09-07-19

Convergence Theory and Conditional Income Convergence in Countries of Sub Saharan Africa from 1990-2015

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Abstract: This paper examines the hypothesis of conditional convergence in income per person for Sub Saharan African (SSA) countries over the most recent twenty-five year period, 1990-2015. The income data are in 2011 PPP$ from the Penn-World Table 9.0 (2017). This is the first study to use them in a study of convergence of per capita income in SSA. New conditioning variables are identified and included in the econometric model of growth. This is important because it might suggest where organizations (e.g., the World Bank or aid agencies) should invest to yield the most economic growth. The main results are for the largest 35 SSA countries, and they include: average per capita income in 2011 PPP$ grew at 1.1 percent over the period of 1990-2014; and conditional convergence is occurring, i.e., countries lagging behind in 1990 grew faster. Countries with a larger share of the labor force in agriculture in 1990 grew slower, as do countries in central Africa. Former British colonies tend to grow faster. Instrumenting the starting year value of per capita income increases the rate of convergence by 80 percent. External support for new agricultural technology or increased nutrition and food availability that increases agricultural productivity would reduce the share of labor in agriculture and increase future growth performance.

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Introduction

Understanding wealth and income of countries and why some countries have the potential to grow at much faster rates is an important issue in economic growth and development literature. Convergence theory is a subset of this literature, and it is concerned with whether poorer countries grow at faster rates than wealthier countries, causing countries to converge in per capita income over time. More specifically, conditional convergence implies that countries converge within their income group (or within some other conditioning variable), for example, poorer developed countries over time converge with the wealthier developed countries.

However, among poor countries there is some doubt as to whether there is conditional convergence. For example, Durlauf et al. (2005) report that for 13 of 36 Sub Saharan African countries (for which data were available) experienced negative growth in GDP per capita over the 40 year period 1960-2000. In countries that experience negative growth over long periods of time, how could they converge to countries with positive growth rates? Hence, further research on conditional convergence in Sub Saharan African countries is an interesting piece of research. It has important implications about where countries, world agencies, and donor agencies should invest in the future.

The objective of this paper is to examine the hypothesis of conditional convergence in income per person for Sub Saharan African (SSA) countries over the most recent twenty-five year period, 1990-2015. This study uses new data on per capita income and income growth that recently became available in purchasing-power-parity 2011 dollars (PPP$), that better adjusts for prices of untraded services than official exchange rate adjusted data (Groningen Growth and Development Center 2017). It also considers new conditioning variables measured at the start of the study period. These variables include colonial affiliation, political stability, corruption level,

regional location, the population growth rate, share of the labor force in agricultural, extent of stunting in children under age five, extent of child labor, literacy rate, life expectancy, and percent of population with access to safe water. Consistent with the national (or regional) growth convergence literature (Barro and Sala-i-Martin 1992, Durlauf et al. 2005), the per capita income growth model is a reduced-form and not a structural model.

This paper finds from new data on GDP per person that average per capita income in SSA was growing at 1.1 percent over the period of 1990-2014. It finds that countries lagging behind in 1990 grew faster and some conditioning variables were important, for example the share of labor in agriculture in 1990, and colonial UK affiliation. Thus, the paper provides evidence for conditional convergence in SSA and the importance of certain conditioning variables. In addition, the paper provides some new evidence that instrumenting the beginning period value of per capita income increases significantly the rate of convergence in per capita income. Our findings provide important information for organizations such as The World Bank and foreign aid agencies of developed countries could invest in new agricultural technologies or nutrition and food availability (Fukase and Martin, 2017) programs that would increase agricultural productivity and reduce the share of the labor force in agriculture, which promises to increase the rate of future economic growth.

The second section of this paper examines literature that motivates the questions asked in this paper. The third section considers the materials and methods that are used. The fourth section presents the regression results. Finally, the paper concludes by presenting a general discussion, and the final section contains the conclusion.

Selective Literature Review

Pritchett (1997) reported that over the period 1870-1990 advanced countries experienced convergence, however, there is neither large amount nor good data on long run growth rates of developing countries. Thus, his goal was to determine whether this was true for developing countries as well. He reported lower growth rates for less developed countries in comparison to developed, so that per capita incomes diverged. Pritchett found that there was generally no acceleration of growth absolutely to a new higher steady state or even conditionally in developing countries. In addition, for the period 1960-1990, using the Penn World table, he found a deceleration of growth rates in 81 of the 103 developing countries. This is surprising because if these countries are going to experience per capita income convergence with the developed countries, they must be experiencing positive (and rapid) growth. On the other hand, short periods of explosive growth were reported for some Eastern Asian countries, but thirteen SSA Arican countries experienced economic growth disasters (Durlauf et al. 2005). Overall, Pritchett found that developed countries converged and that low-income countries were diverging from the developed countries.

