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The Comparative Economics of Catch-Up in Output per worker, total factor productivity and technological gain in Sub-Saharan Africa

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Abstract

After investigating the effect of external financial flows on total factor productivity and technological gain, we use the beta catch-up and sigma convergence to compare dispersions in output per worker, total factor productivity and technological gain in Sub-Saharan Africa (SSA) for the years 1980-2010. The comparative evidence is articulated with income levels, years of schooling, and health factors. We find; first, a positive association between foreign direct investment, trade openness, foreign aid, remittances and total factor productivity. However, when foreign direct investment is interacted with schooling, it is direct effect becomes negative on total factor productivity. Second, beta catch-up is between19.22% and 19.70% per annum with corresponding time to full catch-up of 25.38 years and 26.01 years respectively. Third, we find sigma-convergence among low-income nations and upper-middle income nations separately, but not for the entire sample together. Fourth, schooling in SSA is not yet a significant source of technology, but it can make external financial inflows more effective. Policies to induce external financial flows are not enough for development if absorptive capacity is low. More policy implications are discussed.

JEL Classification: E23 F21O11 O33 O55
Key terms: External capital flows, Human capital, Total Factor Productivity, Convergence, and Sub-Saharan Africa

1. Introduction

While productivity is arguably the most crucial aspiration of Africa, there is little consensus on how to achieve it. One of the intriguing debates has been between factor accumulation and total factor productivity. In a study of the East Asian economies, Young (1995) finds that factor accumulation played a major role, and he allocates a minor role to total factor productivity. The proponents of total factor productivity as the major differentiating factor between economies include: Abramovitz (1986), Romer (1986, 1993), Temple (1999), Nelson and Pack (1999), Klenow and Rodriguez-Clare (1997), and Easterly and Levine (2001), Durlauf, Johnson, and Temple (2005). Devarajan, Easterly, and Pack, (2003)uphold that it is the low productivity rather than the level of investment that has been the main constraint to Africa’s growth.They maintain that until the sources of low productivity in Africa are better understood, advocacy for more investment as a source of growth is premature. In his search for lessons to Africa from China’s growth, while Anyanwu (2014) points to higher domestic saving and investment, he also recommends technological adaption through innovation among other policies. External financial flows are the key channels of technological transfer and adoption.

There is vast literature about the determinants and effects of external financial flows on economic growth and convergence. However not much has been done on whydespite the increase in the flows, productivity and its convergence among African economies remains low. One strand of literature focuses on trade openness. Baliamoune (2009) studies 41 African countries from 1980-1999, and finds that greater openness to trade may enhance growth in countries with relatively high income but depress it in lower-income countries. She finds no support for conditional convergence. In a follow up, Baliamoune-Lutz (2011) finds that there is an inverted-U relationship between exports to the Organisation for Economic Co-operation and

Development (OECD) countries and growth in Africa from 1995-2008.This suggests there is a threshold above which the effect of exports on growth would be negative. Elu and Price (2010) estimate firm-level production functions in five Sub-Saharan African countries from 1992-2004. They find no relationship between productivity-enhancing foreign direct investment and trade with China, and no effect of trade openness with China on the growth rate of total factor productivity. However, Miller and Upadhyay (2000) study 83 nations, of which 16 are from SSA, from 1960-1989, using 5 year averages. They find that opening an economy to trade generally benefits total factor productivity, and the effect of human capital on total factor productivity in low-income countries moves from negative to positive as the country moves from a low to a higher level of openness. In their follow up, Miller and Upadhyay (2002), using the same dataset, find that low- and middle-income countries benefit from the adoption of more advanced technology, and exhibit convergence of total factor productivity.

The second strand of literature focus on economic integration as a potential source of convergence. Hammouda, Karingi, Njuguna, and Jallab (2009) study 42 African nations from 1981 to 2003, and find that despite the importance of regional economic integration in Africa there is very little income convergence. Hammouda et al. (2009) attribute the slow convergence to a couple of factors, two of which are: slow growth due to slow accumulation of factor production and low total factor productivity; and the limited inflow of foreign direct investment into Africa which is shared by a few countries has constrained the accumulation of capital that is essential to output growth.

