Effects of Human Capital (Health) on Economic Growth in Africa: Role of Trade, Analysis by Gender Health and Income Level

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Effects of Human Capital (Health) on Economic Growth in Africa: Role of Trade, Analysis by Gender Health and Income Level

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Abstract

The paper examines the effects of human capital (health) on economic growth by highlighting the complementary role of trade, the effect of women's and men's health on growth, and comparing the effect of health on growth in low-income countries (LICs) to that in lower-middle-income countries (LMICs) between 1980 and 2021 in Africa. The instrumental variables (IV) approach with fixed effects (IV-FE) is used to control for the endogeneity issue, such as omitted variables and error measurement. The findings reveal that health significantly enhances growth in Africa, but only in LMICs. Also, health of both male and female significantly increase growth in Africa. Furthermore, adult survival is more relevant for growth than life expectancy. Finally, the marginal effect (ME) of life expectancy at birth increases with the level of trade above a certain threshold; above the level of trade equal to 38.745 % of GDP this ME becomes positive and statistically significant. Also, the ME of adult survival growth rate increases with the level of trade above and below certain thresholds; between the interval 71.952 and 136.319, the ME of adult survival growth rate is positive and statistically significant. These findings imply that health improvements and better alignment of health and trade policies are needed to stimulate growth in Africa.

Keywords: Health human capital; Trade; Economic growth; Interaction models; Instrumental variables approach

JEL classification: C36; F1; I15; O11; O47

1 Introduction

Human capital (education, skills, and health of people) plays a crucial role in promoting growth (Xu and Pan, 2025; Bloom et al., 2024; Fumagalli et al., 2024; Zhang and Wang, 2021; Zhao and Zhou, 2021; Acemoglu and Johnson, 2014, 2007; Cervellati and Sunde, 2011). Expenditures on education are often encouraged by the fact that education makes a strong contribution to economic growth. However, health measures have contributed to health improvements, and the literature also considers health as a key determinant of growth. The link between health of people and growth rate has become an interesting and crucial theme of the debate, especially in the context of COVID-19, among researchers (Zhao and Zhou, 2021; Hartwig, 2010), policymakers, and international institutions (World Bank-WB, World Health Organization-WHO). Health improvements are a social preoccupation. Descriptive evidence shows improvements in health (life expectancy at birth, adult survival rate) in some relatively poor economies (Acemoglu and Johnson, 2014). GDP per capita growth rates fluctuate over time. The highest rate of the real GDP per capita is about 2.4% in 1995-1999 (while it drops to -1.7% in 2020-2021), which is below 7%, the eighth goal of Sustainable Development Goals (SDGs) (authors' computation using data from the World Bank). Good health is an important factor of economic growth and economic development. Especially, Gallup and Sachs (2001) suggest that eradicating malaria in Sub-Saharan Africa (SSA) could raise that continent's GDP per capita growth by as much as 2.6% a year.

Until 1940, there is a large gap in improvements in public health between some developed areas (such as Western Europe and, the United States are marked) and the least developed regions such as America, Africa, and Asia. Some explanations of this situation are the existence of few effective drugs against the major diseases in these least developed regions and the colonial governments who marginalize these public expenditures. However, health improvements, after 1940, are observed in poor economies due to a meteoric rise in pharmaceutical and chemical innovations around the world which offered cures effective against major killers in these countries (ii) the creation of WHO that significantly contributes to the spread of medical and the transfer of public health technology to underdeveloped economies and (iii) a change in international values, especially trade openness. As pointed out by Preston (1975), after the 1930s, "Universal values assured that health breakthroughs in any country would spread rapidly to all others where the means for implementation existed".

The link between health human capital and growth can be traced back to the endogenous growth theory. The direct effect of health on growth is justified by the fact that healthier workers are more productive and earn higher wages because they are physically and mentally more energetic and robust (Weil, 2007; Bloom et al., 2004). Health can also increase economic growth by stimulating productivity, capital accumulation (both physical and human capital, such as education) (Herzer, 2020; Bucci et al., 2019; Acemoglu and Johnson, 2014, 2007). According to the Malthusian literature (where population growth outpaces agricultural production, leading to poverty and famine), health improvements have an ambiguous effect on economic growth. Indeed, exploring the exogenous growth theory, the physical capital dilution effect of population growth suggests that a growth of population leads to the dilution of the stock of physical capital per capita which, in turn, reduces GDP per capita (Fumagalli et al., 2024; Bucci et al., 2019).

Besides, Bloom et al. (2020) report two channels relating to women's health-growth nexus. First, the better health of mothers directly affects the health of children through in-utero effects and the mother's ability to breastfeed and nourish their children in other ways (Field et al., 2009). Female health thereby improves development prospects over the long run via direct intergenerational transmission of human capital (Bloom et al., 2014). Second, female health may lower fertility and thus youth dependency with a knock-on effect on female labor participation and educational investments (Bloom et al., 2009). Lower fertility arises as a direct consequence of improved reproductive health through the availability of contraceptives (Bailey, 2006), but it is also triggered indirectly as a response to changes in the female opportunity costs of child-rearing and changes in the returns to education. Despite the fact that women's health improvements might contribute to economic growth, the micro literature shows that households tend to prefer male health improvements over female health improvements due to some norms and values (Bloom et al, 2020).

In line with the above literature, it is clear that trade and health are interconnected. If health, a component of human capital, influences education as suggested by the above studies (Herzer, 2020; Weil, 2007; Bloom et al., 2004), it is evident that health affects trade. Intuitively, trade is one important mechanism via which health affects growth. Health influences the workforce and its quality and therefore trade flows. The Heckscher-Ohlin-Samuelson (HOS) trade theory shows that economies' factor endowments determine the pattern of trade, suggesting that human capital plays a crucial role in explaining patterns of trade flows or comparative advantage (Unel, 2015; Bombardini et al., 2012). Human capital, as a primary source of comparative advantage and trade flows, was first invoked as an explanation for the Leontief paradox. Reciprocally, trade can influence health (and growth) via diverse channels such as generated income, technology transfer, increasing trade in medical supplies and drugs, especially vaccines in developing States, environmental quality, food (in)security, facilitating the transfer of diseases, good practices across borders, dangerous economic activity, and vulnerability of small States associated with trade (Giuntella et al., 2020; Owen and Wu, 2007; Levine and Rothman, 2006; Antweiler et al., 2001). These channels show the ambiguous combined effect of health and trade on growth. However, studies analyzing the interaction effect of health and trade on growth are almost nonexistent.

The existing empirical literature is inconclusive, notably in high-income countries (Weil, 2007). Life expectancy and adult survival rates are often used as proxies of health human capital (Albarrán, 2018; Hansen and Lϕnstrup, 2015; Acemoglu and Johnson, 2007). Some studies find a positive effect of life expectancy on growth. These studies include Ogundari and Awokuse (2018) for Sub-Saharan Africa (SSA). Other studies (Hansen and Lϕnstrup, 2015, for developed countries; Acemoglu and Johnson, 2014, 2007, for 47 countries excluding African countries) find a negative effect of life expectancy on growth. The last category of studies finds a mixed effect: Acemoglu and Johnson (2014, 2007); Ogunleye (2014) for SSA countries; Cooray (2013) for 210 countries. Bane (2018) finds in low- and middle-income African countries a positive effect and negative (insignificant) effect, respectively, of life expectancy in level on GDP growth instead of GDP per capita growth. Using the interaction (between lagged GDP and adult survival) model, Bhargava et al. (2001) show a positive effect of adult survival on economic growth in low-income countries and a negative effect for the US, France, and Switzerland. Besides, at the SSA continental level, Gyimah-Brempong and Wilson (2004) focus on the growth model in the quadratic framework while Odhiambo (2021), Sarpong et al. (2018), Piabuo and Tieguhong (2017) focus on health in the form of expenditures. This paper focuses on the African continent in line with Bane (2018) but uses alternative measures of health and growth and explores the complementary role of trade. The question is what are the effects of health human capital on economic growth in Africa? This question can be divided into three sub-questions. Does human capital in the form of health (overall, male and female) enhance economic growth? Is the effect of health on economic growth in low-income countries (LICs) different from that in lower-middle-income countries (LMICs)? Does the effect of health on growth in Africa increase as the level of trade increases?

The paper is closely related to the studies on the connection between health human capital and economic growth, especially the recent study by Bane (2018) at the African level. However, we contribute to the existing literature in four ways. First, we think that adopting a different specification helps to understand the effect of health on growth and possible inconsistencies from the literature, especially in Africa. Indeed, while we focus on African countries like Bane (2018) and Ogundari and Awokuse (2018), we rely on a different specification that includes both levels and rates of health. In particular, unlike the recent study by Bane (2018), which uses GDP as a proxy of growth, the present paper employs GDP per capita growth. Ridhwan et al. (2022) show the differential effects of life expectancy on GDP growth and GDP per capita growth. Furthermore, in addition to life expectancy at birth used by these authors, this research employs adult survival rates as a proxy of health. We think that the effects of both health proxies can be different because both measures capture different complementary aspects of health. Indeed, for example, adult survival refers to the mortality working age (thus less sensitive to child mortality rates) while life expectancy at birth is strongly sensitive to child mortality rates.

Second, we also think that health can have a differential effect on economic growth depending on the country's income level. Thus, one contribution of the study by Bane (2018) is the consideration of two sub-groups in Africa: low- and middle-income countries using the World Bank's old classification of countries by income level. However, using the World Bank's new classification (Table A1), the effect of health on growth in LMICs can differ from that of the whole middle-income countries (including both lower-middle- and upper-middle-income countries). Thus, the t-tests (mean-comparison tests) indicate a statistically significant difference in the means of income in low-income countries or income in lower-middle-income countries and that in others (Table A2). Considering the above gaps, including those at the aggregated level, this paper revisits the disaggregated analysis by income level.

Third, we think that improvement in female health is more important for the African region than for other regions due to the prevalence of some norms and values in Africa. Besides, Table A2 shows a statistically significant difference in the means of health, in particular, the adult survival growth rate, of males and females. Indeed, introducing simultaneously female and male health, the main results by Cooray (2013) show insignificant effects of the life expectancy of females and males on growth. This simultaneous inclusion leads to the multicollinearity issue (Table A4). Thus, our contribution is to show that, using a different specification, health can have differential and/or significant effects on growth depending on gender. Fourth, in a globalized world, potential health policies might include trade policies. This is crucial because health has ambiguous effects on economic growth. However, previous studies completely ignore the effect of this type of interaction. This paper is the first one that explores the combined effect of health and trade on growth.

The general objective is to investigate the effects of health human capital on economic growth in Africa. Specifically, to explore the direct effect of health human capital on economic growth in Africa and compare the effect of female health human capital on economic growth to that of male health. To compare the effect of health human capital on economic growth in LICs to that in LMICs. To examine whether the effect of health capital on growth in Africa increases as the level of trade increases.

The remainder of the study is structured as follows: Section 2 presents the methodology and data while Section 3 displays some diagnostic tests and findings. Section 4 concludes.

