]. The coefficient β and γ represent the parameters to be estimated.

Applying the difference operator on the logarithm elements, equation (2.a) can be rearranged and rewritten in terms of relative variation. Thus, we obtain the following equation (2.b):

$$ln\left(\frac{LEXP_{it_1}}{LEXP_{it_0}}\right) = \beta ln\left(\frac{SELC_{it_1}}{SELC_{it_0}}\right) + \gamma ln\left(\frac{HI_{it_1}}{HI_{it_0}}\right) + \Delta_{t_0 t_1} \lambda_t + \Delta_{t_0 t_1} \varepsilon_{it} \qquad (2.b)$$

6 As the constant is initially absent in this equation, introducing this variable will allows to capture the difference in the coefficients of the times dummies. This is easily mathematically demonstrable that this will be equivalent to $\Delta_{t_0 t_1} \lambda_t$.

This equation is then estimated by 2SLS over three sub-periods and over the entire period. Table3 presents the results from these estimations.

Table 3: Variation of Life expectancy

	FIRST-DIFFERENCE 2SLS			
VARIABLES	**(1980-1989)**	**(1990-1999)**	**(2000-2010)**	**(1980-2010)**
Gdp_pcapita	-7.2e-06	2.4e-05**	-2.3e-06	9.1e-06*
	(0.149)	*(0.043)*	*(0.183)*	*(0.083)*
Share_Public_health_expenditure	0.126**	0.010**	2.2e-05*	0.068***
	(0.046)	*(0.017)*	*(0.099)*	*(0.005)*
Sanitary_access_rate	1.330**	-0.012	0.021	0.098**
	(0.026)	*(0.596)*	*(0.361)*	*(0.016)*
Safe_water_access_rate	2.771	-0.027	0.040*	0.148***
	(0.117)	*(0.547)*	*(0.058)*	*(0.003)*
Adult_literacy_rate	-0.005	0.004*	0.018**	0.117**
	(0.673)	*(0.078)*	*(0.037)*	*(0.011)*
Fertility_rate	0.314***	-0.321**	-0.095**	-0.170**
	(9.2e-04)	*(0.028)*	*(0.044)*	*(0.018)*
Urbanization _rate	-0.025	0.090**	0.037	-6.4e-05*
	(0.101)	*(0.018)*	*(0.338)*	*(0.099)*
Physician_per_1000inhabt	6.3e-04	0.012***	0.004*	0.012**
	(0.886)	*(0.002)*	*(0.060)*	*(0.034)*
Prevalence_HIV	**---**	-0.011**	-0.004*	-0.055***
	---	*(0.030)*	*(0.098)*	*(3.8e-08)*
Extreme_Poverty_headcount_ratio	-0.003	-0.027**	0.004	-0.060**
	(0.637)	*(0.018)*	*(0.817)*	*(0.012)*
Gini_index	-0.010*	0.056**	-0.028	0.117**
	(0.082)	*(0.045)*	*(0.536)*	*(0.029)*
Constant for $\Delta_{t_0 t_1} \lambda_t$	0.010***	-0.011**	0.038***	0.022**
	(2.0e-06)	*(0.039)*	*(6.8e-07)*	*(0.049)*
Sub-regions dummies	yes	yes	yes	yes
Observations	**45**	**45**	**45**	**45**
R-squared	**0.786**	**0.565**	**0.589**	**0.722**

Pvalue in parentheses *** p<0.01, ** p<0.05, * p<0.1
As Prevalence_HIV=0 for all countries between 1980-1989, thus this variable is dropped from regressions for this period[7].