Asongu has investigated real and monetary policy convergences in existing (Asongu, 2013a) and potential (Asongu, 2014a) monetary zones in Africa. The findings from the two African French Colonies (CFA) zones and the two proposed monetary unions of East and West

Africa suggest the need for policies that reduce structural and institutional differences which inhibit convergence. Conversely, from an overall African perspective, there is substantial evidence of convergence in short-run finance or financial intermediary development dynamics of depth, activity, efficiency and size (Asongu, 2014b); a tendency that is scantily apparent in long-term finance or stock market performance dynamics (Asongu, 2013b). Asongu (2014c) has also investigated convergence in real per capital income and human development (adjusted for inequality) in 38 African countries for the period 1981-2009 to conclude that the income component of the Human Development Index (HDI) is moving slower than others in the process of convergence and thus requires more policy attention.

The third strand of literature focuses on human capital. Cole and Neumayer (2006) study 52 nations of which 8 are from SSA, using data at five yearly intervals for the period 1965-1995. They focus on the health aspect of human capital, while controlling for international trade, inflation and agricultural share of GDP, and find that poor health is negatively associated with total factor productivity. Other authors that find an adverse effect between poor health and economic growth are: Gallup and Sachs (2000), McCarthy et al. (2000), Arcand (2001), and Bhargava et al. (2001). Sala-i-Martin (2005) uses the theory of growth with poverty traps to illustrate that health has a direct effect on productivity. He explains that while the aggregate productivity of the economy depends on the business activities that citizens decide to undertake, sometimes the choice of activities is affected by the health conditions of the region in which they live, such as malaria and sleeping sickness.

The fourth strand of literature focuses on technology. Jerzmanowski (2007) finds that the bulk of income differences are caused by the fact that many countries operate below the technology frontier, whereby 43 percent of the variation in output per worker is explained by inefficiency. Jerzmanowski argues that many developing countries would gain access to better technologies if they could accumulate physical capital faster than human capital, that is, their *k/h* ratios are low relative to those suited to the most productive technologies. Caselli (2005) who uses a development accounting approach to give a bird's-eye view of differences in income per worker across countries, maintains that efficiency is as important as capital in explaining income differences.

The above strands of literature leave room for improvement in at least four key areas which this paper addresses. First, the channels of technology transfer and their effects on total factor productivity and relative real gross domestic product per capita which is a proxy for the technological gap(Wan, 2004). Notwithstanding the fact that external financial flows into Sub-Saharan Africa have quadrupled since 2000 (African Economic Outlook report, 2014), productivity and relative incomes have not been boosted due to lack of the requisite absorptive capacity. We therefore investigate the role of human capital, that is, schooling and health, in enabling external financial flows to increase productivity and technological change.

Second, we search for evidence of catch-up and convergence in 'output per worker', total factor productivity (TFP) and technological gain. This contribution builds on the need for more economic integration and policy harmonization discussed in Africa (Akpan, 2014; Kayizzi-Mugerwa et al., 2014; Njifen, 2014). Others: Charaf-Eddine and Strauss (2014); Baricako and Ndongo (2014); Nshimbi and Fioramonti (2014); Ebaidalla and Yahia (2014); Ofa and Karingi (2014); Shuaibu (2015) and Tumwebaze and Ijjo (2015).Thisinquiry is based on two theories: (i) countries with lower levels of the underlying factors (per worker output, TFP and technological gain) are more likely to catch-up their counterparts of higher levels. (ii) According to Martin and Sunley (1998) and Temple (1999)if technology is a public good and can cross national borders, over time Sub-Saharan African (SSA) countries should be able to adapt and adopt modern technology, and in the long-run the rate of technological progress would be similar among SSA. However, if there are variations in the opportunities and/or abilities to emulate the existing modern technology we may not observe any convergence.

Third, in order to avail room for more policy options, we disaggregate the dataset into some fundamental panels, based on income-levels. The choice of income-levels is in line with African literature on TFP (Miller and Upadhyay, 2002). Moreover, theoretical and empirical convergence literature is consistent on the position that it is unlikely to find convergence within a heterogenenous set of countries (Islam, 1995; Narayan, 2011, p. 2773; Asongu, 2013a, p. 46).

Fourth, building on the narrative of the third strand, we further improve space for policy implications by conditioning the convergence analysis on health-oriented factors, notably: HIV prevalence, Malaria reported cases and Life expectancy. The intuition for this fourth component is that low human capital may constrain the opportunity and ability to gain efficiency, and account for the convergence and/or the lack of.

The rest of the study is organized as follows. Section 2 engages the data and methodology. The empirical results and discussions are covered in Section 3 while Section 4 concludes.