2 Methodology and data

2.1 Estimating framework

Following the endogenous growth theories, especially human capital theory by Mankiw et al. (1992) and Lucas (1988), Acemoglu and Johnson (2007) suggest the following estimating equation:

$$y_{it} = \theta x_{it} + Z_{it}^{'}\phi + \upsilon_i + \mu_t + \varepsilon_{it} \quad (1)$$

where, y_{it} represents the log GDP per capita, x_{it} denotes the log health (X_{it}). In line with health empirical literature (Hansen and Lφnstrup, 2015; Acemoglu and Johnson, 2014; Bloom et al., 2014), health is introduced in the regression both in level and growth rate. The research expects the positive sign of the parameter associated with the health growth rate. Z is a vector of control variables. v_i captures country-fixed effects. Taking into account these effects is important because the country characteristics will be naturally correlated with health and thus with the error term ε_{it}. Besides, many other country-specific factors will simultaneously influence health and economic outcomes. If ϕ is equal to 0, the initial model is:

$$y_{it} = \theta \cdot x_{it} + \upsilon_i + \mu_t + \varepsilon_{it} \quad (2)$$

The literature suggests that for estimation objectives, turning the production function into a growth equation is useful (Bloom et al., 2004). Following this procedure, country-fixed effects seem to be eliminated from the error term by means of first differencing:

$$y_{it} = \theta \cdot \Delta x_{it} + \Delta\mu_t + \Delta\varepsilon_{it} \quad (3)$$

where $\Delta y_{it} \equiv y_{it}-y_{it-1}$, $\Delta x_{it} \equiv x_{it}-x_{it-1}$. Time dummies are included that act as proxies for the average worldwide level and growth rate of TFP (Bloom et al., 2004). While the growth model (3) eliminates country fixed effects, the empirical literature suggests that since model (3) is only an estimating model, the interpretation of θ comes from the structural conditional expectation $E(y_{it} \mid x_{it}, v_i, \mu_t) = \theta x_{it} + v_i + \mu_t$ from model (2) (Hansen and Lϕnstrup, 2015; Wooldridge, 2002). In this vein, θ provides an estimate of how the log level of health affects the log level of GDP per capita, Equation (2), conditionally on both country and time-fixed effects. Therefore, some studies opt for the partial adjustment model through the error term (Hansen and Lϕnstrup, 2015; Acemoglu and Johnson, 2014; Bloom et al., 2014). Thus, in line with these studies, the Equation (2) is modified by adding x_{it-1} and y_{it-1} on the right-hand side:

$$y_{it} = \theta \cdot x_{it} + \varphi \cdot x_{it\_1} - \pi \cdot y_{it-1} + \upsilon_i + \mu_t + \varepsilon_{it} \quad (4)$$

According to Hansen and Lϕnstrup (2015), Acemoglu and Johnson (2014), and Bloom et al. (2014), in terms of the equivalence of Equation (4), the baseline model can be specified as:

$$\Delta y_{it} = \theta \cdot \Delta x_{it} + (\varphi + \theta) \cdot x_{it\_1} - (\pi + 1) \cdot y_{it-1} + \upsilon_i + \mu_t + \varepsilon_{it} \quad (5)$$

In line with Hansen and Lϕnstrup (2015), Acemoglu and Johnson (2014), the explanatory variable of interest is the growth rates of health. However, in the second step, for the sensitivity analysis, control variables (vector Z) are added. We recall that y represents GDP per capita (GDPpc). In terms of growth rate, we use the symbol GDPpcGr (GDPpc growth rate) in the following text. Also, x is a proxy of health which can be life expectancy (Lif) or adult survival rate (Surv). In terms of growth rate, LifGr and SurvGr symbols are used in the following paragraphs. Following the literature, control variables include Trade (Trade), education (Edu), population growth (PopGr), investment (Inv), foreign direct investment (Fdi), governance (polity 2), domestic credit (Cre), inflation (INF) and mobile cellular subscriptions (Mobile).

The last step is the investigation of the effect of the interaction between health and trade on economic growth. The effect of trade on health is unclear. While trade liberalization is associated with some gains (transfer of knowledge useful for improving health or good health practices), trade also reduces the quality of the environment and leads to an increase in food insecurity via nutrition transition, especially in terms of utilization such as obesity and overweight, which are associated with non-communicable diseases (NCDs) such as diabetes, cardiovascular diseases, and cancer (Giuntella et al., 2020; Owen and Wu, 2007), all of which has an impact on health. Also, trade can affect health by influencing trade in medical supplies and drugs, especially vaccines in developing States (Giuntella et al., 2020; Owen and Wu, 2007; Levine and Rothman, 2006; Antweiler et al., 2001). Taking into account the interaction term (INT) between health and trade (and control variables, Z), the augmented model is:

$$\Delta y_{it} = \theta \cdot \Delta x_{it} + (\varphi + \theta) \cdot x_{it\_1} - (\pi + 1) \cdot y_{it-1} + \lambda \cdot INT + Z' \cdot \phi_{it} + \upsilon_i + \mu_t + \varepsilon_{it} \quad (6)$$

2.2 Estimation technique

Equations (5) and (6) represent the two-way fixed effects models that allow for differences across both units (economies) and time. Indeed, the strategy of the identifying restriction implies that there are no unit-specific and time-invariant omitted factors. υ_i denotes the country-fixed effects (FE) that capture the impact of country-specific factors that may differ among the countries at any given time but do not vary over time (such as landlocked, land area, language, religion). μ_t controls for the impact of macroeconomic and other factors that affect all the countries at any given time but vary over time (such as Ebola, COVID-19). The inclusion of time-FE also controls for the change in some observable variables (Mamba and Balaki, 2023). Models (5) and (6) are often referred to as the least squares dummy variable (LSDV) equations, suggesting that they can be estimated by ordinary least squares (OLS).

Thus, this research starts with a simple OLS (pooled OLS) regression before applying the OLS regression with country- and year-FE (panel OLS), known as the LSDV procedure, to understand the importance of these FE (Hansen and Lϕnstrup, 2015; Acemoglu and Johnson, 2014; Bloom et al., 2014). For example, applying this procedure, Hansen and Lϕnstrup (2015) find that the coefficient of the initial life expectancy changes sign while the magnitude of the growth rate of life expectancy doubles with the inclusion of the unobserved country-FE. Second, the inclusion of these FE produces similar findings (in terms of the magnitude of the coefficients) to those obtained using a fixed effect (FE) model which is appropriate for unbalanced panel data. We recall that Equation (5) represents the baseline model and can be augmented. Given that changes in health may be correlated with other omitted variables which influence economic growth even after controlling for initial health and income (initial income also controls the reverse causality issue), to demonstrate the causal effect of improvements in health on economic growth, we include control variables. Taking into account country and year-fixed effects (and including control variables) helps to solve another problem of endogeneity, that is the problem of omitted variables.

However, the literature often identifies three sources of endogeneity including the problem of omitted variables, error measurement and reverse causality. From this perspective, the preference is to use the instrumental variable (IV) approach (two-stage least squares, 2SLS, and especially 2SLS+FE) to control the endogeneity issue of the variable of interest (Hansen and Lϕnstrup, 2015; Acemoglu and Johnson, 2014; Lorentzen et al., 2008). Therefore, OLS and FE are only used to check robustness. The literature identified instruments that can be used to instrument human capital. As mentioned by Acemoglu et al. (2014), both institutions and human capital are treated as endogenous and instrumented with the same variables (historical variables). These instruments are (i) historical variables such as religion (Catholic, Muslim, Protestantism), legal origin or language (English, French), and Ethnolinguistic, (ii) geographic factors, including latitude (distance from the equator), land area, and landlocked (Lorentzen et al., 2008). These instruments are slow-moving and not caused by current education or institutional quality, hence, they can provide plausible exogenous variation. However, they strongly shape education systems, institutional structures and governance quality. For example, language facilitates the diffusion of knowledge and administrative systems, and often linked to colonial education policies and bureaucratic structures. Tropical regions faced higher disease burdens, had lower European settlement, leading to weaker institutions and lower human capital development. Ideally, land area is a time-invariant variable. However land becomes variable since the land area of some countries in our sample has been modified over time: Algeria from 2015, Madagascar from 2011 (and 2013), Sudan from 2012 and Uganda from 2011. Also, lagged values (Mamba and Balaki, 2023; Mamba and Balaki, 2022; Mamba, 2021; Lorentzen et al., 2008; Bloom et al., 2004; Acemoglu et al., 2003) or initial values (Acemoglu and Johnson, 2007) of the variables of interest can be used. In particular, dummy variables are used only for 2SLS while time-variant variables can be used for 2SLS or 2SLS+FE. Besides, Marson et al. (2023) instrument trade with the trade of the rest of the world.

Furthermore, in practice, the important concern is the validity of the instruments used. Indeed, Bloom et al. (2014) doubt the validity of the use of the initial values of life expectancy by Acemoglu and Johnson (2014) as instruments. Thus, for the validity of the instruments used, some diagnostic tests are conducted to test the relevance of the instruments as suggested by Baum et al. (2003). According to these authors, an instrument variable must satisfy two requirements. Thus, a good instrument must be (i) correlated with the included endogenous regressor(s), and (ii) orthogonal to the error term. The first requirement can be tested via the F statistic from the fit of the first-stage regression. Under the alternative hypothesis, that is, the significant F statistic, we conclude that the instruments affect endogenous regressor(s). Turning to the second requirement, the Hansen J statistics (HJS) are employed to implement tests of overidentifying restrictions. The joint null hypothesis (the insignificant HJS) is that the instruments are valid, meaning that they are orthogonal to the error term and that the excluded instruments are correctly excluded from the estimated model.

Additional diagnostic tests are also needed to justify the choice of instruments and, therefore, their relevance. The Kelibergen-Paap under-identification LM test is conducted to test whether the excluded instrument is linked to the endogenous variable. The significant LM statistic implies the rejection of the null hypothesis that the excluded instruments are irrelevant and unlinked to the endogenous variable. The Cragg-Donald test for weak identification is implemented via the Cragg-Donald F statistic to assess whether the excluded instruments are or are not strongly linked to the endogenous variable. The null hypothesis implies that the excluded instruments are weakly linked to the endogenous variable. The Anderson-Rubin Wald test helps to test the combined significance of endogenous variables. Under the null hypothesis, the insignificant χ^2 statistic of the Anderson-Rubin Wald test, the coefficients associated with the endogenous variables are jointly equal to zero. Finally, to validate our findings, the research conducted additional diagnostic tests, including correlation and multicollinearity tests, and unit root test. Also, Wald tests are implemented to test the significance of the country- and year-FE.

2.3 Data

We use four data sources. Data on life expectancy and adult survival are from World Development Indicators (WDI). Life expectancy at birth (years) shows the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life. Adult survival rate indicates the probability of dying between the ages of 15 and 60 (the probability of a 15-year-old person dying before reaching age 60), if subject to age-specific mortality rates of the indicated year between those ages. However, as data on adult survival are available in the most recent years only, this variable is calculated following the procedure adopted in the World Bank database as follows: Adult survival rate is equal to 1000−Adult mortality rate. This procedure adopted in the World Bank dataset is used by Gyimah-Brempong and Wilson (2004) to calculate the infant survival rate and not the adult survival rate. Also, Weil (2007) focuses on adult survival for men only.

Other variables such as trade openness (% of GDP), total population, investment (% of GDP), and foreign direct investment inflows (% of GDP) are collected from the same database. The education human capital proxy is collected from the Penn World Table (PWT), which recently introduced a human capital index based on the average years of schooling from Barro and Lee (2013) and an assumed rate of return to education. The governance variable, *polity2*, is from the polity IV project database. It is a scale variable varying from strongly autocratic (-10) to strongly democratic (+10). Due to the data availability, the sample covers 14 to 36 African countries over the period 1980-2021. Besides, for the analysis by income level, we only consider low-income countries and lower-middle-income countries because for Upper-middle-income countries the sample is too small (only five countries). It is unbalanced panel data. The list of countries is reported in the appendix (Table A1).

3 Findings and discussion

3.1 Effects of health on economic growth

Box 1 reports some preliminary tests. This section starts the discussion with the estimation of the standard human capital growth model before expanding it with the contributions of this research. Wald tests are implemented to test the significance of the country- and year-FE. In almost all regressions, the statistic associated with F is significant at the 5% threshold. This implies the existence of country- and year-FE. Indeed, part 1 of Table 1 focuses on the effects of standard variables on economic growth. Without controlling for country- and year-FE, the pooled OLS regression shows that domestic investment and education are the main drivers of economic growth. However, the OLS-FE (LSDV) regression indicates that only domestic investment significantly enhances economic growth in Africa. This finding is robust to the 2SLS regression. However, the findings in Column (4) show that domestic investment and education are the determinants of growth.

In the second step, this section focuses on the baseline models by adding the health growth rate and level before introducing all control variables. Parts 2 and 3 of Table 1 report the findings where the variable of interest is the health growth rate. The main findings are reported in Columns (3)’ and (4)’ for life expectancy as an explanatory variable, and (3)’’ and (4)’’ for adult survival as an explanatory variable. Indeed, as previously discussed, the IV approach is applied to deal with the endogeneity of health. Therefore, these findings rely on diagnostic tests to test the relevance of instruments used via significant F statistics from the first-stage regressions and insignificant HJS tests. Also, at the 5% level, Kleibergen-Paap LM, Cragg-Donald Wald F and Anderson-Rubin Wald tests further confirm the relevance of the instruments.