Durlauf et al. (2005) looks at the historic divergence in living standards. In the 1700s all countries were poor, in the 18th and 19th century growth rates in Western Europe increased. The global inequality seems to stem from a few Western economies growing while the majority of countries did not. Though there are a few important exceptions, such as a few developing countries growing at really fast rates, including parts of Eastern Asia. They state that growth in per capita income seems to be correlated with growth in GDP per worker, except in countries that had low labor force participation rates at the beginning of the period. When looking at a table of GDP per worker, relative to the US for 1960 and 2000, major Western European

countries had similar growth rates as the US (e.g., the UK), or faster growth rates (e.g., France, Italy). Now rich countries were significantly poorer than the US 60 years ago, such as Japan and Korea, drastically improved, while countries such as Argentina performed badly. Looking at the median and mean there was a slight increase suggesting a slight convergence. They also reported that 13 Sub Saharan African countries experienced growth disasters over 1960-2000. However, new and updated income data have become available in the Penn World Table version 9.0 making it possible to measure per capita income as GDP per person in purchasing-power-parity (PPP$) 2011 U.S. dollars (World Bank, 2016). PPP$ data better account for the low price of nontraded services in developing countries. None of the other papers on convergence consider per capita income growth in real PPP units or for the period 1990-2014.[1]

Our paper is similar to Pritchett's work in the aspect that it tests for whether developing countries experience convergence, but we use a formal econometric model and income data from a newly updated Penn World table. In our formal model, it is also possible to examine the effects of various conditioning variables. SSA was largely bypassed by the Green Revolution (Pingali, 2012) and the Gene Revolution (Bazuin et al., 2011) and includes several of the poorest countries of the world. Hence, it is a region that needs further analysis, and we focus on the performance of countries in SSA rather than the general category of developing countries.

Materials and Methods

The Data

The study chooses 35 countries in SSA for empirical analysis (see Table 1 for list of 35 countries). This is a very large share of all of the countries in this region but excludes very small countries with less than 1.5 million people in 1990, and those for which data are not available.

[1] Dervis (2012) discusses prospects of more rapid income convergence between the rich and poor countries of the world since 1990, but SSA seems to be largely insulated from the fundamental trends that he emphasizes.

The income and population data are taken from The Penn World Tables version 9.0, which became available in 2017 (see Femstra et al., 2015, for details). They are the most updated version, which is significant because it has not yet been used for convergence analysis in Africa. New stunting data were also obtained directly by contacting the World Health Organization in Geneva, Switzerland on stunting in children less than 5 years of age in 1990 for the countries of SSA.

Table 1 displays the per capita real GDP in 2011 PPP's for 1990 and 2014 that will be later used in the empirical analysis. It also includes a comparison to GDP in 1990 and 2014 in

Table 1. Per capita real GDP per person in real dollars for Sub Saharan African countries: 1990 and 2014

Countries	PPP per_cap_1990	PPP per_cap_2014	Real* per_cap_1990	Real* per_cap_2014	Avg ann growth in PPP	Avg ann growth real terms*
Benin	1202	1922	1461	8533	0.020	0.074
Burkina Faso	912	1565	780	1461	0.023	0.026
Burundi	798	772	632	806	-0.001	0.01
Cameroon	2370	2698	2561	2705	0.005	0.002
Central African Republic	1079	594	977	570	-0.025	-0.022
Chad	1411	2013	949	1963	0.015	0.030
Côte d'Ivoire	2311	3352	2961	2982	0.015	0.000
Ethiopia	866	1323	658	1467	0.018	0.033
Ghana	1903	3570	1846	3728	0.026	0.029
Kenya	2061	2769	2455	2914	0.012	0.007
Madagascar	1012	1237	1633	1352	0.008	-0.008
Malawi	958	949	847	1137	0.000	0.012
Mali	733	1434	1040	1497	0.028	0.015
Niger	846	852	827	886	0.000	0.003
Nigeria	845	5501	2949	5537	0.078	0.026
Sierra Leone	1590	1419	1968	2048	-0.005	0.002
South Africa	8366	12128	9671	12154	0.015	0.010
Sudan	1588	3781	2046	3585	0.036	0.023
Tanzania	1118	2213	1352	2439	0.028	0.025
Uganda	808	1839	833	1923	0.034	0.035
Zambia	1343	3726	2240	3516	0.043	0.019
Zimbabwe	4262	1869	1417	1688	-0.034	0.007

*Real rates are using an exchange rate conversion

exchange rate dollars. It is interesting that per capita GDP in 1990 ranges from $798 in Burundi to $8,366 for South Africa, and for 2014, the range is from $594 in the Central African Republic to $12,128 for South Africa. For the great bulk of the countries there is growth in GDP per capita

in 2011 PPP's, but for five of the thirty-five countries (Burundi, Central African Republic, Malawi, Niger and Zimbabwe) per capita income declines over this period and for the Central African Republic and Zimbabwe, per capita income is roughly 50% lower in 2014 than in 1990. However, only 15% of the countries were experiencing negative growth, which is much lower than reported by Durlauf et al. (2005) using earlier data. An alternative measure of real GDP per person is in real exchange rate dollars. The majority of the countries have a higher beginning per capita GDP using real exchange rate dollars. When comparing the average annual growth in PPP terms and real terms, growth rates were generally similar except for Benin and Nigeria.