2. Model, Data, and estimation methodology

2.1. Data and estimation methodology

The dataset is made up of 31 selected sub-Saharan African (SSA) countries over the time period 1980-2010, taken from the World Bank Database. Countries are included on the basis of data availability especially for the average years of schooling. We have three categories of variables: (i) Production function variables: output per worker, physical capital per worker, labor force, and average years of schooling. Real Gross Domestic Product (GDP) per worker is derived from GDP per capita and physical capital per worker, which in turn is generated from the gross capital formation as a percentage of GDP using the perpetual inventory method. Labor force is the percentage of the total population between 15 and 64 years, we use the Barro-Lee average years of schooling per person 15 years and older. (ii)External financial flows: foreign direct investment, foreign aid, remittances, and trade openness. (iii)Human capital: schooling, prevalence of human immunodeficiency virus (HIV), malaria cases reported, and life expectancy. Prevalence of HIV refers to the percentage of people ages 15-49 that are infected with HIV while malaria cases reported refers to the sum of confirmed cases of malaria by slide examination or rapid diagnostic test and probable cases of malaria. Life expectancy at birth indicates 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. In accordance with the Barro-Lee five-year averaging of the years of schooling, all data are averaged over a 5-year periods: 1980, 1985, 1990, 1995, 2000, 2005, and 2010.

Panel data methods of Fixed Effects and General Method of Moments (GMM) are used. The Two-Step System GMM method (Arellano and Bond, 1991; Arellano and Bover, 1995; Blundell and Bond, 1998) in accordance with Roodman (2009a, b) is preferred for four reasons: first, it allows us to control omitted variables that persistent over time. Second, several lags of the regressors can be used as instruments where required, thus alleviating measurement error and endogeneity biases. If the measurement errors are not persistent, the standard Fixed Effects within-transformation may worsen the problem of measurement errors. Third, Arellano-Bond estimator was designed for small-T and larger-N panels. Fourth, it allows us to control for cross-sectional dependence. The general GMM equation is specified as follows:

$$\ln(Z)_{it} = \sum_{f=1}^{h} \beta_1 \ln(Z)_{it-f} + \gamma_l \ln(X)_{it-l} + \delta_i + \varepsilon_{it}$$

$$\mathrm{E}[\delta_i] = E[\varepsilon_{it}] = E[\delta_i \varepsilon_{it}] = 0 \qquad (1)$$

where Z is a vector of the dependent variables, X is vector of the independent variables key of which are external financial flows and measures of human capital; δ_i are the unobserved time-invariant country-specific effects while ε_{it} are the observation error terms.

The specifications are two-step with forward orthogonal deviations as opposed to differencing. The procedure is preferred for two reasons: first, the two-step procedure is robust since it is heteroscedasticity-consistent while the one-step assumes homoscedasticity. Second, unlike first differencing, the forward orthogonal deviations accounts for cross-sectional dependence that may bias estimated coefficients (Baltagi, 2008b). Consistent with Love and Zicchino (2006), the specific effects from the cross-sections are eliminated with the use of forward orthogonal deviations. With this approach, lags of one period in the regressors are valid instruments because they are uncorrelated with the error term that has been transformed. The findings satisfy post-estimation diagnostics, notably: the difference-in-Hansen test for exogeneity of instruments, the Hansen test of over-identification (OIR) and the Arellano & Bond (1991) test for serial correlation of second order(AR (2)).The instruments matrix is also collapsed to avoid the proliferation of instruments.

2.2. Total Factor Productivity

We estimate total factor productivity (TFP) from a production function specified as follows:

$Y = AK^{\alpha}\left[e^{\varphi(E)}L\right]^{\beta}$ where 0<α <1, and 0<β <1 (2)

Y denotes real GDP, A is total factor productivity, K is total physical capital, E represents schooling, φ is the rate of growth of education, and L denotes the total labor force. We do not restrict that ($\alpha + \beta$) equal to one. Hence we allow for the possibility of the increasing returns to scale. Dividing by L we transform equation (2) into per worker terms.

$$y = Ak^{\alpha}e^{\beta\varphi(E)}L^{\alpha+\beta-1} \tag{3}$$

Taking the natural logarithms of equation (3) provides us with equation (4).

$$\mathrm{Ln}(y) = \ln(A) + \alpha\ln(k) + \beta\varphi E + (\alpha+\beta-1)\ln(L) \tag{4}$$

Let A_0 be the initial endowment of technology, we model technological progress to increase exponentially at the rate of θ as: $A_t = A_0e^{\theta t}$. In the$\lim_{t\to\infty}A_0(1+\theta)^t = A_0e^{\theta t}$. Hence$\ln(A) = \ln(A_0) + \theta t$. Since A_0 does not reflect just technology alone, but also factors such as resource endowments, climate, institution, and so on (Mankiw, Romer, and Weil, 1992), it can be rewritten as$\ln(A_0) = \delta + \varepsilon$. Where δ is a constant and ε is a country-specific shock. Thus equation (4) becomes:

$$\ln(y_{it}) = \delta_i + \alpha\ln(k_{it}) + \beta\varphi E_{it} + (\alpha+\beta-1)\ln(L_{it}) + \varepsilon_{it} \tag{5}$$

The subscripts *i* and *t* represent country and year, respectively. Equation (5) is estimated for 31 SSA nations for the time period 1980-2010, at five-year average intervals, to obtain the TFP as a residual.