4.4. Dynamic Specification

We also attempt to explore dynamic aspect of life expectancy by using standard dynamic models including lagged dependent variable as a regressor. The dynamic specification is a way to overcome the weakness of the previous methods. Its specification is expressed as follow:

[7] All the estimations previously done were made by assigning zero HIV prevalence over 1980-1989 for all countries since no HIV prevalence is observed during that period. And the HIV prevalence is rescaled using ($+10^{-05}$) in logarithmic form.

$$ln(LEXP_{it}) = \alpha + \delta ln(LEXP_{it-1}) + \beta ln(SELC_{it}) + \gamma ln(HI_{it}) + \mu_i + \lambda_t + \varepsilon_{it} \qquad (3.a)$$

Where $ln(LEXP_{it})$ and $ln(LEXP_{it-1})$ are respectively the log of life expectancy at periods t and $t-1$. $SELC_{it}$ and HI_{it} are the other regressors. μ_i, λ_t and ε_{it} represent respectively the country-specific effects, time-specific effects and the error term. If $\delta \neq 0$, thus $ln(LEXP_{it})$ will be function of error term, and OLS estimation will be biased and inconsistent. Eliminating this bias requires, first, undertaking the short first-difference transformation to wipe out the country fixed-effect term. This yields the following estimating equation:

$$\Delta ln(LEXP_{it)} = \delta ln(\Delta LEXP_{it-1}) + \beta ln(\Delta SELC_{it}) + \gamma ln(\Delta HI_{it}) + \Delta\lambda_t + \Delta\varepsilon_{it} \qquad (3.b)$$

To implement this estimation, we use a system of moment equations in system GMM approach (Blundell and Bond, 1998) in which we have two block of a stacked data organized in the form of system. The first block is built out of the data in level (equation 3.a) and the second of data in differences (equation 3.b). In this system, lagged variables in levels serve to instrument the differenced variables and lagged differences to instrument variable in levels.

In panel data with a large number of cross-sections and a small number of time periods, the system GMM estimator has much smaller finite sample bias and is much more accurate in estimating autoregressive parameters. But one caveat of system GMM is that including excessive number of instruments dilutes the power of Hansen's overidentification test and the test may falsely reject the null hypothesis that the instruments are valid[8].

In estimation, lagged life expectancy and per capita income are variables that are treated as endogenous and all of the estimations are performed by the two-step GMM. We check robustness of the model by using different time lags by changing the number of instruments in the system estimation. The results from this estimations are presented in Table 4.

[8] See Roodman (2008) for a discussion on the different problems which can arise by using too many instruments.

Table 4: Dynamic estimation results:

	GMM estimation	
VARIABLES	Coeff	P.values
Lag_ Life_expect	0.600***	(8.6e-07)
Gdp_pcapita	1.1e-06**	(0.015)
Share_Public_health_expenditure	0.015***	(0.002)
Sanitary_access_rate	0.014***	(0.008)
Safe_water_access_rate	0.019**	(0.026)
Adult_literacy_rate	0.010**	(0.027)
Fertility_rate	-2.3e-04	(0.996)
Urbanization _rate	0.016	(0.121)
Physician_per_1000inhabt	0.006**	(0.017)
Prevalence_HIV	-0.009**	(0.030)
Extreme_Poverty_headcount_ratio	-0.029*	(0.074)
Gini_index	-0.008	(0.849)
Constant	1.749***	(0.001)
Time_trend	yes	---
Time dummies	yes	---
Sub-regions dummies	yes	---
Observations	225	---
Number of instruments	38	---
Sargan test of overid.(Not robust, but not weakened by many instruments)	Prob > chi2 =	
Hansen test of overid(Robust, but weakened by many instruments.)	Prob >chi2 =	
Arellano-Bond test for AR(1) in first differences; H0:no serial correlation	Pr > z =	
Arellano-Bond test for AR(2) in first differences; H0:no serial correlation	Pr > z =	

Pvalue in parentheses *** p<0.01, ** p<0.05, * p<0.1

5. Regressions diagnostics

As the degree of robustness of an estimation can strongly dependent on several conditions, it is necessary to run some tests in order to assess the quality of our methods.

After the test of presence of fixed effects, which strongly reject the hypothesis of absence of individual effects (bottom of Table 3) and thus justify the relevance of the use of panels in fixed-effects, the firsts set of tests we performed are those on instruments validity in 2SLS estimations. Presented in Table 6, results from the first stage estimations show that our three instruments are strongly correlated with GDP per capita (top of Table 6). The validity of these instruments is then tested through under-identification and weak identification tests which results are also presented. The under-identification test (Anderson, 1984), aims to test the rank condition of the matrix of the reduced form coefficients. To be valid, the instruments must satisfy the full rank condition meaning that the equation is identified and the excluded instruments are correlated with the endogenous regressor. Using Anderson canonical correlation between instruments and GDP per capita, one can reject the hypothesis of under-identification at 1% level.