Table 1 Regression of the standard human capital growth model and the effects of health on GDP per capita growth

	Standard human capital growth model				Health: life expectancy growth rate				Health: Adult survival growth rate			
	OLS	LSDV	2SLS	2SLS+FE	OLS	LSDV	2SLS	2SLS+FE	OLS	LSDV	2SLS	2SLS+FE
	(1)	(2)	(3)	(4)	(1)’	(2)’	(3)’	(4)’	(1)’’	(2)’’	(3)’’	(4)’’
LnGDPpc_1	-0.759***	-4.833***	-4.609***	-5.050***	-0.847***	-5.145***	-5.087***	-5.759 ***	-0.830***	-5.287***	-5.075***	-5.536***
	(0.298)	(0.909)	(1.005)	(1.014)	(0.236)	(0.803)	(0.848)	(0.889)	(0.267)	(0.868)	(1.009)	(1.024)
Health rate					0.306	0.125	0.393***	0.406**	0.027	0.074	0.398*	0.499**
					(0.249)	(0.301)	(0.149)	(0.162)	(0.133)	(0.168)	(0.213)	(0.207)
LnHealth_1					3.047	5.051*	5.939*	2.473	1.091	3.776**	4.628***	0.949
					(2.223)	(2.658)	(3.573)	(3.537)	(0.999)	(1.677)	(1.775)	(1.859)
LnEdu	2.831***	1.628	0.067	7.359***	1.958***	0.935	1.651	4.998***	2.804***	0.619	2.231	4.572***
	(0.828)	(2.409)	(2.485)	(1.770)	(0.756)	(2.459)	(2.629)	(1.928)	(0.925)	(2.603)	(2.793)	(1.563)
PopGr	0.102	0.638	0.749	0.697	0.021	0.327	0.207	0.391	0.083	0.409	0.453	0.618
	(0.540)	(0.739)	(0.863)	(0.889)	(0.575)	(0.791)	(0.687)	(0.699)	(0.534)	(0.766)	(0.797)	(0.859)
LnInv[a]	1.483***	1.795***	1.350**	1.331**	1.214***	1.661***	1.922***	1.929***	1.356***	1.627***	2.124***	2.094***
	(0.372)	(0.458)	(0.607)	(0.596)	(0.451)	(0.491)	(0.479)	(0.496)	(0.411)	(0.465)	(0.519)	(0.486)
Constant	0.310	31.307***	28.382***		-10.01	-14.15	5.493		2.065*	37.20***	31.04***	
	(3.385)	(8.658)	(9.657)		(9.895)	(13.75)	(18.42)		(1.221)	(8.084)	(10.01)	
Year/country-FE	No	Yes	Yes	NA	No	Yes	Yes		No	Yes	Yes	NA
Countries	36	36	36	36	36	36	36	36	36	36	36	36
Observations	1,372	1,372	1,308	1,308	1,348	1,348	1,291	1,260	1,348	1,348	1,260	1,260
Wald test: F		5.590***	438.8***			5.580***	416.6***			5.750***	423***	
F	8.980***	6.750***	6.690***	11.68***	8.800***	6.950***	6.790***	11.560***	6.460***	6.820***	6.560***	9.470***
R-squared	0.027	0.217	0.226	0.070	0.038	0.221	0.227	0.079	0.028	0.223	0.203	0.353
HJS			0.015	0.056			0.915	0.855			2.043	0.135
Kleibergen-Paap LM			131.4***	126.5***			141.6***	142.4***			119.1***	172.4***
Cragg-Donald F			369.0***	411.0***			298.6***	1556***			578.5***	662.6***
Anderson-Rubin Chi2			8.160**	36.68***			7.300**	6.300**			8.120**	9.390***
1st stage regression												
F_Health rate							462.8***	444.69***			210.54***	239.74***
F_LnEdu			3811.8***	26114***								
F_PopGr			359.9***	866.8***								
F_LnInv			138.1***	128.8***								

Notes: a: applying Ln on investment leads to a reduction of only one observation (which is negative). Thus, Ln is applied to investment in all regressions in this study. NA: Not allowed. HJS, K-P, C-D, and A-R indicate Hansen J statistic, Kleibergen-Paap, Cragg-Donald, and Anderson-Rubin, respectively. 1-year lagged value of education, investment and population rate and 2-year lagged value of education are valid instruments in Columns (3-4). 1-year lagged values of the interaction of life expectancy growth rate with distance from the equator, and with land area (Column (3)’); 1-year lagged values of the interaction of life expectancy growth rate with distance from the equator, and 2-year lagged of the interaction of life expectancy growth rate with land area (Column (4)’) are valid instruments. 2-year lagged values of the interaction of adult survival growth rate and its interaction with distance from the equator in Column (3)", and its interaction with religion (Muslim) in Column (4)’’ are valid instruments. *p<0.1; **p<0.05; ***p<0.01. Robust standard errors in parentheses.

First, the research seeks to discuss the specification framework used in this study. In all regressions, the lagged values of GDP per capita (income) are significantly and negatively correlated with economic growth. This finding confirms the choice of the dynamic specification used in this study. Bloom et al. (2015) find a negative significant effect of lagged values of GDP per capita on growth. Table 1 shows that life expectancy and adult survival in level do not affect economic growth. We find a positive correlation between growth rates of health and economic growth in all regressions. However, these findings reveal an insignificant effect of growth rates of health on economic growth when the OLS and LSDV methods are applied. The main findings show that an increase in growth rates of health is associated with an increase in economic growth. Bloom et al. (2015) obtain a positive and significant (and insignificant negative) effect of both the level and growth rate of life expectancy at birth on growth using OLS (and 2SLS, respectively), while Hansen and Lϕnstrup (2015) report a negative significant effect of both level and growth rate of life expectancy at birth on growth. Besides, Bane (2018) reports an insignificant positive effect of life expectancy in level on growth in Africa while Ogundari and Awokuse (2018) find a positive significant effect of life expectancy in level on growth in SSA. One possible explanation of the difference between our findings and those of Bloom et al. (2015) and, in particular, Hansen and Lϕnstrup (2015) can be explained by the sample studied.

Besides, these findings show that education and domestic investment remain the main drivers of growth. In sum, health human capital significantly enhances economic growth in Africa. However, while the growth rates of the two proxies of health significantly enhance economic growth, the main findings show that the effect of adult survival growth rate (0.499) on economic growth is larger in magnitude than that of life expectancy growth rate (0.406). The differentiated effects of these mortality indicators can be explained by the fact that life expectancy and adult survival capture different complementary aspects of mortality. For example, adult survival is less sensitive to child mortality rates (but strongly sensitive to the working-age population), while life expectancy at birth is strongly sensitive to child mortality rates.

Furthermore, for robustness checks, Table A6 shows how the inclusion of control variables can influence the effect of health on economic growth. Additionally, before the investigation of the interaction effect of health and trade, trade is considered as an additional explanatory variable of interest. The findings based on the IV approach show that the effects of the growth rates of life expectancy and adult survival remain positive and significant. We note, however, that the magnitude of the effect of the growth rate of life expectancy on growth decreases while the magnitude of the effect of the growth rate of adult survival on growth increases with the inclusion of control variables. The effect of trade on economic growth remains significant and positive in almost all regressions. This finding is in line with trade and endogenous growth theories. Ogundari and Awokuse (2018) find a positive effect of trade on economic growth. Among standard variables, domestic investment remains a source of economic growth. Besides, domestic credit and inflation are the main factors.

Finally, this research tries to identify some main economies driving the above results. The findings, reported in Table A7, show the positive effect of life expectancy growth rate on economic growth in Algeria, Cameroon, Kenya, Nigeria and South Africa. Also, adult survival growth rate enhances growth in Algeria, Cameroon, and Kenya. At the same time, trade reduces economic growth in Kenya while trade enhances growth in Algeria, Cameroon, and South Africa.

3.2 Disaggregated analysis by health gender: Female health as a driver of economic growth

In this section, Table 2 compares the effect of the growth rate of life expectancy of males to that of females. Here also, the findings based on traditional estimation techniques (OLS and FE) show the insignificant effect of the growth rates of male life expectancy and female life expectancy on economic growth. However, the lagged life expectancy in level significantly enhances economic growth only when the Pooled OLS method is applied. Besides, the findings show the significant negative effects of the lagged values of the real GDP per capita on economic growth (in all regressions) at the 1% level. This confirms the quality of the dynamic specification.

The main findings reported in Columns (3-4) and (3-4)' rely on diagnostic tests to test the relevance of instruments used via significant F statistic and insignificant HJS tests. These findings show the positive and significant effects of the growth rates of life expectancies of males and females on economic growth. These findings are not robust to the traditional technique of regressions. Interestingly, the findings show that the coefficient associated with the life expectancy of females (0.451) appears to be similar to that associated with the life expectancy of males (0.441). These findings are supported by the t-test. They findings contradict the point of view of the micro literature that tends to support only male health improvements as highlighted by Bloom et al. (2020). Also, unlike Cooray (2013), who reports an insignificant positive correlation between these proxies of health and growth in 210 countries over 1990-2008, the policy implication here is that the health of males and females are important for growth in Africa.

Table 2 Comparative effects of life expectancy of male and female on GDP per capita growth

	Health: life expectancy growth rate of male				Health: life expectancy growth rate of female			
	OLS	LSDV	2SLS	2SLS+FE	OLS	LSDV	2SLS	2SLS+FE
	(1)	(2)	(3)	(4)	(1)'	(2)'	(3)'	(4)'
LnGDPpc_1	-0.705***	-5.438***	-4.927***	-4.883***	-0.741***	-5.455***	-4.928***	-4.829***
	(0.268)	(0.949)	(1.014)	(1.103)	(0.267)	(0.946)	(1.013)	(1.106)
Health rate	0.345	0.151	0.312**	0.441***	0.405	0.173	0.327**	0.453***
	(0.270)	(0.306)	(0.145)	(0.161)	(0.271)	(0.308)	(0.148)	(0.165)
LnHealth_1	3.954*	4.523	4.988	3.574	4.935**	4.968	5.078	3.003
	(2.084)	(2.902)	(4.174)	(3.851)	(2.192)	(3.023)	(4.293)	(3.790)
LnTrade	0.711**	0.924	1.179**	0.986**	0.734***	0.928	1.177**	1.018**
	(0.279)	(0.611)	(0.462)	(0.444)	(0.279)	(0.622)	(0.463)	(0.442)
LnEdu	2.433***	0.156	-0.429	4.039	2.195***	0.428	-0.007	4.632*
(PWT)	(0.819)	(2.677)	(2.775)	(2.635)	(0.824)	(2.630)	(2.755)	(2.672)
PopGr	-0.124	0.321	0.234	0.279	-0.163	0.305	0.237	0.303
	(0.608)	(0.855)	(0.715)	(0.716)	(0.616)	(0.857)	(0.715)	(0.725)
LnInv	0.865*	1.256**	1.366***	1.376***	0.838*	1.255**	1.376***	1.398***
	(0.453)	(0.505)	(0.527)	(0.477)	(0.450)	(0.502)	(0.524)	(0.475)
FDI	0.054	-0.001	-0.008	0.039	0.049	-0.001	-0.008	0.039
	(0.040)	(0.043)	(0.042)	(0.041)	(0.040)	(0.042)	(0.041)	(0.041)
LnCre	-0.529**	-0.586	-1.104***	-1.258***	-0.633***	-0.690	-1.095***	-1.244***
	(0.238)	(0.401)	(0.391)	(0.433)	(0.239)	(0.398)	(0.394)	(0.435)
Polity2	0.054**	0.006	0.029	0.044	0.053**	0.006	0.030	0.045
	(0.024)	(0.055)	(0.052)	(0.052)	(0.023)	(0.055)	(0.052)	(0.051)
INF	-0.017***	-0.020***	-0.018***	-0.024***	-0.018***	-0.019***	-0.018***	-0.024***
	(0.005)	(0.006)	(0.005)	(0.004)	(0.005)	(0.006)	(0.005)	(0.004)
Mobile	-0.013***	0.009	0.009	-0.001	-0.014***	0.010	0.008	0.003
	(0.003)	(0.011)	(0.011)	(0.006)	(0.004)	(0.011)	(0.011)	(0.006)
Constant	-14.38	18.63	9.997		-17.87*	16.62	9.191	
	(9.428)	(14.36)	(21.44)		(9.862)	(15.03)	(22.29)	
Year/country fixed effects	No	Yes	Yes	NA	No	Yes	Yes	NA
Countries	36	36	36	36	36	36	36	36
Observations	1,299	1,299	1,230	1,246	1,299	1,299	1,230	1,246
Wald test F		4.480***	346.1***			4.430***	342.0***	
F	7.640***	6.270***	6.390***	10.05***	8.170***	6.240***	6.370***	9.980***
R-squared	0.065	0.237	0.241	0.109	0.069	0.237	0.241	0.109
HJS			1.599	0.537			1.612	0.416
K-P LM			29.24***	177.7***			28.95***	174.1***
C-D F			393.9***	680.6***			359.2***	674.9***
A-R Chi2			14.06***	17.21***			14.58***	17.07***
First stage regression								
F_Health rate			117.9***	93.89***			131.9***	109.6***
F_Trade			400.2***	475.7***			401.0***	476.1***

Notes: NA: Not allowed. HJS, K-P, C-D, and A-R indicate Hansen J statistic, Kleibergen-Paap, Cragg-Donald, and Anderson-Rubin, respectively. Terms of trade and 2-year lagged values of life expectancy growth rate of male (in Column (3)) (and female in Column (3)') and land area are valid instruments. 2-year lagged values of trade of the rest of the world, land area and life expectancy growth rate of male (in Column (4)) and female (in Column (4)') are valid instruments.