2.3. Technological gain

The second variable of interest is the relative real gross domestic product per capita which is a proxy for technological gap. This variable is based on the Wan (2004) theory of catching up. Let $v_{it} = x_{it}/z_{it}$, where x is the real GDP per capita in country *i* while *z* is the real GDP per capita of the leading hypothetical economy. Taking achievability into perspective, *z* is set to an initial value of $40,000 in 1980, but allowed to grow at a moderate annual compound rate of 2 percent. The 2 percent which is implicit rate of innovation in the advanced leading economy is also the average long-run growth rate of advanced economies established in literature for Europe and the U.S.A (Armstrong, 1995) and for Australia (Cashin, 1995). According to Todaro and Smith (2012), $40,000 is the same figure used as the goalpost by the United Nations Development Programme (UNDP) in the computation of the Human Development Index (HDI) for developing countries. It therefore follows that $0 < v \leq 1$. If v=1, then the developing SSA has attained its short-term goal. All of the 31 nations in our sample have real GDP per capita income of less than $40,000.

Following Wan (2004), the growth rate of x_{it} depends on the value of v_{it}, such that the lower the$v_{it}$the faster the growth rate of x_{it}. According to Lucas (1988) there would be an accelerating trend until x^0, beyond which a developing economy would experience a decelerating trend in the growth rate. At the same time x^0 canvary over time. For a developing country to catch up with the leading economy, it is expected to initially grow faster than 2 percent. Since we assume that there is no or minimal innovation in the developing countries, the technological gain is attained through contact with, and emulation of, the advanced economies. At the same time technological spillovers, that is, effective emulation, need a proper environment, namely, human capital and policy regimes or institutions as specified in equation (6).

$$\mathrm{Ln}(v_{it}) = \delta_i + \mu \ln(contact_{it}) + \rho \ln(schooling_{it}) + \tau \ln(health_{it}) + \gamma polity2_{it} + \varepsilon_{it} \quad (6)$$

4.4. Convergence Tests

Finally, we test for the conditional β-convergence and σ-convergence of output per worker, total factor productivity, and technological gain among the SSA nations. Our goal here is to test whether technology is becoming more evenly distributed in SSA. We compute the conditional β-

convergence using the two-step system GMM with autocorrelation tests and controls for cross sectional dependence. The conditional β-convergence tests whether economies converge, not to a common steady state (equalization of incomes) but to their own long-term steady-state. To test for conditional convergence we introduce additional X variables to the growth regression using panel cross-sectional data specified as follows:

$$\left(\frac{1}{T}\right)\ln\left(\frac{y_{it}}{y_{i,t-1}}\right) = \alpha + \beta ln\left(y_{i,t-1}\right) + \delta X_{i,t} + \varepsilon_{i,t} \tag{7}$$

Where $X_{i,t}$is a vector of variables that hold constant the steady state of economy i, and those we include are foreign direct investment, trade openness, foreign aid, remittances, polity2, schooling, prevalence of HIV, malaria cases reported, and life expectancy. The left hand term is the annualized growth rate of each of the three measures productivity: either output per worker or total factor productivity or relative income per capita. We compute the left hand term as a logarithmic difference between output per worker (or total factor productivity or relative income per capita) between 1976-1980 and 1981-1985,… and between 2001-2005 and 2006-2010, each divided by 5. Following Barro (1991), Mankiw, Romer, and Weil (1992), and Barro and Sala-i-Martin (1995), having introduced the $X_{i,t}$ variables in equation (6), we infer conditional convergence if β is negative.

Concerning σ-convergence we follow Sala-i-Martin (1999), that a group of countries are said to be converging in the sense of σ if the dispersion of their levels of output per worker or total factor productivity or relative income per capita tends to decrease over time. That is, if $\sigma_{t+1} < \sigma_t$, where $\sigma_t$is the time t standard deviation of $ln\left(y_{i,t}\right)$ across i.