Tabe 5: 2SLS estimation first stage results and instruments validity

Gdp_pcapita	Coef.	Std. Err.	t	P>|t|
Term_of_trade_shock	0.087	0.026	3.366	0.001
Ratio_invest_gdp	0.038	0.014	2.661	0.008
Trade_openness	0.193	0.091	2.124	0.035
Control variables	yes	---	---	---
Number of obs	271			
Prob > F	0.000			
Centered R2	0.561			
Underidentification test				
Anderson canon. corr. LM statistic	Chi-sq(3)=	16.756	P-val=	
Weak identification test				
Cragg-Donald Wald F stat= 8.87	H0 rejected according to Stock-Yogo critical values for K1=1 and			
Weak-instrument-robust inference				
Anderson-Rubin Wald test	Chi-sq(3)=	32.90	P-val=	
Stock-Wright LM S statistic	Chi-sq(3)=	29.34	P-val=	
Overidentification test				
Sargan statistic	Chi-sq(2)=	40.400	P-val =	

Since the under-identification hypothesis is rejected, we test the weak identification hypothesis which arises when instruments are weakly correlated with the endogenous regressor. Using Cragg-Donald Wald F statistic and Stock-Yogo critical values table, one can also reject this hypothesis at 20% maximal IV relative bias and 25% maximal IV size which means that 2SLS estimator performs better than OLS estimator at these respective significance levels.

The third diagnostic test is the Weak-instrument-robust inference which aims to test the significance of the endogenous regressor in the structural equation. It's implemented by estimating the reduced form of the structural equation and testing joint nullity of excluded instruments coefficients. Using Anderson-Rubin (1949) and Stock-Wright (2000) tests statistics since both tests are robust to the presence of weak instruments, one can clearly reject at 1% level the hypothesis of joint nullity of the coefficient of excluded instruments in the reduced form.

Although previous tests tend to relatively reinforce the credibility of the instruments, the Sargan over-identification test is less favorable since the results of this test reject the over-identification hypothesis in which the instruments are supposed to be uncorrelated with the error terms and properly excluded from the base equation. Rejection of this hypothesis leads us to doubt of the validity of the instruments.

One of the main reasons that have led us to use dynamic estimation approach is the difficulty to find very credible instruments for GDP per capita. The GMM system approach estimation appears as one of the most robust methods providing the opportunity to get instruments directly from the variable itself using potential instruments available. The identification conditions are

mainly based on lags of independent variables. In estimation, we first checked for the robustness using different lags structures. For that, we depart from the AR test using Arellano-Bond autocorrelation test.

The purpose of the Arellano-Bond autocorrelation test is to test the assumption that the error term in the levels equation are not autocorrelated. Given that the error term in the first-difference equation has negative first-order autocorrelation, we cannot reject the hypothesis of absence of second order autocorrelation in the residuals of the first-difference equation. This means that we can choose our instruments between 2 and deeper lags periods. Hence, according to Arellano Bond AR test results and the rule of thumb that the number of instruments should be less than the number of groups (45), we finally retained between 2 and 3 lags periods in which we found that the estimated results still stable using only this interval. Also, our specification tests appear relatively satisfactory as the Hansen's over-identifying restrictions are conclusive at 5 % level (see table 5).

6. Discussion of results

In most of our estimations, we find globally a positive effect of GDP per capita on life expectancy. In pooling approach (Table 2), the coefficient associated with this variable is positive and statistically significant at 5% level. We obtain the same results using panel fixed-effects OLS estimation method although the coefficient loses significance in 2SLS estimation (Table 3). In the long difference method on 3 sub-periods (1980-1989, 1990-1999, 2000-2010), we find that the coefficient on income is significant only for 1990-1999 sub-period (Table 4) and thus in the entire period regression.