Now, the following paragraph compares the effect of the growth rate of adult survival of males to that of females (Table 3). First, the findings show significant effects of the lagged values of the real GDP per capita on economic growth (in all regressions) at the 1% level. This confirms the choice of the dynamic specification framework. Again, the main findings reported in Columns (3-4) and (3-4)' rely on diagnostic tests to test the relevance of instruments used via significant F statistics and insignificant HJS tests. Also, at the 5% level, Kleibergen-Paap LM, Cragg-Donald Wald F and Anderson-Rubin Wald tests further support the relevance of the instruments.

Table 3 Comparative effects of adult survival of male and female on GDP per capita growth

	Health: adult survival growth rate of male				Health: adult survival growth rate of female			
	OLS	LSDV	2SLS	2SLS+FE	OLS	LSDV	2SLS	2SLS+FE
	(1)	(2)	(3)	(4)	(1)’	(2)’	(3)’	(4)’
LnGDPpc_1	-0.691***	-5.549***	-4.479***	-4.415***	-0.717**	-5.650***	-4.560***	-4.412***
	(0.293)	(1.056)	(1.136)	(1.258)	(0.294)	(1.060)	(1.124)	(1.253)
Health rate	0.063	-0.022	0.494**	0.569**	0.112	-0.029	0.557**	0.609***
	(0.142)	(0.161)	(0.236)	(0.225)	(0.148)	(0.174)	(0.249)	(0.225)
LnHealth_1	1.159	3.168**	4.094**	2.333	2.297**	3.976**	4.865**	2.079
	(0.854)	(1.544)	(1.658)	(1.720)	(1.070)	(1.771)	(1.990)	(1.963)
LnTrade	0.681**	0.969	1.482***	1.346***	0.709**	0.963	1.455***	1.337***
	(0.296)	(0.599)	(0.477)	(0.514)	(0.290)	(0.597)	(0.478)	(0.516)
LnEdu	3.112***	-0.039	-1.805	3.995	3.142***	0.236	-0.535	5.055*
(PWT)	(0.892)	(2.991)	(2.919)	(2.893)	(0.876)	(2.812)	(2.896)	(2.959)
PopGr	0.044	0.415	0.427	0.499	0.004	0.419***	0.400	0.489
	(0.581)	(0.842)	(0.893)	(0.940)	(0.587)	(0.828)	(0.849)	(0.891)
LnInv	0.980**	1.243**	1.651***	1.538***	0.899**	1.236**	1.623***	1.454***
	(0.426)	(0.504)	(0.545)	(0.512)	(0.420)	(0.499)	(0.529)	(0.491)
FDI	0.063	-0.002	-0.006	0.031	0.064	-0.004	-0.003	0.032
	(0.042)	(0.042)	(0.037)	(0.039)	(0.042)	(0.042)	(0.037)	(0.039)
LnCre	-0.322	-0.529	-1.189***	-1.451***	-0.419	-0.534	-1.065***	-1.346***
	(0.261)	(0.401)	(0.412)	(0.464)	(0.260)	(0.405)	(0.403)	(0.448)
Polity2	0.057**	-0.003	0.034	0.051	0.056**	0.001	0.034	0.049
	(0.024)	(0.053)	(0.053)	(0.051)	(0.024)	(0.053)	(0.053)	(0.051)
INF	-0.017***	-0.021***	-0.018***	-0.023***	-0.018***	-0.020***	-0.017***	-0.024***
	(0.005)	(0.006)	(0.005)	(0.004)	(0.005)	(0.006)	(0.005)	(0.004)
Mobile	-0.010***	0.008	0.007	-0.004	-0.011***	0.008	0.007	-0.007
	(0.003)	(0.011)	(0.010)	(0.006)	(0.004)	(0.011)	(0.011)	(0.007)
Constant	0.389***	38.58***	26.12**		1.367***	39.32***	26.09**	
	(3.199)	(8.686)	(10.55)		(3.218)	(8.563)	(10.27)	
Year/country fixed effects	No	Yes	Yes	NA	No	Yes	Yes	NA
Countries	36	36	36	36	36	36	36	36
Observations	1,299	1,299	1,246	1,246	1,299	1,299	1,246	1,246
Wald F test		4.740***	358.9***			4.580**	348.8***	
F	6.180***	6.230***	6.220***	8.870***	6.670***	6.170***	6.110***	9.090***
R-squared	0.052	0.237	0.200	0.10	0.060	0.238	0.205	0.10
HJS			0.716	0.099			0.760	0.120
K-P LM			89.36***	91.55***			106.3***	104.6***
C-D F			341.7***	369.1***			378.6***	413.3***
A-R Chi2			15.69***	18.38***			15.98***	19.13***
First stage regression								
F_Health rate			61.10***	77.53***			90.61***	118.9***
F_Trade			247.3***	240.7***			253.0***	239.3***

Notes: NA: Not allowed. HJS, K-P, C-D, and A-R indicate Hansen J statistic, Kleibergen-Paap, Cragg-Donald, and Anderson-Rubin, respectively. 1-year lagged values of trade of the rest of the world land area and 2-year lagged values of adult survival growth rate of male in Columns (3) and (4) are valid instruments. 1-year lagged values of trade of the rest of the world land area and 2-year lagged values of adult survival growth rate of female in Columns (3)' and (4)' are valid instruments.
*p<0.1; **p<0.05; ***p<0.01. Robust standard errors in parentheses.

The findings show that an increase in the growth rate of adult survival results in an increase in economic growth. Interestingly, here, the findings show that the coefficient associated with adult survival of females (0.609) is larger than that associated with adult survival of male

(0.569). This is in line with the t-test. Also, in terms of magnitude, the effects of adult survivals of females (0.609) and males (0.569) are larger than those of life expectancies of females (0.451) and males (0.441), respectively. Besides, adult survival at this level does not affect on economic growth. Furthermore, trade significantly enhances growth in almost all regressions.

3.3 Disaggregate analysis by income level

This section is devoted to the disaggregated analysis by income level following the recent World Bank classification (Table A1). Table 4 reports the effect of the growth rate of life expectancy on economic growth. Here also, the findings show significant effects of the lagged values of the real GDP per capita on economic growth (in all regressions) at the 5% level. This confirms the choice of the dynamic specification framework. In particular, for the validity of the instruments used, the main findings reported in Columns (3-4) and (3-4)' rely on diagnostic tests to test the relevance of instruments used via significant F statistics and insignificant HJS tests. Kleibergen-Paap LM, Cragg-Donald Wald F and Anderson-Rubin Wald tests also support the relevance of instruments used at the 5% level. Unlike the aggregate analysis in Table A6, Table 4 shows that an increase in both growth rate and level of life expectancy does not affect economic growth in low-income countries, while these variables significantly enhance economic growth in lower-middle-income countries within Africa (these findings are robust to the estimation techniques and controlling for country- and year-FE).

This difference can be explained by a high level of life expectancy observed in lower-middle-income countries in comparison with low-income countries. Indeed, on average, the level of life expectancy in lower-middle-income countries is about 58.3 years against 51.9 years in low-income countries. From the theoretical perspective, countries experiencing high levels of life expectancy are likely to stimulate savings, investments and innovation and therefore economic growth. These findings contrast those reported by Bane (2018) concerning the effect of life expectancy in level on growth. Some possible explanations include the measure of economic growth (Bane, 2018, uses growth of GDP rather than growth rate of GDP per capita), the specification framework used, and perhaps the exclusion of upper-middle-income countries from the middle-income countries. Besides, trade remains a main driver of growth in both samples.

Table 4 Effects of life expectancy growth rate on GDP per capita growth by income level

	Low-income countries				Lower-middle-income countries			
	OLS	LSDV	2SLS	2SLS+FE	OLS	LSDV	2SLS	2SLS+FE
	(1)	(2)	(3)	(4)	(1)’	(2)’	(3)’	(4)’
LnGDPpc_1	-2.011***	-8.292***	-7.978***	-7.829***	-1.903***	-4.849***	-3.717**	-3.879**
	(0.719)	(2.002)	(1.993)	(1.99)	(0.484)	(1.613)	(1.544)	(1.637)
Health rate	0.195	0.067	0.165	0.209	0.828***	0.692***	0.683***	0.835***
	(0.434)	(0.435)	(0.251)	(0.255)	(0.173)	(0.219)	(0.210)	(0.184)
LnHealth_1	2.573	7.264	7.495	5.597	4.916**	14.59***	11.50***	12.37***
	(3.793)	(7.088)	(9.489)	(9.045)	(2.129)	(4.830)	(4.274)	(4.563)
LnTrade	-0.158	0.393	0.995*	1.339**	1.431***	2.951***	3.702***	4.502***
	(0.511)	(0.791)	(0.552)	(0.595)	(0.504)	(0.785)	(0.870)	(0.898)
LnEdu	0.550	10.30	7.339	6.289	1.525	-5.692	-5.549	-2.224
(PWT)	(1.326)	(6.956)	(6.065)	(5.098)	(1.145)	(4.533)	(4.439)	(3.723)
PopGr	0.564	0.345	0.275	0.558	-0.876***	-0.618	-0.134	-0.874*
	(0.956)	(0.952)	(0.687)	(0.816)	(0.294)	(0.628)	(0.576)	(0.520)
LnInv	2.211***	2.549***	2.674***	2.391***	0.028	-0.361	-0.087	-0.322
	(0.752)	(0.862)	(0.833)	(0.734)	(0.578)	(0.835)	(0.783)	(0.844)
FDI	0.103**	0.095	0.067	0.049	0.021	-0.043	-0.039	-0.004
	(0.043)	(0.065)	(0.060)	(0.052)	(0.078)	(0.082)	(0.067)	(0.068)
LnCre	-1.711***	-0.799	-1.184*	-1.607**	-0.591*	-0.495	-1.142**	-1.393***
	(0.608)	(0.859)	(0.767)	(0.789)	(0.338)	(0.494)	(0.467)	(0.506)
Polity2	0.005	0.050	0.052	0.018	-0.029	-0.051	-0.019	-0.001
	(0.048)	(0.081)	(0.077)	(0.091)	(0.034)	(0.059)	(0.057)	(0.057)
INF	-0.019	-0.021*	-0.020*	-0.027**	-0.023***	-0.023***	-0.021***	-0.027***
	(0.012)	(0.013)	(0.012)	(0.013)	(0.004)	(0.006)	(0.004)	(0.003)
Mobile	-0.001	0.015	0.016	-0.013	-0.005	0.009	0.005	0.005
	(0.010)	(0.022)	(0.017)	(0.015)	(0.005)	(0.016)	(0.015)	(0.008)
Constant	-0.335	17.14	10.80		-7.889	-26.73	-30.44	
	(14.43)	(26.72)	(35.54)		(8.912)	(19.69)	(18.53)	
Year/country fixed effects	No	Yes	Yes	NA	No	Yes	Yes	NA
Countries	13	13	13	13	18	18	18	18
Observations	494	494	474	474	616	616	591	591
Wald F test		2.720***	146.5***			2.800***	178.2***	
F	3.140***	3.050***	3.300***	4.860***	6.870***	4.340***	4.560***	9.580***
R-squared	0.081	0.243	0.238	0.120	0.139	0.312	0.335	0.179
HJS			1.191	0.235			0.1705	0.382
K-P LM			27.66***	17.91***			65.86***	74.39***
C-D F			233.4***	284.7***			330.5***	339.5***
A-R Chi2			8.240**	7.860**			23.96***	42.02***
First stage regression								
F_Health rate			29.27***	30.45***			540.7***	873.9***
F_Trade			454.3***	290.1***			181.2***	176.5***

Notes: NA: Not allowed. HJS, K-P, C-D, and A-R indicate Hansen J statistic, Kleibergen-Paap, Cragg-Donald, and Anderson-Rubin, respectively. Exchange rate and 2-year lagged values of life expectancy growth rate and land area are valid instruments in Column (3) while 1-year lagged values of trade and 2-year lagged values of life expectancy growth rate and land area in Column (4) are valid instruments. Terms of trade and 1- and 2-year lagged values of trade and life expectancy growth rate, respectively, are valid instruments in Columns (3)’ and (4)’.
*p<0.1; **p<0.05; ***p<0.01. Robust standard errors in parentheses.