The Model

Consistent with the economic growth literature, the growth convergence equation is:

$$(1) \quad (\frac{1}{T}) \ln (\frac{y_{it+T}}{y_{it}}) = B_1 + B_2 \ln y_{it} + \sum_{j=3}^{J} B_j X_{ij} + \mu_i$$

where *i* refers to the particular country in the study, *t* is the starting data, and *T* is the total length of period over which growth convergence is considered. In addition, the dependent variable in equation (1) is the average rate of growth of per capita income for country *i* over time period *T*, lny_{it} is the value of real per capita income at the starting date for country *i* and year *t*. *Xj'*s are conditioning variables, and μ_i represents all other factors affecting the growth convergence rate. It is a random variable that is assumed to have a zero mean and constant variance. For convergence in per capita income, growth rates across countries conditionally requires that β_2 is negative. This says that the countries lagging behind in *t* must grow faster over the next *T* years than the leading countries. Hence, the rate of convergence in per capita income is increasing in the size of β_2.

If β_1 is positive and β_2 are negative and significant, and the other $\beta_j s$ are not significant, unconditional convergence occurs.

The specific empirical specification of the growth equation for the study is as follows:

(2) $(\frac{1}{24})$ [ln (y_{2014}) - ln (y_{1990})] = β_1+$\beta_2$ln(y_{1990})+$\beta_3$aglabor_1990+β_4UK+$\beta_5$westafrica +$\beta_6$centralafrica+$\beta_7$life_exp_90+$\beta_8$per_water_90+$\beta_9$lit_90+β_{10}child_lab_90+β_{11}corr_90+β_{12} pop_growth+β_{13}ocean+β_{14}pol_stab+β_{15}stunt+μ

where y_{2014} and y_{1990} are per capita real income in 2014 and 1990. This is a reduced form model of aggregate economic growth of nations in the spirit of Barro and Sali-a-Martin (1992) and Durlauf et al.(2005), and in these studies, equations (1) and (2) are not structural models of economic growth.

As noted above, for per capita income convergence, β_2 must be negative. An increase in log per capita in 1990 should be associated with a lower rate of economic growth of per capita income over 1990-2014. This is a condition needed for lagging countries in 1990 to catch up by 2014. Thus, in the long run these countries will converge. Hence, if β_2 is negative, there will be evidence for conditional convergence.

We have a short list of key conditioning variables and a sizeable list of other possible conditioning variables. We first discuss the key conditioning variables that are available in the beginning of the study period. A higher percent of people in agriculture is expected to have a negative effect on the future average rate of growth because it signals low labor productivity in agriculture. This is likely to slow the rate of future growth (Huffman and Orazem 2007).

Many believe that the UK did a better job investing in a new legal system, property rights and infrastructure, including education, in countries it colonized than other countries, e.g., France, Netherlands. They most likely also adopted English as a language, which is important for understanding much of the advances published in scientific journals. For these reasons, a country that was a UK colony is expected to grow more rapidly (Heldring and Robinsons, 2012).

West, Central, and East Africa have different natural resources, including that Central African countries tend to have less rainfall than West or Eastern Africa. This impacts the production potential of crops (and pastureland). Many of these countries struggle to get enough food and water to grow crops to feed their people and famines sometimes occur. With a low and variable water and food supply, these countries are likely to be less productive and grow more slowly. East Africa is the default category.

Other possible conditioning variables at the beginning of the study period include life expectancy at birth, polluted drinking water, stunting of children, and low literacy. A longer life expectancy at birth is important for creating an opportunity to live and work longer, and a longer life generally increases benefits from investing in human capital. If people are expecting to live longer, there is a larger benefit of learning while young and going to school (Huffman and Orazem 2007). This increases incentive for households, individuals, and society to invest more in education, on-the-job training, and health. When more human capital is available, labor productivity, and more generally economic growth are expected to be higher. However, increasing life expectancy may also lead to population growth, which in turn could decrease income per capita. Work by Cervillate (2006) found that in pre-transitional countries, increase in life expectancy increased population growth rate enough to lower per capita income. While in post-transitioning countries, increase in life expectancy led to an acceleration in human capital and an increase in per capita income. Other things equal, higher population growth would have negative effects on per capita income growth due to diluting factors of production (Cervillate, 2006).