3. Estimation Results

We use fixed effects and two-step system GMM techniques to estimate a Cobb-Douglas production function specified in Equation (5) to obtain the total factor productivity. The results are reported in Table 1. Total factor productivity is obtained as the residual of column (4), in an estimation that includes the years of schooling. This specification is adopted from Mankiw, Romer and Weil (1992), who maintain that leaving out human capital affects the coefficients on physical capital investments and labor. The capital per worker elasticity of output is 0.257 while the implied labor elasticity is 0.602. The schooling coefficient $\beta\varphi$ is composite: the implied φ is 0.139, which is the growth rate of schooling. Hence $\phi\ (E_i)$ measures the effect of the average years of schooling on output per worker.

Table 1: production function estimates of equation (5)

Dependent variable: income per worker ln(y): entire sample 31 nations				
	Fixed Effects			Two-Step system GMM
	(1)	(2)	(3)	(4)
Lagged ln(y)				0.398*** (0.001)
Ln(k)	0.329*** (0.000)	0.347*** (0.000)	0.357*** (0.000)	0.257*** (0.000)
Ln(L)		0.306 (0.223)	0.139 (0.573)	-0.141** (0.034)
Schooling			0.109*** (0.000)	0.084*** (0.000)
Constant	4.56*** (0.000)	-0.179 (0.963)	1.68 (0.667)	4.05*** (0.006)
R-squared (within)	0.278	0.284	0.335	
Observations	207	207	207	178
AR(1)				(0.872)
AR(2)				(0.147)
Hansen test[p-value]				0.143
Implied estimated β		0.959	0.782	0.602

Notes. Ln: logarithm. P-values in brackets

We then examine the effects of external financial flows on total factor productivity, controlling for human capital and polity2. The results are reported in Table 2. The lagged total factor productivity variable is positive and close unity elasticity. This suggests that technological emulation in SSA is more or less at a constant rate. We find that foreign direct investment (FDI), trade openness, foreign aid, remittances, schooling, and life expectancy directly increase total factor productivity, which is in line with Islam (1995) and Benhabib and Spiegel (1994). Using interactive terms, we also find that schooling makes FDI and openness to more effectively increase total factor productivity (Borensztein, De Gregorio, and Lee, 1998); Miller and

Upadhyay, 2000). While FDI has a positive direct effect on total factor productivity, but when interacted with schooling, the direct effect is either insignificant or negative. This mixed effect of FDI on total factor productivity could be due to the type of FDI generally received by the SSA countries which is more resource- and market-seeking than efficiency-seeking (Gui-Diby and Renard, 2015).

The results in Table 2 also show that the prevalence of HIV and malaria reduce total factor productivity. On the other hand, increase in life expectancy is positively associated with total factor productivity. Our results are in line with Engel (2003) and Cole and Neumayer (2006). Table 3 presents the estimation results of the effects of external financial flows and human capital on technological gain for human capital and polity2. Again, the lagged relative income variable is positive and close to unity elasticity implying a constant rate of catching-up. Again we find that poor health in terms of increased prevalence of HIV and malaria reduces relative income, the proxy of technological gain. The poor spend all their income and savings to save lives (Sala-i-Martin, 2005).

Table 2: Effects of FDI, openness, schooling, and health on total factor productivity