Alternatively, Table 5 reports the effect of the growth rate of adult survival on economic growth. These findings are in line with those reported in Table 4. However, unlike the aggregate analysis in Table A6, Table 5 shows that an increase in both growth rates and levels of adult survival does not affect economic growth in low-income countries (main findings reported in Column (3) and mainly in Column (4)). These findings are robust to controlling for country- and year-FE.

Table 5 Effects of adult survival growth rate on GDP per capita growth by income level

	Low-income countries				Lower-middle-income countries			
	OLS	LSDV	2SLS	2SLS+FE	OLS	LSDV	2SLS	2SLS+FE
	(1)	(2)	(3)	(4)	(1)’	(2)’	(3)’	(4)’
LnGDPpc_1	-1.689**	-8.445***	-8.278***	-7.913***	-2.145***	-5.537***	-3.165**	-3.272**
	(0.787)	(2.088)	(2.267)	(2.349)	(0.471)	(1.550)	(1.502)	(1.586)
Health rate	-0.037	-0.155	-0.924	-0.811	0.274**	0.123	0.298***	0.359***
	(0.389)	(0.409)	(1.249)	(1.317)	(0.119)	(0.137)	(0.102)	(0.091)
LnHealth_1	-1.135	-5.701	-1.116	-1.5439	4.455***	9.819***	4.888***	4.600**
	(2.175)	(4.641)	(5.948)	(5.970)	(1.591)	(2.895)	(1.904)	(2.077)
LnTrade	-0.254	0.538	1.725**	1.483**	1.549***	2.872***	3.921***	4.108***
	(0.538)	(0.739)	(0.703)	(0.634)	(0.505)	(0.773)	(1.157)	(1.166)
LnEdu	1.199	9.855	13.57	17.319	2.104**	-4.936	-6.063	-0.904
	(1.557)	(8.252)	(12.89)	(14.15)	(1.024)	(4.260)	(4.566)	(3.827)
PopGr	0.809	0.486	0.651	0.999	-1.018***	-0.797	-0.179	-0.808
	(0.888)	(0.919)	(0.983)	(1.145)	(0.266)	(0.594)	(0.590)	(0.547)
LnInv	2.230***	2.610***	2.605***	2.051***	-0.169	-0.503	-0.057	-0.062
	(0.729)	(0.881)	(0.899)	(0.746)	(0.586)	(0.824)	(0.786)	(0.853)
FDI	0.111**	0.096	0.077	0.089	0.022	-0.040	-0.033	0.011
	(0.047)	(0.065)	(0.060)	(0.060)	(0.078)	(0.081)	(0.067)	(0.068)
LnCre	-1.401**	-0.663	0.162	-0.229	-0.593*	-0.393	-1.167**	-1.346***
	(0.619)	(0.842)	(1.391)	(1.547)	(0.328)	(0.472)	(0.495)	(0.517)
Polity2	0.021	0.037	-0.024	-0.001	-0.041	-0.057	-0.012	-0.007
	(0.048)	(0.078)	(0.109)	(0.096)	(0.034)	(0.057)	(0.058)	(0.058)
INF	-0.021	-0.023*	-0.019	-0.027*	-0.024***	-0.025***	-0.022***	-0.027***
	(0.014)	(0.013)	(0.013)	(0.015)	(0.004)	(0.006)	(0.004)	(0.003)
Mobile	0.002	0.014	0.005	-0.027	-0.003	-0.001	0.004	0.004
	(0.009)	(0.024)	(0.029)	(0.028)	(0.005)	(0.015)	(0.015)	(0.008)
Constant	6.136	46.94***	37.66***		15.94***	42.89***	-7.643	
	(5.742)	(11.92)	(14.27)		(4.382)	(13.72)	(13.76)	
Year/country fixed effects	No	Yes	Yes	NA	No	Yes	Yes	NA
Countries	13	13	13	13	18	18	18	18
Observations	494	494	484	484	616	616	591	591
Wald F test		2.670***	124.6***			2.720***	164.3***	
F	3.150***	2.970***	2.510***	3.860***	6.580***	4.360***	4.22***	8.050***
R-squared	0.077	0.244	0.192	0.101	0.130	0.314	0.323	0.163
HJS			0.911	0.198			0.096	0.775
K-P LM			10.12***	8.120**			102.9***	112.6***
C-D F			79.22***	86.50***			145.6***	132.0***
A-R Chi2			8.280***	8.180***			15.69***	25.98***
First stage regression								
F_Health rate			9.860***	9.680***			83.69***	113.7***
F_Trade			513.9***	449.8***			77.27***	98.60***

Notes: NA: Not allowed. HJS, K-P, C-D, and A-R indicate Hansen J statistic, Kleibergen-Paap, Cragg-Donald, and Anderson-Rubin, respectively. 1-year lagged values of adult survival growth rate and trade of the rest of world and 2-year lagged values of land area are valid instruments in Columns (3) and (4) while terms of trade and 1- and 2-year lagged values of trade of the rest of world and adult survival growth rate, respectively, are valid instruments in Column (3)’ and (4)’.
*p<0.1; **p<0.05; ***p<0.01. Robust standard errors in parentheses.

Also, unlike the previous findings reported in Table A6, an increase in both growth rates and level of adult survival is associated with an increase in economic growth in lower-middle-income countries in all regressions. Indeed, on average, the proportion of 15-year-olds who survive till 60 years of age in lower-middle-income countries (71%) is greater than that in low-income countries (65%). An increase in adult survival rate leads to an increase in the number of individuals of waking age, the motivation for people to invest in their education or that of their children, stock of knowledge, innovation activity, productivity, and then growth. Table 5 shows that, independently of the sub-sample considered, an increase in trade leads to an increase in economic growth. In sum, this research concludes that health is a main engine of economic growth in lower-middle-income countries within Africa but health has no effect on growth in low-income countries.

Besides, considering the full sample, the research tries to assess whether the marginal effect of health growth rate on economic growth depends on the country's income level. As both health growth rate and GDP per capita have independent effects on growth (see Table 1 and A6), the literature (Acemoglu et al., 2003) assumes that only part of the effect of health growth rate may be mediated via GDP per capita. The main findings reported in Table A8 show that the marginal effect of health growth rate on growth depends on the country's income level. This indicates that part of the effect of health growth rate is mediated via GDP per capita suggesting the presence of a complementarity link between health and income.

3.4 Effect of the interaction between health and trade on economic growth

This section investigates the complementarity (or substitutability) relationship between health and trade by analyzing the combined effect of these two variables on economic growth. Thus, the study introduces an interaction term between these two variables. These variables are commonly known as constitutive terms. A positive effect implies a complementarity link while a negative effect means a substitutability relationship. Health and trade are two components of the interaction terms. The coefficients associated with these components must be interpreted as conditional, but not unconditional or average, effects. Except for the Columns (1) and (1)', the findings reported in Table 6 are obtained by controlling for country- and year-FE. The findings, based on traditional techniques, show that the coefficients associated with health growth rate proxies are insignificant while those associated with trade are positive and significant, except the findings reported in Column (4)'. Table 6 shows an insignificant effect of the coefficients associated with the interaction terms when these traditional techniques are applied.

However, the findings based on traditional techniques suffer from the endogeneity issues. Relying on diagnostic tests to test the relevance of instruments used via significant F statistics and insignificant HJS tests, the IV approach is applied in Columns (3-4) and (3-4)'. Additionally, at the 5% level, Kleibergen-Paap LM, Cragg-Donald Wald F and Anderson-Rubin Wald tests further support the validity of the instruments. Except for the significant negative effect of the growth rate of adult survival on economic growth in Column (4)', the coefficients associated with the growth rates of life expectancy and adult survival are negative and insignificant (Bloom et al., 2014 also show that the sign changes when moving the OLS to 2SLS regression). However, as the effect of health on growth depends on the level of trade openness, it is not correct to say that an increase in health should result in a decrease in economic growth. Indeed, the marginal effect (ME) of health when trade (*LnTrade*) is zero on economic growth is not independent of trade, meaning that it is connected with a specific value of trade. This interpretation is correct for a conditioning variable with a natural zero. Indeed, after applying *Ln* on trade, the minimum and maximum values of trade are roughly -0.243 and 5.416, respectively. Considering the findings reported in Columns (4) and (4)' as main findings, this means that the ME of the growth rate of life expectancy (growth rate of adult survival, respectively) on economic growth is -1.305 (-2.825, respectively) when trade is zero.

Concerning the interaction term, except for the results reported in Column (4'), the main findings in Columns (3-4) and (3-4)' show the positive and significant effects of the interaction terms on economic growth. The positive effect of the interaction between health and trade reveals the existence of a complementary relationship between health and trade. Therefore, the ME of health on economic growth increases as the level of trade increases. These findings have some theoretical explanations. Indeed, trade stimulates the effect of health on growth via diverse channels such as generated income, increased trade in medical supplies and drugs, especially vaccines in developing States, food security, access to knowledge useful for improving health outcomes (Giuntella et al., 2020; Owen and Wu, 2007; Levine and Rothman, 2006; Antweiler et al., 2001).

The above paragraph focuses only on the sign and significance of constitutive terms and their interactions. We go beyond the traditional findings to interpret the ME of health on economic growth. In fact, for illustration purposes, the effective ME of the growth rate of life expectancy (*LifGr*) on economic growth (*GDPpcGr*) is given by the Equation (7):

$$\partial GDPpcGr_{it} / \partial LifGr_{it} = -1.305 + 0.447 \cdot LnTrade_{it} \quad (7)$$

Alternatively, the effective ME of the growth rate of adult survival rate (A*SurvGr*) on economic growth (*GDPpcGr*) is given by the Equation (8):

$$\partial GDPpcGr_{it} / \partial ASurvGr_{it} = -2.825 + 0.717 \cdot LnTrade_{it} \quad (8)$$

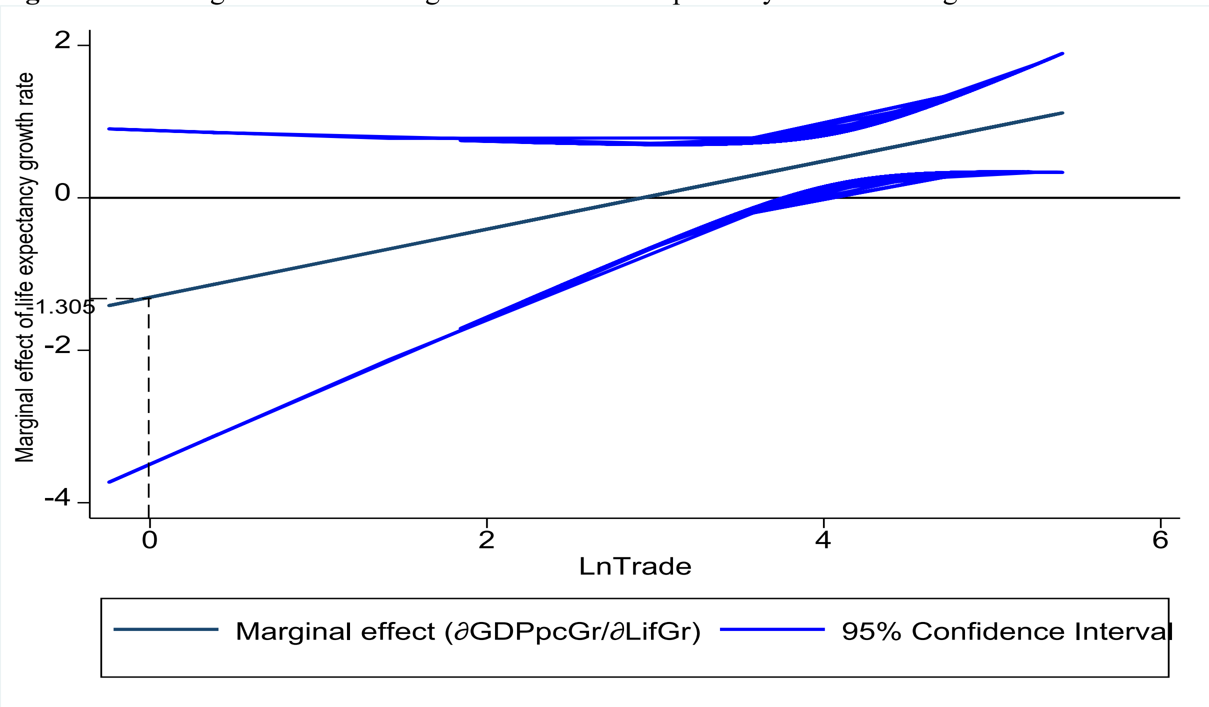
Table 6 Effects of the interaction between health and trade on GDP per capita growth