Polluted drinking water is a major carrier of diseases leading to other health problems which lower labor productivity (Fogel, 1994). Eighty-eight percent of diseases in developing

countries comes from unsafe drinking water (Prüss-Üstün, 2008). If unsafe water causes health problems, children would be less likely to attend school and might generally have low energy for work, which would lead to low labor productivity and income growth of a country. Hence, countries with access to safe drinking water are expected to grow faster.

Stunting, which reflects long-term food deprivation, has permanent effects likely compromising organ systems of children and making them unusually short in adult stature (Fogel, 1994). Thus, stunted adults are likely to have low labor productivity. Therefore, countries that have a higher rate of stunting are expected to have lower rates of economic growth convergence.[2]

Since education is hard to measure and SSA countries have low levels of completed schooling, literacy rate is an alternative measure of education and will be used here. People who are literate are better able to acquire and process information for their home and job which will make them more productive and lead to higher economic growth (Schultz, 1977). They are also able to do undertake work requiring greater skills and be more mobile geographically. Thus, countries that have higher literacy rates are expected to grow faster. However, if there is a high rate of child labor (children 7-14 years of age working regularly), these children will not be in school and it will have long-term effects on their labor productivity. Hence, countries with a higher rate of child labor are expected to grow less rapidly.

If a country has less corruption and the people have higher trust in government, they may feel secure in making human capital and other investments that would promote future economic growth. In addition, the economy is more likely to be viewed as fair, encouraging people to work

[2] Stunting of children is also an indicator of just how nutritionally impoverished the general population of a country is likely to be and might cause per capita income in 1990 to be lower than otherwise.

harder, opposed to situations where people get ahead using bribes rather than hard work. Hence, countries with higher rates of corruption are expected to grow more slowly (Huang (2001).

If a country is on the ocean, they have more opportunities for sea ports and shipping, which gives them easier access to international trade. They are better able to import and export more goods, which could increase economic activity for the country, including creating more jobs. Hence, countries on the ocean are expected to grow faster.

Table 2 reports short definitions of each variable in the empirical growth model, and summary statistics— sample mean (for 35 countries) values and standard deviation for these variables. Of particular interest is that the average annual rate of growth of per capita real income over the 24 years period in 2011 PPP's is 1.1 percent. This is the mean for the dependent variable in our growth model. The average annual growth rate of the population over the 24 year period is 2.7%. In 1990, the beginning of the study, the mean share of the labor force working in agriculture is 69%, the mean life expectancy at birth is 52 years, and the mean literacy rate is 47%, 38% of children under 5 are stunted, 31% of children 10-14 years of age were working in the labor force, and 43% of the countries were colonized by the British. Finally, sixty-seven percent of the countries are located on the sea coast.

The $\beta_j s$ in equation (2) are to be estimated using a single cross-section of 35 countries with the dependent variable being the average annual growth rate of per capita GDP in 2011 PPP$s. The explanatory variables are the 1990, or beginning year, value of per capita income and a variety of conditioning variables under the assumption that equation (2) is a reduced-form, it can be estimated by STATA OLS. We will compare the signs of these estimated coefficients with the expected signs, and then perform tests of the null hypothesis that each of them is equal

to zero versus the alternative that they are not zero at the 5% significance level. [3] Estimated coefficients that are not significantly different from zero will be considered for exclusion from later estimates of the empirical growth rate convergence model.

Table 2. Short Definitions and Summary Statistics for the Variables (N=35)

Name	Symbol	Mean/Sd	Description
Annual Growth	ann_growth	.011/.032	Average annual growth rate of per capita income over 1990-2014.
Log of per capita income 1990	log_per_c_90	3.245/.347	Log of per capita income 1990.
Population Growth	pop_growth	.027/.012	Average growth of population from 1988-1990.
Ocean	ocean	.6/.497	1 if country is located on ocean. 0 if no.
Agricultural Labor	aglabor_1990	68.971/19.679	Share of the labor force 15 years and older working in agriculture.
Political Stability	pol_stab	(-0.662)/1.021	Political stability and absence of violence.
West Africa	west_africa	.371/.490	1 if country is located in West Africa. 0 if no.
Central Africa	central_africa	.171/.382	1 if country is located in Central Africa. 0 if no.
Life Expectancy 1990	life_exp_1990	51.742/7.289	Life expectancy at birth.
% of population with access to safe water	per_water_1990	51.228/19.339	Share of households with access to safe drinking water.
Literacy Rate 1990	lit_1990	46.914/20.043	Percent of population that is literate.
Child labor 1990	child_lab_1990	31.374/13.462	Share of children 10-14 in labor force.
UK	UK	.428/.502	1 if country has colonial affiliation with UK. 0 if no.
Corruption 1990	corr_1990	(-.537)/.751	Control of corruption.
Stunting	stunt_1990	38.590/15.520	Share of children under 5 years of age that are stunted.