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Lagged dependent variable	1.01*** (0.000)	0.901*** (0.000)	1.01*** (0.000)	0.969*** (0.000)	0.866*** (0.000)	0.939*** (0.000)	0.897*** (0.000)	0.961*** (0.000)	0.986*** (0.000)	1.06*** (0.000)
Ln(fdi)	-0.012 (0.448)	0.041* (0.062)	0.061** (0.011)	0.031** (0.013)	-0.054** (0.042)	-0.004 (0.898)	-0.051** (0.012)	-0.012 (0.341)	-0.014 (0.439)	0.013 (0.398)
Ln(open)	0.279*** (0.001)	-0.108 (0.278)	-0.063 (0.258)	0.077* (0.065)	0.191** (0.033)	-0.016 (0.785)	0.187** (0.016)	-0.151 (0.122)	0.180** (0.037)	0.117 (0.488)
Ln(aid)	0.066** (0.045)	-0.004 (0.894)	0.116** (0.011)	0.045** (0.012)	0.003 (0.903)	0.073** (0.013)	0.007 (0.778)	0.024 (0.278)	0.032* (0.065)	0.065** (0.043)
Ln(remi)	0.030 (0.146)	0.035** (0.035)	0.048** (0.018)	0.025*** (0.001)	0.003 (0.849)	0.012 (0.520)	0.006 (0.650)	0.054*** (0.001)	0.059*** (0.004)	0.009 (0.640)
Schooling		0.075*** (0.009)	0.017 (0.262)	-0.033 (0.193)	0.047*** (0.002)	0.045*** (0.004)	0.023* (0.078)	-0.062 (0.305)	0.116** (0.043)	0.058 (0.636)
Ln(HIV)		-0.131*** (0.000)			-0.034*** (0.004)			-0.026 (0.209)		
Ln(malaria)			-0.025** (0.015)			-0.018* (0.072)			0.007 (0.162)	
Ln(lifeexp)				0.554*** (0.000)			0.354*** (0.000)			0.436*** (0.000)
Avpol2		0.007 (0.210)	-0.004 (0.183)	0.001 (0.924)	-0.001 (0.937)	0.000 (0.993)	0.002 (0.149)	0.002 (0.386)	-0.001 (0.767)	0.004* (0.081)
Ln(fdi)* Schooling					0.010*** (0.007)	0.002 (0.652)	0.010*** (0.004)			
Ln(open)*Schooling								0.027* (0.090)	-0.018 (0.167)	-0.012 (0.668)
Constant	-1.44*** (0.001)	0.959 (0.157)	0.144 (0.794)	-2.29*** (0.000)	-0.015 (0.932)	0.359 (0.135)	-1.56*** (0.000)	0.638 (0.241)	-0.937** (0.015)	-2.83*** (0.000)
Observations	116	116	101	116	116	101	116	116	101	116
Countries	31	31	30	31	31	30	31	31	30	23
Instruments	15	19	19	27	25	25	25	23	23	23
AR(1)	0.374	0.113	0.301	0.167	0.840	0.357	0.248	0.559	0.996	0.031
AR(2)	0.139	0.869	0.443	0.199	0.214	0.126	0.168	0.346	0.345	0.115
Hansen Test [p-value]	0.231	0.711	0.392	0.359	0.232	0.318	0.217	0.115	0.143	0.518

Notes. Ln: logarithm. P-values in brackets. AR(1) and AR(2) are presented in P-values. Fid: Foreign Direct Investment. open: trade openness. Aid: foreign aid. Remi: remittances. lifeexp: Life Expectancy. Avpol2: Average Polity2.

Table 3: Effects of FDI, openness, schooling, and health on technological gain

	Relative real GDP per capita: entire sample of 31 nations									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Lagged dependent variable	0.873*** (0.000)	1.16*** (0.000)	0.819*** (0.000)	0.965*** (0.000)	1.03*** (0.000)	0.836*** (0.000)	0.908*** (0.000)	0.865*** (0.000)	0.875*** (0.000)	0.904*** (0.000)
Ln(fdi)	0.030*** (0.003)	0.076*** (0.004)	0.043* (0.080)	0.026* (0.099)	0.087*** (0.000)	0.018 (0.513)	-0.007 (0.592)	0.051*** (0.000)	0.087*** (0.000)	0.048*** (0.002)
Ln(open)	0.287*** (0.000)	0.127 (0.236)	0.180* (0.087)	0.231** (0.013)	0.110* (0.059)	0.193** (0.021)	0.137** (0.031)	-0.30 (0.736)	0.180** (0.043)	-0.168 (0.290)
Ln(aid)	-0.043* (0.055)	-0.009 (0.819)	-0.097** (0.030)	-0.059** (0.042)	0.054** (0.031)	-0.092** (0.022)	-0.063* (0.073)	-0.088*** (0.001)	-0.28 (0.337)	-0.047 (0.103)
Ln(remi)	0.007 (0.515)	0.032** (0.034)	0.018 (0.445)	-0.036 (0.134)	0.011 (0.439)	0.003 (0.856)	-0.018 (0.256)	0.005 (0.957)	0.001 (0.926)	0.005 (0.629)
Schooling		-0.035 (0.313)	0.011 (0.254)	-0.022 (0.192)	0.017 (0.259)	0.008 (0.602)	0.003 (0.981)	-0.112 (0.121)	0.072 (0.253)	-0.089 (0.425)
Ln(HIV)		-0.104*** (0.001)			0.001 (0.999)			-0.050** (0.016)		
Ln(malaria)			0.011 (0.251)			0.009 (0.239)			-0.011* (0.082)	
Ln(lifeexp)				0.369*** (0.002)			0.615*** (0.000)			0.936*** (0.000)
Avpol2		0.011** (0.023)	-0.011** (0.031)	0.001 (0.666)	-0.003 (0.229)	-0.013*** (0.000)	-0.007 (0.851)	-0.006 (0.810)	-0.005** (0.038)	-0.003 (0.468)
Ln(fdi)* Schooling					-0.004 (0.148)	0.009** (0.047)	0.006** (0.019)			
Ln(open)* Schooling								0.029* (0.065)	-0.018 (0.226)	0.022 (0.383)
Constant	-1.65*** (0.000)	0.507 (0.266)	-1.48** (0.031)	-2.31*** (0.000)	-0.549* (0.064)	-1.46*** (0.004)	-3.23*** (0.000)	-0.274 (0.521)	-1.06*** (0.005)	-3.31*** (0.004)
Observations	138	118	121	138	118	121	138	118	121	138
Countries	31	31	30	31	31	31	31	31	30	31
Instruments	16	21	22	22	27	24	24	23	26	24
AR(1)	0.161	0.171	0.062	0.100	0.042	0.036	0.058	0.103	0.089	0.034
AR(2)	0.669	0.928	0.742	0.474	0.372	0.599	0.338	0.665	0.346	0.741
Hansen Test [p-value]	0.362	0.907	0.195	0.416	0.572	0.320	0.505	0.214	0.657	0.271