	Health: Life expectancy growth rate				Health: Adult survival growth rate			
	OLS	LSDV	2SLS	2SLS+FE	OLS	LSDV	2SLS	2SLS+FE
	(1)	(2)	(3)	(4)	(1)'	(2)'	(3)'	(4)'
LnGDPpc_1	-0.726***	-5.488***	-4.978***	-4.926***	-0.704**	-5.636***	-4.991***	-5.086***
	(0.266)	(0.966)	(0.989)	(1.088)	(0.293)	(1.068)	(1.069)	(1.193)
Health rate	0.679	0.626	-1.569	-1.305	0.482	0.346	-1.882	-2.825**
	(0.958)	(0.980)	(1.149)	(1.089)	(0.712)	(0.819)	(1.313)	(3.391)
LnHealth_1	4.430**	4.607	4.844	3.204	1.696*	3.628**	3.277*	0.570
	(2.097)	(3.007)	(3.621)	(3.175)	(0.969)	(1.666)	(1.784)	(2.205)
LnTrade	0.748***	0.967	1.619***	1.977***	0.706**	0.978*	1.012*	2.119***
	(0.269)	(0.593)	(0.538)	(0.519)	(0.291)	(0.597)	(0.561)	(0.562)
Interaction	-0.082	-0.126	0.486*	0.447*	-0.097	-0.092	0.485*	0.717
	(0.256)	(0.246)	(0.278)	(0.264)	(0.168)	(0.185)	(0.282)	(0.771)
LnEdu	2.281***	0.213	-0.132	5.173*	3.097***	-0.129	0.989	7.631
(PWT)	(0.812)	(2.645)	(2.793)	(3.159)	(0.879)	(2.949)	(3.348)	(5.439)
PopGr	-0.151	0.290	0.426	0.412	0.015	0.393**	0.577	0.679
	(0.604)	(0.847)	(0.813)	(0.854)	(0.584)	(0.836)	(0.876)	(1.046)
LnInv	0.861*	1.249**	1.446***	1.293***	0.939**	1.226**	1.552***	1.335
	(0.449)	(0.503)	(0.478)	(0.467)	(0.424)	(0.503)	(0.489)	(0.495)
FDI	0.052	0.001	-0.019	0.015	0.064	-0.002	-0.006	0.025
	(0.041)	(0.043)	(0.039)	(0.039)	(0.042)	(0.042)	(0.037)	(0.041)
LnCre	-0.580**	-0.599	-1.045**	-1.313**	-0.367	-0.545	-0.867**	-0.924**
	(0.241)	(0.393)	(0.382)	(0.412)	(0.261)	(0.394)	(0.395)	(0.424)
Polity2	0.053**	0.007	0.018	0.031	0.056**	-0.001	0.018	0.021
	(0.024)	(0.054)	(0.059)	(0.052)	(0.024)	(0.053)	(0.059)	(0.054)
INF	-0.017***	-0.019***	-0.017***	-0.024***	-0.017***	-0.020***	-0.018***	-0.024***
	(0.005)	(0.006)	(0.005)	(0.004)	(0.005)	(0.006)	(0.005)	(0.004)
Mobile	-0.013***	0.011	0.007	-0.003	-0.011	0.009	0.001	0.005
	(0.004)	(0.011)	(0.010)	(0.006)	(0.004)	(0.011)	(0.011)	(0.008)
Constant	-16.134*	18.60	7.949		0.856	39.46***	29.93***	
	(9.525)	(15.16)	(18.53)		(3.219)	(8.790)	(9.083)	
Year/country fixed effects	No	Yes	Yes	NA	No	Yes	Yes	NA
Countries	36	36	36	36	36	36	36	36
Observations	1,299	1,299	1,246	1,246	1,299	1,299	1,246	1,273
Wald F test		4.440***	336.8***			4.670***	342.3***	
F	7.250***	6.220***	6.000***	9.600***	6.010***	6.170***	5.900***	8.730***
R-squared	0.067	0.237	0.234	0.101	0.054	0.238	0.228	0.052
HJS			0.390	0.679			3.585	0.925
K-P LM			227.9***	224.4***			26.54***	21.31***
C-D F			597.1***	602.6***			48.43***	212.3***
A-R Chi2			16.67***	255.1***			14.18***	21.98***
First stage regression								
F_Health rate			1057***	1700***			178.4***	137.97***
F_Trade			328.9***	306.0***			116.0***	213.5***
F_Intearction			1442***	2072***			155.3***	125.1***

Notes: NA: Not allowed. HJS, K-P, C-D, and A-R indicate Hansen J statistic, Kleibergen-Paap, Cragg-Donald, and Anderson-Rubin, respectively. 1-year lagged values of life expectancy growth rate, its interaction with the English language, trade and trade of the rest of world in Columns (3) and (4) are valid instruments; 1-year lagged values of trade of the rest of world and adult survival growth rate and its interaction with land area and 2-year lagged values of trade and its interaction with adult survival growth rate in Column (3)' while 1-year lagged values of trade and adult survival growth rate and their interaction term and the interaction between latitude and trade in Column (4)' are valid instruments. *p<0.1; **p<0.05; ***p<0.01. Robust standard errors in parentheses.

The question is: what is the effective ME of health on economic growth when *LnTrade* is different from zero? As the conditioning variable (trade) is continuous, we need a simple figure to answer this question. Figures 1-2 (associated with Table 7) provide the MEs of the growth rates of life expectancy and adult survival on economic growth, respectively. The oblique straight line indicates how the ME of health on economic growth changes with the level of trade. For a given point on this line, the ME of health is *∂GDPpcGr/∂(LifGr or ASurvGr) = θ +φ.LnTrade*. 95% confidence intervals (blue lines) around this line determine the conditions under which the effect of health growth rate on economic growth is statistically significant. In line with Mamba (2021), the following standard rule is applied: health significantly influences economic growth if the upper and lower bounds of the confidence interval are above or below the zero line. Referring to Figure 1, (also Table 7), the research seeks to show the non-linear effect of life expectancy growth rate on economic growth exploring the above standard rule. However, Figure 1 shows that the negative effect is always non-statistically significant. Indeed, from *LnTrade* equals *-0.243* (roughly, *Trade* is equal to 0.785% of GDP, the minimum value of trade) to 3.657 (trade equals 38.745% of GDP), the ME of life expectancy growth rate is insignificant. However, between these values [0.785 and 38.745], the ME changes the sign passing from the negative to the positive direction after *LnTrade* equals 2.889 (roughly, Trade is equal to 18.156% of GDP). After, the value of trade equals 38.745% of GDP, the ME of life expectancy becomes positive and significant as shown in Figure 1. It implies that the ME of life expectancy at birth increases with the level of trade above a certain threshold, above the level of trade equals 38.745 % of GDP, this ME becomes positive and statistically significant.

Figure 1 The marginal effect of the growth rate of life expectancy on economic growth



Source: Authors' computation using the findings from Column (4)

Another issue in analyzing the effective ME when exploring the interaction model is the identification of its significance degree. Indeed, Table 7 specifies at which threshold of trade the ME is significant. According to this Table, the ME of life expectancy on economic growth is significant at the 10%, 5% and 1% levels. Also, the ME of adult survival growth rate on economic growth is significant at the 10%, 5% and 1% levels. In sum, Table 7 provides evidence that the sign and the degree of significance depend on the level of trade.

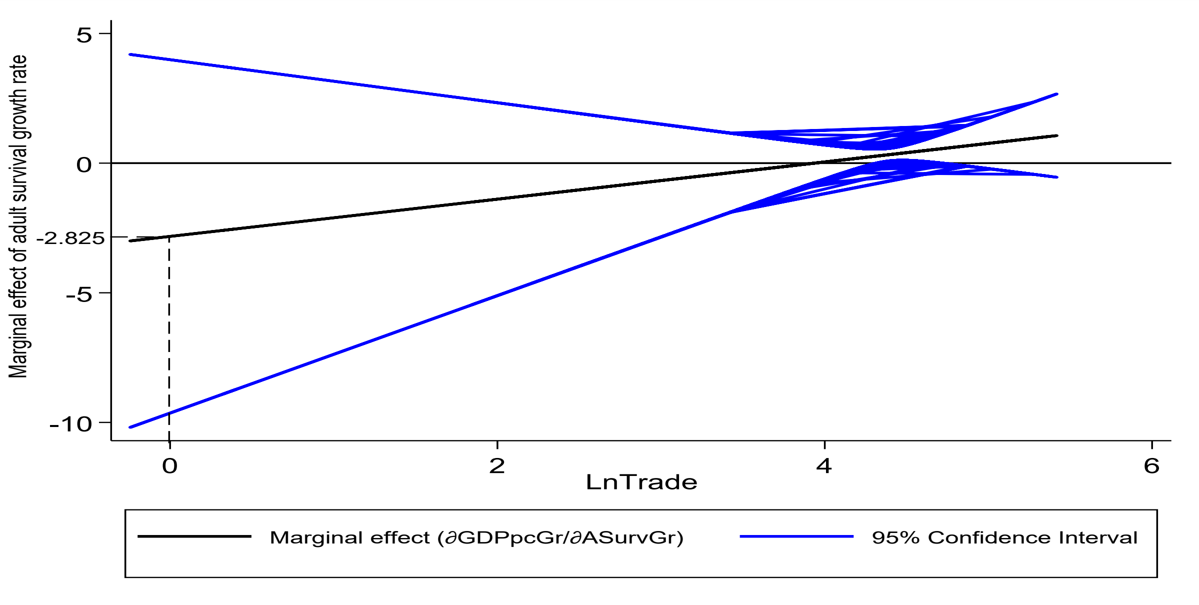
Table 7 Hypothesis tests whether health affects economic growth

Marginal effect of life expectancy at birth growth rate on economic growth			Marginal effect of adult survival growth rate on economic growth		
LnTrade (1)	Dydx (2)	S.E.(dydx) (3)	LnTrade (1)’	Dydx (2)’	S.E.(dydx) (3)’
-0.243	-1.413	1.153	-0.243	-2.999	3.578
0.198	-2.683	3.238	0.198	-2.683	3.238
1.418	-1.502	1.969	1.418	-1.808	2.298
2.212	-0.317	0.521	2.212	-1.238	1.1686
2.899	-0.009	0.353	3.031	-0.650	1.057
3.657	0.329	0.200	4.276	0.243	0.149
3.660	0.329*	0.199	4.279	0.245*	0.148
3.749	0.369**	0.187	4.318	0.273**	0.133
3.913	0.443***	0.171	4.399	0.332***	0.119
4.000	0.482***	0.187	4.503	0.405***	0.147
4.200	0.571***	0.168	4.730	0.569**	0.287
4.601	0.750***	0.214	4.915	0.701*	0.421
5.001	0.929***	0.293	5.001	0.763	0.485
5.416	1.114***	0.388	5.416	1.061	0.799

Source: Authors’ computation using the findings from the Columns (4) and (4)’. *p<0.1; **p<0.05; ***p<0.01

A similar reasoning is applied to the Figure 2. Like Figure 1, Figure 2 (and Table 7) shows the non-linear relationship between adult survival growth rate and economic growth. However, the negative effect is always non-statistically significant. Indeed, from *LnTrade* equals *-0.243* (roughly, *Trade* is equal to 0.785% of GDP, the minimum value of trade) to 4.276 (trade equals 71.952% of GDP), the ME of adult survival growth rate is insignificant. However, between these values [0.785 and 71.952] this ME changes the sign passing from the negative to the positive direction after *LnTrade* equals 3.031 (roughly, Trade is equal to 20.718% of GDP). Between, the values of trade]71.952, 136.319] for *LnTrade* equals 4.276 and 4.915, respectively, the ME of adult survival growth rate becomes positive and significant. After the value of trade equals 136.319% of GDP, the ME of adult survival growth rate becomes insignificant and positive as shown in Figure 1 and Table 7. Here, the effect of adult survival growth rate increases with the level of trade above and below certain thresholds; between the interval]71.952, 136.319], the ME of adult survival growth rate is positive and statistically significant.

Figure 2 The marginal effect of the growth rate of adult survival on economic growth



Source: Authors' computation using the findings from Column (4)'

4 Conclusion and policy implications

The paper analyzes the effect of health human capital on economic growth in Africa using annual data over the period 1980-2021. The paper uses two alternative measures of health, including levels and growth rates of life expectancy and adult survival. The relevance of this question is underlined in current debates on the costs and benefits of new health programs. Obviously, public support for more universal health coverage is influenced by whether or not the population believe that health improvement stimulates economic growth. The research also seeks to explore conditions under which the effect of health can be effective. Indeed, unlike several previous works, health is analyzed in terms of gender (female health and male health, separately). Also, African countries are divided into two sub-groups: low-income countries and lower-middle-income countries following the recent World Bank classification. Finally, the paper explores the complementarity/substitutability relationship between health and trade through the interaction model.