The Regression Results

Estimates of equation (2) are reported in table 3. Regression R5 includes a full set conditioning variables as suggested by income convergence equation (2). However, it is obvious that with only 35 observations and 15 coefficients to be estimated that we are asking too much of data, which is reflected in low t-values of many of the estimated coefficients (Greene, 2003). Hence, we turn to regressions R1, which tests the convergence hypotheses with an abbreviated

[3] Under the assumption that μ_is are normally distributed, the test statistic will be the "t."

empirical model of per capita income convergence—share of the labor force being in agriculture and for a country having colonial British ties. In this regression, the estimated coefficient β_2 is negative, as required for conditional convergence, and significantly different from zero at the 5% significance level. The estimated coefficient of 0.05 implies that a 10% increase in per capita income in 1990 would be associated with a 0.5 percentage point decline in the average rate of growth of per capita income over 1990-2014. This is large enough to be economically meaningful. The size of the estimated coefficient for the share of the labor force being in agriculture is economically small, i.e., a 10 percentage point increase in the labor force in agriculture reduces average growth of per capita income by 0.09%, but significantly different from zero. If a country was a UK colony, the average annual rate of growth of per capita income would be 1.1 percentage points higher. This result is statistically significant at the 30 percent level. The R^2 for this equation is 0.19.

In regressions R2, we have added two more conditioning variables—whether a country is located in West or Central Africa (relative to East Africa). The estimated coefficients for both of these dummy variables are negative, suggesting that the average rates of growth of per capita income over 1990-2014 is 2.5 percentage points lower in Central than East Africa. This coefficient is significantly different from zero at the 15 percent level. However, average per capita income growth in West Africa is not different from East Africa for any plausible significance level. The estimated coefficient for the percentage of the labor force in agriculture is unaffected by adding these dummy variables. However, the inclusion of these two dummy variables reduces the size of the estimated coefficient for log per capita income in 1990 by about 29 percent and reduces the statistical significance of this coefficient implying that log per capita income in 1990 is correlated with these regional dummy variables. In addition,

Table 3: Estimates of the Per Capita Income Growth Equations for Countries in Sub Saharan Africa, 1990-2014 (absolute value of t values are in parenthesis)

	Average Rate of Growth of Per Capita Income (gy)					*log_per_cap*
Variables	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**
plog	--	--	-0.0818	-0.0726	--	--
	--	--	[2.43]	[2.15]	--	--
log_per_cap	-0.0504	-0.0414	--	--	0.02	--
	*[2.20]	[1.67]	--	--	[0.44]	--
aglabor_1990	-0.0009	-0.0009	-0.0013	-0.0012	-0.0016	--
	[2.32]	[2.04]	[2.61]	[2.47]	[2.09]	--
UK	0.0116	0.0023	0.018	0.0077	0.00114	--
	[1.06]	[0.18]	[1.59]	[0.59]	[0.06]	--
west_africa	--	-0.0065	--	-0.0043	-0.0253	--
	--	[0.05]	--	[0.35]	[1.04]	--
central_africa	--	-0.0249	--	-0.0273	-0.0562	--
	--	[1.44]	--	[1.65]	[1.77]	--
life_exp_90	--	--	--	--	-0.0029	--
	--	--	--	--	[1.51]	--
per_water_90	--	--	--	--	-0.0002	0.0031
	--	--	--	--	[0.36]	[1.35]
lit_90	--	--	--	--	-0.0005	--
	--	--	--	--	[0.80]	--
child_lab_90	--	--	--	--	0.0009	-0.0085
	--	--	--	--	[0.94]	[2.79]
corr_90	--	--	--	--	-0.0189	0.0556
	--	--	--	--	[1.41]	[0.92]
pop_growth	--	--	--	--	-0.1574	--
	--	--	--	--	[0.26]	--
ocean	--	--	--	--	0.006	--
	--	--	--	--	[0.44]	--
pol_stab	--	--	--	--	0.0081	0.0181
	--	--	--	--	[0.98]	[0.42]
stunt	--	--	--	--	-0.0004	-0.0163
	--	--	--	--	[0.30]	[3.29]
_cons	0.2356	0.2108	0.3588	0.3341	0.2456	4.0722
	[2.43]	[2.03]	[2.60]	[2.42]	[1.26]	[14.2]
R^2	0.1945	0.248	0.2179	.2891	0.4034	0.7190
N	35	35	35	35	35	35

R3 and R4 are estimated by instrumental variables using the information in R6, where *child_lab_ stunting* are instruments. They do not have statistically significant coefficients in the growth equ

* absolute value of t values

adding these two variables boosts the R^2 a little. Aglabor is statistically significant with the same coefficient as in regression R1, but aglabor is less significant than in regression R1. [4]