Trying to treat properly the endogeneity problem of GDP per capita, we proceed to dynamic panel estimation where we instrument potential endogenous variables with their lagged values. The results obtained from this approach show positive and significant effect of income on at 5% level (Table 5).

Regarding variables directly related to the health system, we found that the share of public health expenditure has significant positive effect on life expectancy and this result is robust whatever the chosen estimation method. The number of physician per 1000 inhabitants also appears strongly correlated with life expectancy (See Table 2 to table 5).

Turning to the other socioeconomic variables, we found that most of the selected variables impact significantly life expectancy. It appears that improved sanitation and safe water access

have positive and statistically significant impact on life expectancy (Table 3 through 5). Adult literacy rate is also positively and significantly correlated to higher life expectancy. The coefficient associated with variable is robustly significant in almost all of our regressions. Furthermore, our estimations results confirm those of earlier studies on the effect of the AIDS epidemic on life expectancy in sub-Saharan Africa countries. We found that the prevalence of HIV is significantly associated with low life expectancy. This result is significant at 1% in almost all of our estimations. As for the effect of poverty and inequality, the results show that poverty negatively influences life expectancy while the impact of inequality appears to be mixed. Indeed, globally we found a significant negative correlation between extreme poverty and life expectancy (Table 2 to Table 5) while the sign of the coefficient associated with the Gini index is very changing depending on the estimation method. In pooling, the coefficient is positive and significant at 10% in the 2SLS estimation. In the fixed-effect and dynamic panel method, this significance disappears. But, in the difference approach, we find that the coefficient is negative and significant for the period 1980-1989, positive and significant for 1990-1999, but not significant for the period 2000-2010. This shows the difficulty to conclude any consistent effect of inequality on health status without a very thorough analysis of the relationship between the two variables.

Conclusion

In this paper, we have analyzed the impact of socioeconomic factors on life expectancy in SSA countries by applying different estimation methods which treat the problem heterogeneity between countries and deal with the endogenous nature of some of explanatory variables. For that, we used successively the pooling approach, the fixed-effect panel method, the difference method and particularly the system GMM approach to estimate the determinants of life expectancy considered as indicator global health status in a given country. In these estimations, we used a cross-country panel dataset from 45 SSA countries.

The empirical results show that GDP per capita has statistically significant positive impact in enhancing health status. On the other hand, we found that the health system factors (captured by the share of government health spending and the number of physicians per 1000 inhabitants), strongly affect positively the life expectancy. Regarding other socioeconomic factors, we found that adult literacy and access to improved sanitation and safe water have positive and significant impact on health status. We also found that the prevalence of HIV has a strong negative impact on life expectancy. Furthermore, our estimations results show that extreme poverty appears

negatively correlated with life expectancy while the impact of inequality appears not conclusive given the changing sign and significance in most of our regressions.

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Appendix

List of countries in the sample

Code	Name	Code	Name
AGO	Angola	MLI	Mali
BDI	Burundi	MOZ	Mozambique
BEN	Benin	MRT	Mauritania
BFA	Burkina Faso	MUS	Mauritius
BWA	Botswana	MWI	Malawi
CAF	Central African Republic	NAM	Namibia
CIV	Cote d'Ivoire	NER	Niger
CMR	Cameroon	NGA	Nigeria
COG	Congo, Rep.	RWA	Rwanda
CPV	Cape Verde	SDN	Sudan
DJI	Djibouti	SEN	Senegal
ERI	Eritrea	SLE	Sierra Leone
ETH	Ethiopia	SOM	Somalia
GAB	Gabon	SWZ	Swaziland
GHA	Ghana	TCD	Chad
GIN	Guinea	TGO	Togo
GMB	Gambia, The	TZA	Tanzania
GNB	Guinea-Bissau	UGA	Uganda
GNQ	Equatorial Guinea	ZAF	South Africa
KEN	Kenya	ZAR	Congo, Dem. Rep.
LBR	Liberia	ZMB	Zambia
LSO	Lesotho	ZWE	Zimbabwe
MDG	Madagascar		