The instrumental variables (IV) approach with fixed effects (IV-FE) is used to control for the endogeneity issue of health (and trade) in unbalanced models. The findings are compared to those of traditional techniques such as the ordinary least squares (OLS) and OLS-FE methods. The main findings reveal that health affects economic growth in Africa but only in lower-middle-income countries. In particular, for the positive effect of life expectancy growth rate on economic growth, Algeria, Cameroon, Kenya, Nigeria and South Africa are some main economies driving this result, and for the positive adult survival growth rate on economic growth, some main economies driving this result are Algeria, Cameroon, Kenya. Besides, in almost all regressions, trade openness is seen as a main engine of economic growth in Africa, especially in Algeria, Cameroon, and South Africa. Additionally, both women's and men's health enhances economic growth in Africa suggesting that female health should not be neglected. Furthermore, adult survival is more relevant for growth than life expectancy because the former captures the health of the working-age population. The findings also show that the effect of health increases with the level of trade above a certain threshold. Indeed, the marginal effect of life expectancy at birth increases with the level of trade above a certain threshold; above the level of trade equals 38.745 % of GDP this marginal effect becomes positive and statistically significant. Also, the marginal effect of adult survival growth rate increases with the level of trade above and below certain thresholds; between the interval 71.952 and 136.319, the marginal effect of adult survival growth rate is positive and statistically significant.

These findings have crucial policy implications in relation to public health programs that facilitate access to medical care. Thus, our findings suggest that the evidence that improvements in health (in terms of life expectancy and adult survival rates) enhance economic growth is encouraging. This is in line with the oriented debate concerning the benefits resulting from health reform in developing countries such as those from the African region. Importantly, public support for more universal health coverage must be oriented not only towards improvements in life expectancy and adult survival rates of male but also improvements in health of female. Furthermore, African countries need to promote their development by moving from low-income countries to lower-middle income to improve health and then economic growth. Finally, there is a need to better align health and trade policies to avoid a substitutability interrelationship between these two policies and obtain the positive effective marginal effect of health on economic growth.

Future research can focus on the interaction effect of trade (policy) and health and nutrition outcomes such as undernourishment and obesity which are associated with non-communicable diseases (NCDs) such as diabetes, and cardiovascular diseases. Alternatively, future research can investigate the effect of trade on health and nutrition outcomes.

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Appendices

Box 1 Some preliminary tests

This section focuses on some preliminary tests such as correlation and multicollinearity test and unit root test. Correlation and multicollinearity tests are displayed in Table A4. The correlation tests show a strong correlation between some observed variables since the literature suggests that there is a problem of correlation when the coefficient of correlation between two variables is greater than the critical value of 0.5. Indeed, the correlation between the lagged values of life expectancy and GDP per capita is roughly 0.56 which is greater than 0.50. Also, the coefficient of correlation between domestic credit and the lagged value of GDP per capita is about 0.52 and the coefficient of correlation between domestic credit or education and the lagged value of life expectancy is about 0.55. The high coefficient of correlation, 0.69, is observed between the lagged value of GDP per capita and education.
To overcome this issue, the multicollinearity test through the mean Variance Inflation Factor (VIF) analysis is implemented (Table A4). The value of the mean VIF is about 1.71 (and 1.68 for a growth model with adult survival as an explanatory variable of interest) and below the critical value of 5 suggesting that there is no problem with correlation and multicollinearity. Besides, Table A4 shows that there is no problem with multicollinearity by considering country- and year-FE. Therefore, unlike previous studies that follow our specification, all observed variables could be introduced in the equation without the risk of multicollinearity (Ali and Mamba, 2025; Mamba and Balaki, 2023; Mamba and Ali, 2022; Mamba and Balaki, 2022; Mamba, 2021). Another important diagnostic test is the unit root test. From this perspective, the unit root test of Maddala and Wu (1999) is often applied. One advantage of this test is its application for both balanced and unbalanced panel data. The findings reported in Table A5 show that all variables are stationary at the level.

Table A1 Sample and sub-groups in Africa

	Low-income countries	**Lower-Middle income countries**	**Upper-Middle income countries**
1	Burkina-Faso	Algeria	Botswana
2	Burundi	Benin	Gabon
3	Central African Republic	Cabo Verde	Mauritius
4	Gambia	Cameroon	Namibia
5	Madagascar	Congo	South Africa
6	Mali	Côte d'Ivoire	
7	Mozambique	Egypt	
8	Niger	Eswatini (ex Swaziland)	
9	Rwanda	Ghana	
10	Sierra Leone	Kenya	
11	Sudan	Mauritania	
12	Togo	Morocco	
13	Uganda	Nigeria	
14		Senegal	
15		Tanzania	
16		Tunisia	
17		Zambia	
18		Zimbabwe	

Notes: Since 2015, the World Bank classification distinguishes four categories of countries instead of three groups. This classification is entered into force in 2017. Indeed, the traditional category middle-income countries is subdivided into two sub-groups including lower-middle- and upper-middle-income countries. Besides, the World Bank's classification explored is based on the year 2021. We note that this classification varies one year to another because income intervals vary due to some factors such as inflation. For example, in 2019 and 2021, Mauritius is considered as high- and upper-income country respectively. Finally, for the analysis by income level, Chad, Guinea, Guinea-Bissau and Malawi are exclude from low-income countries because data on some variables, especially on education, are unavailable. For the same reason, Comoros is excluded from the lower-middle income countries.

Table A2 Mean-comparison tests (t test)

Health			
variables	**Male (1)**	**Female (2)**	**Mean difference (1)-(2)**
Life expectancy rate growth rate	0.573	0.563	0.010(0.779)
Adult survival growth rate	0.807	0.759	0.047**(2.305)
Development (income) level			
Variables	**Other (1)**	**Low-income countries (2)**	**Mean difference (1)-(2)**
Real GDP per capita	2920.373	591.247	2329.126***(22.772)
Development (income) level			
Variables	**Other (1)**	**Lower-middle-income countries (2)**	**Mean difference (1)-(2)**
Real GDP per capita	2222.835	1758.644	464.190***(4.128)

Notes: *p<0.1; **p<0.05; ***p<0.01. t in parentheses.

Table A3 Variable definitions and summary statistics panel data over the period 1980-2021

Variables	Obs	Mean	SD	Min	Max	Source
Variables of interest						
GDP per capita growth, GDPpcGr (%°	1,466	0.911	5.041	-64.442	31.877	WDI
Life expectancy growth, LifGr	1,440	0.554	1.379	-14.013	13.097	WDI
LifGr for male, LifGr_Mal	1,440	0.557	1.419	-14.597	13.838	WDI
LifGr for female, LifGr_Fem	1,440	0.549	1.344	-13.419	12.334	WDI
Adult surviavl growth, SurvGr	1,440	0.771	3.258	-41.317	32.311	WDI
SurvGr for male, SurvGr_Mal	1,440	0.796	3.622	-45.962	37.317	WDI
SurvGr for female, SurvGr_Fem	1,440	0.748	3.012	-37.781	28.489	WDI
Control variables						
Trade, Trade, (% of GDP)	1485	63.184	29.599	0.785	188.65	WDI
Years of schooling and returns to education, Edu	1,476	0.011	0.007	-0.036	0.043	PWT
Population growth, PopGr (%)	1,476	0.025	0.009	-0.068	0.081	WDI
Investment, Inv (% of GDP)	1,400	21.494	9.969	-2.424	93.547	WDI
Foreign direct investment, nets inflows, Fdi (% of GDP)	1,452	2.292	4.039	-28.624	39.811	WDI
Polity2, scale: -10 and +10	1,502	-0.198	6.034	-9.000	10.000	Polity4
Domestic credit to private sector by banks, Cre (% of GDP)	1,419	20.312	17.405	0	106.26	WDI
Inflation, GDP deflator (INF)	1,486	12.094	27.656	-29.173	558.56	WDI
Mobile cellular subscriptions, Mobile (per 100 people)	1,468	28.914	42.725	0	165.59	WDI

Notes: PWT denotes Penn World Table

Table A4 Correlation matrix and multicollinearity test

	1	2	3	4	5	6	7	8	9	10	11	12
1	1.00											
2	-0.09	1.00										
3	0.56	-0.01	1.00									
4	0.38	-0.01	0.27	1.00								
5	0.69	-0.03	0.55	0.37	1.00							
6	-0.34	0.19	-0.10	-0.18	-0.35	1.00						
7	0.38	0.03	0.42	0.23	0.23	0.01	1.00					
8	0.02	0.10	0.15	0.25	0.11	0.02	0.26	1.00				
9	0.52	0.01	0.55	0.39	0.39	-0.32	0.18	0.04	1.00			
10	0.14	0.08	0.23	0.15	0.34	-0.09	0.02	0.14	0.19	1.00		
11	-0.07	-0.04	-0.11	-0.18	-0.02	0.03	-0.08.	-0.07	-0.27	-0.05	1.00	
12	0.38	0.15	0.49	0.16	0.57	-0.22	0.19	0.23	0.36	0.37	-0.08	1.00
VIF	2.68	1.12	2.20	1.43	2.89	1.39	1.39	1.23	1.99	1.24	1.12	1.88
MVIF = 1.71												
MVIF (with year and country fixed effects) = 4.68												

Notes: LnGDPpc_1=1; LifGr=2; LnLif_1=3; LnTrade=4; LnEdu=5; PopGr=6; LInv=7; Fdi=8; LnCre=9; Polity2=10; INF=11; MOB=12. VIF and MVIF denote Variance Inflation Factors and Mean VIF, respectively. When we consider adult survival as a proxy of health the average VIF is about 1.65 (4.54 when we include year- and country-fixed effects) which is inferior to that when we use life expectancy as a proxy of health. Besides, the simultaneous introduction of life expectancies of female and male in level leads to a MVIF=9.17 (and 13.58 when growth rate of life expectancies are added).

Table A5 Maddala and Wu unit root test

Variables	Chi2	Decision
GDPpcGr	963.79***	I(0)
LnGDPpc_1	161.86***	I(0)
LifGr	245.04***	I(0)
LnLif_1	435.61***	I(0)
SurvGr	269.66***	I(0)
LnSurv_1	453.09***	I(0)
LnTrade	268.83***	I(0)
EduGr	172.76***	I(0)
PopGr	209.21***	I(0)
Inv	303.02***	I(0)
Fdi	474.80***	I(0)
LnCre	188.26***	I(0)
Polity2	210.05***	I(0)
INF	1124.75***	I(0)
Mobile	143.40***	I(0)