It is possible that log per capita income in 1990 is endogeneous (or contains measurement error), and that instrumenting $\ln(y_{1990})$ in equation (2) would be interesting. In regression R6, we now regress $\ln(y_{1990})$ on five variables—percent of households with access to safe water, share of children 10-14 working, extent of corruption of the government, political stability, and share of children under five that are stunted. These variables are included for the expected immediacy of their impact on per capita income in 1990. However, we place the most emphasis on the child labor and stunting variables. We argue that the extent of stunting of children under five at the start of the period (1990) is a good proxy for just how nutritionally impoverished children are but also the population in general are. This would reduce labor productivity. The results in R6 show that a country with a higher stunting rate for children and/or more child labor have lower per capita income in 1990, which implies these countries start farther behind 1990. In addition, these two variables have estimated coefficients that are significantly different from zero at the 5 percent level.[5]

We now re-estimate R1 and R2 by replacing the actual value of lny_{i1990} with its predicted value (*plog*) from regression R6, and report these new estimates in regressions R3 and R4. Hence, our strategy now becomes one of estimating the growth convergence equation by the Instrumental Variable Method. Moreover, the discussion of the instrumental variable (IV) estimator in the context of our estimation problem is included in Appendix A. Under the null

[4] We also experimented with adding back into regressions R1 and R2 single regressors for average population growth over 1988-1990 (pop_growth), control of corruption in 1990 (corr_90), and both of these variables. However, none of these estimated coefficients was significantly different from zero at even the 10% level.
[5] The R^2 for R6 is 0.719, and the sample F value for the null hypothesis that this equation has no explanatory power is 14.8. The tabled value of the F for 5 and 29 degrees of freedom at the 5% significance level is 2.55.

hypothesis that the regressors included in regression R5 are exogenous, the estimates of the regression coefficients in regressions R3 and R4 are consistent, while OLS estimates are not The estimate of β_2 is now 80% larger in regressions R3 and R4, than in regressions R1 and R2, i.e., a 10% increase in per capita income in 1990 reduces the average rate of growth of per capita income by 0.7 to 0.8 percentage points. This is a large increase, and implies a much higher rate of per capita income convergence. Also, the t-values of the estimated coefficients are general larger, or more significant, in regressions R3 and R4 than in regressions R1 and R2.

Discussion

We now undertake more discussion of the empirical results. Some overall findings are as follows: a larger share of the labor force in 1990 engaged in agricultural labor reduces future economic growth. This was the strongest variable throughout all regressions, surprisingly. The results support the idea that when a country has a larger share of its labor force in agriculture, agriculture is not very productive. If the productivity of agriculture could be increased significantly, it might be possible for some of the agricultural labor to transition to the non-agricultural sector in a way that would increase the rate of future economic growth (Huffman and Orazem 2007).

We consistently find that if a country had a UK colonial affiliation, it has a higher rate of economic growth. This suggests that countries have at least a small advantage for future economic growth if they speak English, or that the systems, e.g., legal, including property rights, the UK put in place complemented later economic growth of per capita income. However, the statistical significance of this coefficient is never smaller than 12 percent. Results from R2 and R4 show that Central African countries grew more slowly than other countries in SSA. This area

is generally drier so there is more frequently a problem with water and food availability, which creates barriers to economic growth.

The share of children working in 1990 (child_lab_ 90) and the share of children under 5 who are stunted (Stunt) have their impacts on per capita income convergence through their impact on per capita income in 1990, or the starting value, but not directly on the per capita income convergence rate though conditioning variables. This is a new and interesting finding.

It is surprising that access to safe water did not affect the economic growth rate. We do not have an explanation for this since water is key to good health, which in turn is key to productivity. Also puzzling, the literacy rate in SSA did not have a negative coefficient in the growth regressions. This could result if technology being used is very simple and jobs don't require more human capital, so literacy doesn't matter much for growth. However, the significance is not strong.

SSA countries seem to be at a stage of development where increasing education does not increase future economic growth. With SSA having a share of their population working in agriculture, they may not have access to current information about likely problems with local corruption. This could explain why corruption does not affect the growth convergence rate.

Conclusion

The goal of this paper was to provide new evidence on the tendency of per capita income in SSA countries to converge over the most recent 25 year period, including examining the effects of new conditioning variables such as education, health and demographics at the starting date on the future rate of economic growth. The main hypothesis was that an increase in log of per capita in 1990 would lower the average rate of growth over 1990-2014. We found evidence of per capita income convergence over 1990-2014 in our conventional model, but when we

instrument per capita income in 1990, the rate of convergence in per capita income increased by a surprising 80%. A one percent increase in log of per capita in 1990 leads to a 0.7 to 0.8 percent decrease in per capita income growth, which is quite large.