Notes. Ln: logarithm. P-values in brackets. AR(1) and AR(2) are presented in P-values. Fid: Foreign Direct Investment. open: trade openness. Aid: foreign aid. Remi: remittances. lifeexp: Life Expectancy. Avpol2: Average Polity 2.

Having established that contact with the advanced economies increases total factor productivity and technological gain, and that better human capital increases the effectiveness of the external financial flows, we use the *β*-convergence and *σ*-convergence to investigate whether a combination of these dynamics would result into faster convergence among the SSA nations. We test for convergence in the output per worker, total factor productivity, and relative income per capita, controlling for the external financial flows, schooling, and the health variables. Table 4 reports the conditional *β*-convergence results for the entire sample and for the low income countries. We do not have enough data for regressions on the middle income. We find evidence of conditional *β*-convergence among the SSA in this sample.

For comparative purposes, we also compute the catch-up rate and time required for full catch-up. For instance, with a beta value of -0.036, the catch-up rate is 19.28% per annum (pa) [(-0.036+1)/5] and the corresponding time to full catch-up is 25.93 years [500%/19.28%]. Five years and 500% are employed in the computation because tau is 5 since, we have employed 5 year intervals to mitigate short-term or business cycle disturbances (Asongu and Nwachukwu, 2015). Comparatively, we observe the following. First, the catch-up rate is between 19.22% and 19.70% per annum. Second, the corresponding time to full catch-up is between 25.38 years and 26.01 years.

Table 4: Conditional β-Convergence

	Includes HIV prevalence		Includes Malaria cases reported		Includes Life expectance	
	All countries (31)	Low income countries (25)	All countries (30)	Low income countries (24)	All countries (31)	Low income countries (25)
β-income per capita [observations]	-0.036*** (0.000) [116]	-0.026*** (0.010) [80]	-0.015*** (0.009) [101]	-0.021** (0.043) [70]	-0.031*** (0.000) [116]	-0.034*** (0.000) [80]
Catch-up	Yes	Yes	Yes	Yes	Yes	Yes
Catch-up rate	19.28 % p.a	19.48 % p.a	19.70 % p.a	19.58 % p.a	19.38 % p.a	19.32 % p.a
Time to Full Catch-up	25.93 yrs	25.66 yrs	25.38 yrs	25.53 yrs	25.79 yrs	25.87 yrs
β-total factor productivity [observations]	-0.019*** (0.003) [96]	-0.039*** (0.000) [67]	-0.019*** (0.000) [84]	-0.034*** (0.000) [59]	-0.022** (0.022) [96]	-0.026*** (0.001) [67]
Catch-up	Yes	Yes	No	Yes	Yes	Yes
Catch-up rate	19.62 % p.a	19.22 % p.a	NA	19.32 % p.a	19.56 % p.a	19.48 % p.a
Time to Full Catch-up	25.48 yrs	26.01 yrs	NA	25.87 yrs	25.56 yrs	25.66 yrs
β-relative income per capita [observations]	-0.033*** (0.000) [117]	-0.026** (0.036) [81]	-0.026*** (0.000) [102]	0.015** (0.043) [71]	-0.032*** (0.000) [117]	-0.033*** (0.000) [81]
Catch-up	Yes	Yes	Yes	No	Yes	Yes
Catch-up rate	19.34 % p.a	19.48 % p.a	19.48 % p.a	NA	19.36 % p.a	19.34 % p.a
Time to Full Catch-up	25.85 yrs	25.66 yrs	25.66 yrs	NA	25.82 yrs	25.85 yrs
All regressions include Schooling, foreign direct investment, openness, foreign aid, remittances, ploity2, and time effects (years).NA: Not Applicable;p.a: per annum; yrs: years						