Notes: ***p<0.01

Table A6 Extended growth models

	Health: Life expectancy growth rate				Health: Adult survival growth rate			
	OLS	LSDV	2SLS	2SLS+FE	OLS	LSDV	2SLS	2SLS+FE
	(1)	(2)	(3)	(4)	(1)'	(2)'	(3)'	(4)'
LnGDPpc_1	-0.721***	-5.445***	-4.926***	-4.853***	-0.703**	-5.604***	-4.511***	-4.339***
	(0.267)	(0.947)	(1.013)	(1.105)	(0.293)	(1.057)	(1.130)	(1.237)
Health rate	0.376	0.162	0.321**	0.448***	0.089	-0.025	0.537**	0.612***
	(0.271)	(0.308)	(0.147)	(0.163)	(0.149)	(0.173)	(0.247)	(0.231)
LnHealth_1	4.493**	4.797	5.083	3.316	1.712*	3.652**	4.586**	1.585
	(2.151)	(2.971)	(4.249)	(3.835)	(0.971)	(1.671)	(1.846)	(1.401)
LnTrade	0.722***	0.924	1.178**	1.002***	0.694**	0.966	1.467***	1.343***
	(0.279)	(0.617)	(0.462)	(0.443)	(0.293)	(0.598)	(0.477)	(0.516)
LnEdu	2.310	0.261	-0.252	4.321	3.143***	0.070	-1.199	3.906
	(0.820)	(2.655)	(2.764)	(2.652)	(0.883)	(2.896)	(2.900)	(2.968)
PopGr	-0.145	0.309	0.232	0.289	0.023	0.411	0.407	0.459
	(0.612)	(0.855)	(0.714)	(0.720)	(0.585)	(0.835)	(0.872)	(0.884)
LnInv	0.847*	1.254**	1.369***	1.387***	0.937**	1.238**	1.639***	1.463***
	(0.453)	(0.504)	(0.526)	(0.476)	(0.424)	(0.502)	(0.538)	(0.502)
FDI	0.051	-0.001	-0.008	0.039	0.063	-0.003	-0.005	0.029
	(0.040)	(0.042)	(0.042)	(0.041)	(0.042)	(0.042)	(0.037)	(0.039)
LnCre	-0.584**	-0.588	-1.101***	-1.254***	-0.367	-0.529	-1.127***	-1.419***
	(0.238)	(0.399)	(0.392)	(0.434)	(0.261)	(0.403)	(0.406)	(0.461)
Polity2	0.054**	0.006	0.029	0.044	0.056**	-0.001	0.034	0.050
	(0.024)	(0.055)	(0.052)	(0.052)	(0.024)	(0.053)	(0.053)	(0.051)
INF	-0.017***	-0.019***	-0.019***	-0.024***	-0.017***	-0.020***	-0.017***	-0.023***
	(0.005)	(0.006)	(0.005)	(0.004)	(0.005)	(0.006)	(0.005)	(0.004)
Mobile	-0.013***	0.010	0.009	-0.002	-0.011***	0.008	0.007	-0.006
	(0.004)	(0.011)	(0.011)	(0.006)	(0.004)	(0.011)	(0.010)	(0.007)
Constant	-16.29*	17.44	9.402		0.886	39.03***	39.03***	
	(9.685)	(14.72)	(21.92)		(3.208)	(8.612)	(8.612)	
Year/country fixed effects	No	Yes	Yes	NA	No	Yes	Yes	NA
Countries	36	36	36	36	36	36	36	36
Observations	1,299	1,299	1,230	1,246	1,299	1,299	1,246	1,246
Wald F test		4.450***	344.1***			4.660***	353.7***	
F	7.920***	6.260***	6.390***	9.74***	6.400***	-	6.180***	8.97***
R-squared	0.067	0.237	0.241	0.10	0.053	0.237	0.203	0.10
HJS			1.622	0.475			0.744	0.129
K-P LM			29.05***	176.4***			97.27***	99.80***
C-D F			359.3***	678.3***			372.8***	382.1***
A-R Chi2			14.36***	17.20***			15.95***	19.04***
First stage regression								
F_Health rate			124.9***	101.2***			74.83***	95.29***
F_Trade			400.5***	475.9***			250.1***	240.1***

Notes: NA: Not allowed. HJS, K-P, C-D, and A-R indicate Hansen J statistic, Kleibergen-Paap, Cragg-Donald, and Anderson-Rubin, respectively. Terms of trade and 2-year lagged values of life expectancy growth rate and land area are valid instruments in Column (3) while 2-year lagged values of life expectancy growth rate, trade of the rest of world and land area in Column (4) are valid instruments. 1-year lagged values of trade of the rest of world and land area and 2-year lagged values of adult survival growth rate are valid instruments in Columns (3)' and (4)'.

*p<0.1; **p<0.05; ***p<0.01. Robust standard errors in parentheses.

Table A7 Effects of health on economic growth in selected African countries

	Health: Life expectancy growth rate					Health: Adult survival growth rate				
	Algeria	Cameron	Kenya	Nigeria	South Africa	Algeria	Cameron	Kenya	Nigeria	South Africa
LnGDPpc_1	-39.31***	-35.28***	-49.76***	-39.95***	-114.1***	-23.09*	-28.74***	-53.36***	-43.33***	-105.9***
	(13.45)	(6.234)	(8.807)	(13.36)	(23.32)	(12.61)	(6.550)	(10.05)	(12.55)	(27.05)
Health rate	15.75***	6.677***	1.292**	10.07**	1.827***	7.477***	1.272**	0.581***	5.245	0.099
	(3.565)	(1.301)	(0.543)	(4.388)	(0.543)	(2.778)	(0.566)	(0.187)	(4.420)	(0.213)
LnHealth_1	251.6***	90.45***	68.88***	101.5	-22.17**	220.8***	-6.320	41.88***	-104.4*	-21.48***
	(49.35)	(29.44)	(25.67)	(85.52)	(10.89)	(85.28)	(20.76)	(16.317)	(60.89)	(6.039)
LnTrade	8.115*	4.248**	-5.497*	4.496*	7.032**	16.53***	8.899***	-6.013*	2.633	8.424**
	(0.480)	(2.151)	(3.193)	(2.317)	(3.462)	(4.420)	(2.058)	(3.083)	(2.357)	(4.263)
LnEdu	-18.262**	-43.88**	-62.95*	-24.23	12.49	0.459	-15.87	-80.117**	-1.311	11.57
	(9.248)	(18.34)	(32.508)	(39.59)	(28.71)	(10.92)	(16.61)	(32.95)	(28.73)	(32.52)
PopGr	9.009**	-14.17***	-23.06***	26.17***	-3.962	10.44*	-4.696	-30.17***	22.37	0.392
	(3.614)	(3.695)	(8.205)	(18.28)	(2.471)	(5.491)	(5.364)	(9.684)	(20.71)	(2.791)
LnInv	-0.779	0.539	16.26***	-6.932	24.49***	0.477	6.219	16.08***	-6.049	20.91**
	(3.125)	(5.671)	(3.695)	(4.669)	(7.951)	(3.812)	(4.901)	(3.481)	(4.185)	(8.807)
FDI	-0.623	-0.289	0.523	-0.184	0.212	-0.262	0.039	0.263	-0.011	0.094
	(0.714)	(0.315)	(0.440)	(0.404)	(0.292)	(0.845)	(0.300)	(0.434)	(0.379)	(0.277)
LnCre	-0.498	0.461	-5.057	-2.338	-11.95**	0.063	2.676	-6.442*	-2.133	-9.002*
	(1.192)	(3.006)	(3.405)	(3.527)	(4.994)	(1.244)	(2.522)	(3.711)	(3.809)	(5.185)
Polity2	0.344	-1.725***	0.027	-0.202	-0.416	0.267	-1.705***	0.101	-0.069	-0.954
	(0.252)	(0.505)	(0.238)	(0.242)	(0.434)	(0.251)	(0.517)	(0.217)	(0.219)	(0.462)
INF	-0.051	-0.115***	-0.003***	-0.023	-0.346***	-0.109***	-0.064**	-0.010	-0.017	-0.349**
	(0.033)	(0.038)	(0.051)	(0.020)	(0.129)	(0.033)	(0.030)	(0.060)	(0.020)	(0.141)
Mobile	-0.082**	0.019	-0.057	0.038	0.109**	-0.136***	0.086*	-0.035	0.243**	0.128**
	(0.038)	(0.046)	(0.065)	(0.145)	(0.051)	(0.048)	(0.044)	(0.062)	(0.119)	(0.062)
Constant	-790.2***	-73.51	176.9*	-141.9	1019***	137.3	155.1***	538.5***	227.1	838.2***
	(174.7)	(91.95)	(96.66)	(323.1)	(203.7)	(101.9)	(47.32)	(107.4)	(140.8)	(203.4)
Observations	40	39	40	39	39	40	39	40	39	39
F	9.690***	145.6***	9.880***	34.730***	15.82***	12.480***	73.000***	9.250***	65.570***	9.890***
R-squared	0.724	0.934	0.673	0.812	0.821	0.672	0.906	0.694	0.808	0.789

Notes: *p<0.1; **p<0.05; ***p<0.01. Robust standard errors in parentheses.

Table A8 Effects of the interaction of health with income (GDP per capita) on GDP per capita growth

	Health: Life expectancy growth rate				Health: Adult survival growth rate			
	OLS	LSDV	2SLS	2SLS+FE	OLS	LSDV	2SLS	2SLS+FE
	(1)	(2)	(3)	(4)	(1)'	(2)'	(3)'	(4)'
LnGDPpc_1	-0.715***	-5.431***	-5.179***	-5.623**	-0.701***	-5.599***	-5.966***	-10.66**
	(0.257)	(0.919)	(1.526)	(2.831)	(0.266)	(1.029)	(1.626)	(5.173)
Health rate	0.455	0.374	-1.205	-23.29**	0.116	0.434	-3.325	-21.59**
	(1.654)	(1.787)	(1.439)	(11.78)	(1.397)	(1.456)	(4.366)	(10.30)
LnHealth_1	4.488**	4.791	4.519	1.989	1.710*	3.638**	3.858**	5.331
	(2.199)	(2.989)	(3.499)	(6.087)	(0.999)	(1.638)	(1.833)	(4.139)
Interaction	-0.012	-0.033	0.219	3.603**	-0.004	-0.010	0.468	3.038**
	(0.219)	(0.236)	(0.202)	(1.758)	(0.178)	(0.184)	(0.577)	(1.436)
LnTrade	0.722***	0.922	0.677	1.043*	0.694**	0.964*	0.806	1.383**
	(0.279)	(0.613)	(0.622)	(0.629)	(0.293)	(0.584)	(0.510)	(0.576)
LnEdu	2.301***	0.221	0.383	17.73**	3.139***	-0.052	0.597	23.06**
	(0.819)	(2.698)	(2.868)	(8.123)	(0.963)	(3.041)	(3.641)	(9.236)
PopGr	-0.146	0.302	0.388	1.142	0.023	0.411	0.497	0.585
	(0.620)	(0.889)	(0.788)	(1.131)	(0.589)	(0.846)	(0.823)	(1.131)
LnInv	0.849*	1.250**	1.506***	1.311*	0.937**	1.239**	1.412***	1.419**
	(0.469)	(0.504)	(0.499)	(0.693)	(0.428)	(0.501)	(0.483)	(0.626)
FDI	0.051	-0.001	0.005	0.022	0.063	-0.003	0.002	0.081
	(0.040)	(0.042)	(0.038)	(0.049)	(0.043)	(0.042)	(0.038)	(0.056)
LnCre	-0.585**	-0.597	-0.934**	-0.708	-0.368	-0.534	-0.625	1.015
	(0.239)	(0.398)	(0.418)	(0.704)	(0.271)	(0.397)	(0.540)	(1.408)
Polity2	0.053**	0.006	0.039	0.089	0.056**	-0.001	0.027	0.094
	(0.025)	(0.055)	(0.055)	(0.055)	(0.025)	(0.053)	(0.059)	(0.063)
INF	-0.017***	-0.019***	-0.018***	-0.018	-0.017***	-0.020***	-0.019***	-0.035***
	(0.005)	(0.006)	(0.005)	(0.015)	(0.005)	(0.006)	(0.006)	(0.008)
Mobile	-0.013***	0.011	0.005	-0.065**	-0.011	0.009	-0.008	-0.069**
	(0.004)	(0.011)	(0.010)	(0.032)	(0.004)	(0.013)	(0.021)	(0.031)
Constant	-16.310*	17.4770	19.41		0.875	39.02***	38.74***	
	(9.434)	(14.852)	(78.62)		(2.917)	(8.531)	(11.60)	
Year/country fixed effects	No	Yes	Yes	NA	No	Yes	Yes	NA
Countries	36	36	36	36	36	36	36	36
Observations	1,299	1,299	1,243	1,243	1,299	1,299	1,243	1,245
Wald F test		4.48***	344.3***			4.680****	329.8***	
F	7.370***	6.190	6.160***	8.240***	5.930***	6.140***	5.570***	4.590***
R-squared	0.067	0.237	0.243	0.102	0.053	0.237	0.214	0.359
HJS			0.392	0.428			0.438	2.023
K-P LM			168.8***	175.6***			9.780***	22.71***
C-D F			181.9***	191.9***			37.29***	5.250***
A-R Chi2			14.29***	11.27**			19.90***	32.58***
First stage regression								
F_Health rate			1132***	1445***			274.8***	173.9***
F_LnGDPpc_1			96.64***	99.26***			95.39***	81.31***
F_Intearction			1325***	1519***			241.9***	164.5***

Notes: NA: Not allowed. HJS, K-P, C-D, and A-R indicate Hansen J statistic, Kleibergen-Paap, Cragg-Donald, and Anderson-Rubin, respectively. 1-year lagged values of health growth rate and its interaction with English language, 1- and 2-year lagged values of the first lag of GDP per capita are valid instruments in Columns (3) and (3)'. GDP per capita of the rest of world, 1-year lagged values of life expectancy, and 2-year lagged values of land area, terms of trade and exchange rate are valid in Column (4). 1- and 2-year lagged values of health growth rate, 2-year lagged values and the first difference of the lag of GDP per capita and GDP per capita of the rest of world are valid instruments in Column (4)'. *p<0.1; **p<0.05; ***p<0.01. Robust standard errors in parentheses.

Mission

To strengthen local capacity for conducting independent, rigorous inquiry into the problems facing the management of economies in sub-Saharan Africa.

The mission rests on two basic premises: that development is more likely to occur where there is sustained sound management of the economy, and that such management is more likely to happen where there is an active, well-informed group of locally based professional economists to conduct policy-relevant research.

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