We find that convergence in income growth in SSA is most likely conditioned by the share of the labor force in agriculture, a country being in Central Africa (rather than in the East or West), and having a colonial affiliation with the UK. A large number of other conditioning variables consistently did not matter for explaining income growth rate convergence over 1990-2014. These included the population growth, child labor, corruption, location on the ocean, higher political stability, higher life expectancy, percent of population with access to safe water, and the literacy rate.

This paper is also significant because it is the first time anyone has used income data in 2011 PPP$ for a study of growth rate convergence in SSA countries, and also the first to examine the impact of a broad set of conditioning variables on future economic growth rates.

If investments (by the World Bank or aid agencies) could be made in new agricultural technology, new seeds, and plants or improved nutrition or food distribution, the productivity of agriculture could be increased such that some labor could move to the non-agricultural sector. This would have prospects for increasing future economic growth rates.

Appendix A. The IV-Estimation Method for the Linear Regression Model

Consider the linear regression model

(1) $y = X\beta + \mu$ where *y* is n x 1, *X* is n x k, β is k x 1, and μ is n x 1. In addition,

$E\mu = 0$ and $E\mu'\mu = \sigma^2 I_n$. Now, multiply equation (1) by X' to obtain

(2) $X'y = X'X\beta + X'\mu$

If we divide both sides of equation (2) by the number of observation n and take the probability limits, we obtain

(3) $p\lim(X'y/n) = p\lim(X'X/n)\beta + p\lim(X'\mu/n)$

and when *X* and μ are asymptotic uncorrelated then $p\lim(X'\mu/n) = 0$, and equation (2) can be written as

(4) $\Sigma_{Xy} = \Sigma_{XX}\beta$

where $\Sigma_{Xy} = p\lim(X'y/n)$, and $\Sigma_{XX} = p\lim(X'X/n)$ (and $\Sigma_{X\mu} = p\lim(X'\mu/n) = \Sigma_{X\mu} = 0$)
We now have the consistent estimator for β in equation (1):

(5) $\beta = (\Sigma_{XX})^{-1}\Sigma_{Xy}$.

If we estimate the population cross moments by $X'X$ and $X'y$, then we obtain the **ordinary least squares estimator**

(6) $\beta_{OLS} = (X'X)^{-1}X'y$, where $\mathrm{Var}(\beta_{OLS}) = \sigma^2(X'X)^{-1}$ and $\hat{\sigma}^2 = \hat{\mu}'\hat{\mu}$, $\hat{\mu} = \hat{y} - X\beta_{OLS}$.

Which is under these conditions a consistent estimator.

However, suppose that *X* is stochastic and contemporaneously correlated with μ, i.e., $p\lim(X'\mu/n) \neq 0$, which arise if there is one or more endogenous regressors in *X*. Then the ordinary least ordinary least squares estimator is no longer a consistent estimator.

To proceed, let's assume there exist a set of n observations on q variables *Z*, which is uncorrelated with μ, i.e., $p\lim(Z'\mu/n) = 0$, and at the same time is correlated with the original regressor *X*, i.e., $p\lim(Z'X/n) \neq 0$. Now multiply equation (1) by Z' to obtain

(7) $Z'y = Z'X\beta + Z'\mu$.

Dividing equation (7) by n and obtaining the probability limits obtains

(8) $p\lim(Z'y/n) = p\lim(Z'X/n)\beta + p\lim(Z'\mu/n)$ and

(9) $\Sigma_{Zy} = \Sigma_{ZX}\beta$

where Σ_{Zy} and Σ_{ZX} are the probability limits of (*Z'y*/n) and (*Z'*X/n). Thus, under these conditions

(10) $\beta = (\Sigma_{ZX})^{-1}\Sigma_{Zy}$

Estimating Σ_{ZX} and Σ_{Zy} by sample moments (*Z*'X/n) and (*Z*'*y*/n), we obtain the **instrumental variable (IV) estimator** for β

(11) $\beta_{IV} = (Z'X)^{-1}Z'y$ where $\mathrm{Var}(\beta_{IV}) = \sigma^2(Z'X)^{-1}$ and $\hat{\sigma}^2 = \hat{\mu}'\hat{\mu}$, $\hat{\mu} = \hat{y} - X\beta_{OLS}$.

By construction, the IV estimator β_{IV} is a consistent estimator for β. It is important to note that It is important to note that the 2-stage least squares estimator is a special case of an IV estimation method, i.e., the IV estimation method is a more general estimation method (Fomby et. al., 1980).

If $(Z'\mu/\sqrt{n})$ is asymptotically normal (N) distributed with zero mean vector 0 and variance-covariance matrix Ψ, i.e., $N(0, \Psi)$, then the asymptotic distribution of the IV estimator is $\sqrt{n}\,(\beta_{IV} - \beta)$, which is asymptotic normal $N[0, (\Sigma_{ZX})^{-1}\Psi((\Sigma_{ZX})^{-1})']$.