Table 5 presents the σ-convergence results which consider the degree of dispersion in the steady-states to which output per worker, total factor productivity, and relative income per capita converge over time. We find σ-convergence among the low-income and the upper-middle income countries, but not for the entire sample and for the lower middle income nations. This result supports the notion of the club convergence among the SSA countries.

Table 5: σ-Convergence

		All countries	Low income countries	Lower Middle Income	Upper Middle Income
σ-output per worker					
	1976-1980	0.943	0.550	0.500	0.791
	1981-1985	0.961	0.444	0.371	0.685
	1986-1990	0.969	0.531	0.399	0.440
	1991-1995	1.055	0.636	0.132	0.396
	1996-2000	1.060	0.623	0.147	0.337
	2001-2005	1.047	0.517	0.320	0.204
	2006-2010	1.045	0.457	0.607	0.119
σ-total factor productivity					
	1976-1980				
	1981-1985	0.910	0.500	0.336	0.509
	1986-1990	0.917	0.578	0.476	0.461
	1991-1995	0.916	0.567	0.091	0.370
	1996-2000	0.955	0.591	0.002	0.396
	2001-2005	0.961	0.512	0.234	0.385
	2006-2010	0.936	0.436	0.622	0.344
σ-relative output per capita					
	1976-1980	0.897	0.418	0.471	0.783
	1981-1985	0.949	0.444	0.423	0.668
	1986-1990	0.961	0.510	0.531	0.400
	1991-1995	1.030	0.569	0.385	0.320
	1996-2000	1.051	0.573	0.238	0.200
	2001-2005	1.055	0.499	0.366	0.114
	2006-2010	1.060	0.473	0.666	0.109

4. Conclusion

The results show that foreign direct investment (FDI), trade openness, foreign aid, and remittances increase total factor productivity and the relative income in SSA, with the strongest positive relationship coming from trade. We control for some indicators of health, and find that while an increase in life expectancy is directly related to total factor productivity, an increase in the prevalence of HIV and malaria are inversely related to it. Poor health not only reduces labor supply and its productivity, it also absorbs savings that would have been invested. Using interactive terms, we find that schooling makes FDI and openness to more effectively increase total factor productivity and technological gain, but schooling has a statistically insignificant effect on technological gain. Again while FDI has a positive direct effect on total factor productivity, but when we interact it with schooling, the direct effect FDI is either insignificant or negative. Schooling in SSA is not yet a significant source of technology, but it can make external financial flows more effective.

We have tested for both conditional β-convergence and σ-convergence in output per worker, total factor productivity, and relative per capita income. We find evidence of conditional β-convergence for both the entire sample all together and the low-income sub-sample, but find evidence of σ-convergence only among the low income and upper middle income nations separately. We do not find σ-convergence for the entire sample or for the lower middle income group of nations. Our results support the view that while technology eventually becomes a public good, and external financial flows involve transfer of technology and can facilitate the convergence of efficiency, all SSA nations do not have the same opportunity and ability to absorb modern technology.

We have found the beta catch-up to be between19.22% and 19.70% per annum with corresponding time to full catch-up of respectively 25.38 years and 26.01 years. The presence of catch-up implies that policies designed to boost underlying factors (output per worker, TFP and technological gain) are feasible if absorptive capacity is enhanced in the SSA nations, paying attention to the country-specific needs. Hence while SSA countries continue to seek attracting higher external financial flows, they should also ensure that the flows heighten productivity. As a policy implication, SSA needs to work towards deepening absorptive capacity in order for the external flows to boost productivity, and accelerate the rate of catching-up.

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Appendix: List of countries in the sample

Benin
Botswana
Burundi
Cameroon
Central African Rep.
Congo, Dem. Rep.
Congo, Rep.
Cote d'Ivoire
Gabon
Gambia, The
Ghana
Kenya
Lesotho
Liberia
Malawi
Mali
Mauritius
Mozambique
Namibia
Niger
Rwanda
Senegal
Sierra Leone
South Africa
Sudan
Swaziland
Tanzania
Togo
Uganda
Zambia
Zimbabwe