Empirical evidence that an endogenous regressor is included in the matrix *X* is that the β_{OLS} and β_{IV} estimator for this variable differ significantly. Conversely, if the OLS and IV estimators are approximately the same, there is no evidence of endogeneity (Greene 2003).

Sources:

Fomby, T.B., R.C. Hill, and S.R. Johnson. *Advanced Econometric Methods*. New York, NY: Spriner-Verlag, 1980, pp. 255-257.

Greene, W.H. *Econometric Analysis*, 5th Edition. Upper Saddle River, NJ, Prentice Hall, 2003.

Wooldridge, J. M. *Econometric Analysis of Cross Section and Panel Data*. 2nd Edition. Cambridge, MA: The MIT Press, 2010.

References

Barro, R.J. and X. Sala-i-Martin. "Convergence," *J. Polit. Econ.* 100 (April 1992):223-51.

Badr, Ziad; Khan, Tariqul; Campbell-White, Oliver C.; Marrian, Nicki [editor]. *African Development Indicators 2001*. Washington, DC : World Bank Group, 2001.

Bazuin, S., H. Azadi and F. Witlox. "Applicationof GM Crops in Sub-Saharan Africa: Lessons from the Green Revolution." *Biotechnology Advances* 29(2011):908-912,

Cervellati, Matteo and Uwe Sunde. "*Life Expectancy and Economic Growth: The Role of the Demographic Transition."* (May 2009):1-3.

Dervis, K. "World Economy, Convergence, Interdependence, and Divergence." *Money* 15, 2012.: Available at: http://www.imf.org/external/pubs/ft/fandd/2012/09/dervis.htm

Durlauf, S. N., P.A. Johnson, and J.R.W. Temple."Growth Econometrics." *Handbook o Economic Growth. Vol IA.* P. Aghion, S.N. Durlauf Editors, New York, NY:Elsevier 2005, pp. 556-677.

Femstra, Robert C., Robert Inklaar and Marcel P. Timmer., "The Next Generation of the Penn World Table" *American Economic Review*, 105(2015):3150-82.

Fogel, R.W. "Economic Growth, Population Theory, and Physiology: The Bearing on Long-Term Processes on the Making of Economic Policy," *American Economic Review* 84(1994):369-395.

Fukase, E. and Will Martin. "Economic Growth, Convergence, and World Food Demand and Supply." The World Bank Group, *Policy Research Working Paper* #8257 (2017).

Greene, W.R. *Econometric Analysis*. 5th Edition. Upper Saddle River, NJ: Prentice Hall 2003.

Groningen Growth and Development Center. "The Data Base: Penn World table Version 9.0." 2017. Available at: https://www.rug.nl/ggdc/productivity/pwt/

Heldring, Leander and Robinson, James A. "Colonialism and Development in Africa", NBER Working Paper 18566, 2012.

Huang Mo, P. "Corruption and econmic Growth." *Journal of Comparative Economics* 29 (2001):66-79.

Huffman, W.E. and P.F. Orazem. “Agriculture and Human Capital in Economic Growth: Farmers, Schooling and Nutrition,” In *Handbook of Agricultural Economics, Vol 3, Agricultural Development*: *Farmers, Farm Production and Farm Markets,* Robert Evenson and P. Pingali, Eds., New York, NY: Elsevier Science, 2007, pp. 2281-2342.

Pingali, P.L. “Green Revolution: Impacts, Limits, and the Path Ahead.” *Proceedings of the National Academy of Science* 109(July 2012):12,302-12308.

Pritchett, Lant. "Divergence, Big Time." *The Journal of Economic Perspectives,* Vol.11, No. (1997): pp. 3-17.

Prüss-Üstün A., Bos, R., Gore, F. & Bartram, J. Safer water, better health: costs, benefits and sustainability of interventions to protect and promote health.[PDF - 60 pages] World Health Organization, Geneva, 2008.

Schultz, T.W. “The Value of the Ability to Deal with Disequilibria.” *Journal of Economic Literature* 13(1975):827-846.

Wooldridge, J. M. *Introductory Econometrics; A Modern Approach*. 6th Edition. Boston Massachusetts; Centage Learning. 2016.

World Bank. *World Development Report 1993: Investing in Health*. New York: Oxford University Press. 1993.

World Bank. *World Development Report 2012 : Gender Equality and Development*. New York: Oxford University Press. 2012.

World Bank. *World Development Report 2014: Risk and Opportunity*. New York: Oxford University Press. 2014.

World Bank. *World Development Report 2016: Digital Dividends*. New York: Oxford University Press. 2016.

World Health Organization. Database. Childhood Stunting by Country.