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Abstract

We employ bootstrap techniques in a production frontier framework to provide statistical inference for each component in the decomposition of labor productivity growth, which has essentially been ignored in this literature. We show that only two of the four components have significantly contributed to growth in Africa. Although physical capital accumulation is the largest force, it is not statistically significant. Thus, ignoring statistical inference would falsely identify physical capital accumulation as a major driver of growth in Africa when it is not.

JEL classification: C14, O10, O40

Keywords: Africa, Bootstrap, Growth, Production Frontier

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1 Introduction

Over the past four decades, the growth performance of Africa has been poor compared to that of other developing countries. In particular, the average annual African per capita real GDP growth has hardly surpassed two percent, while East Asian countries, for instance, have been experiencing impressive growth rates in the ranges of four to eight percent. This weak performance has driven a large body of studies which often argue that low total factor productivity is the main impediment to African growth (see for example Ndulu and O'Connell, 1999, 2009; Hoeffler, 2002; Tahari et al., 2004). Physical and human capital accumulation, on the other hand, have been identified to facilitate growth in Africa (e.g., Berthelemy and Söderling, 2001; Aka et al., 2004). Despite a growing literature, we still lack the understanding of what significantly drives growth in Africa.

In this study, we investigate the sources of productivity growth in Africa by using a production frontier framework. Noteworthy examples in this line include Henderson and Russell (2005, HR hereafter) and Kumar and Russell (2002). These studies take cross-country labor productivity growth over two time periods and decompose it into different sources. Different from these past studies, we maintain that African countries have access to their own production frontier, and not necessarily to the world production frontier, thus benchmarking African economies against one another.[1] Further, studies that use nonparametric production frontier measurement have largely ignored the issue of statistical inference when identifying the sources of labor productivity growth. We therefore make use of bootstrap methods (Simar and Wilson, 1999) to provide statistical inference regarding the growth components. The only related reference we are aware of is Jeon and Sickles (2004), who apply the Simar and Wilson (1999) method to test for significance of Malmquist indices in a cross-country analysis. However, their focus is on environmental factors and their approach does not analyze the role of either physical or human capital accumulation.

Our results show that, over the 1970 – 2007 period, only human capital accumulation and efficiency changes are statistically significant on average. Although physical capital accumulation is the largest component on average, it is not statistical significant. Therefore, if we were to ignore statistical inference, we would falsely identify physical capital accumulation as a major driver of economic growth in the region.

[1] For example, Fethi et al. (2011) advocate existence of separate production frontiers. Similarly, Grosskopf and Self (2006) analyze Southeast Asian economies in isolation from the rest of the world.

2 Methodology

In this section, we follow the methodology of HR to decompose labor productivity growth ($PROD$) into components attributable to (i) efficiency changes (EFF), (ii) technological change ($TECH$), (iii) capital deepening ($KACC$), and (iv) human capital accumulation ($HACC$). We specify the technology that contains four macroeconomic variables: aggregate output and three inputs—labor, physical capital, and human capital. We estimate the technology nonparametrically by means of Data Envelopment Analysis (DEA), which rests on assumptions of free disposability to envelope the data in the smallest convex cone, the upper boundary of which is defined as the "best-practice" frontier. Using DEA, we calculate various distance functions that serve as building blocks for the quadripartite decomposition of the growth of labor productivity between the two periods:[2]

$$PROD \equiv EFF \times TECH \times KACC \times HACC. \tag{1}$$

One major issue with the approach of HR and others in this line of research is that it ignores the issue of statistical significance of the components of labor productivity growth. Indeed, the individual and average components found in HR and related papers are point estimates. They are calculated using the distance functions that are measured relative to the finite sample DEA *estimate* of the true and unobserved frontier. Using the finite sample estimate implies that the distances and consequently the components of the quadripartite decomposition are subject to sampling variation of the estimated frontier.

Simar and Wilson (1998) were the first to show that a *consistent* bootstrap procedure can be used to analyze the sensitivity of distance functions relative to such sampling variations. Simar and Wilson (1999) furthered this idea to estimate the sampling distribution and confidence intervals for Malmquist productivity indices (a measure of productivity change) and its components. Building on Simar and Wilson (1999), we use a bootstrap procedure to provide statistical inference on the components of the quadripartite decomposition. We overcome the challenge of possible time dependence by using a bivariate kernel estimator of the joint density of the DEA estimates of the distance functions. Technical details can be found in Simar and Wilson (1999).

[2]Further details on the decomposition can be found in HR.

3 Data

We derive data for 35 African countries for the period 1970 – 2007 from the Penn World Tables.[3] The number of workers is obtained as RGDPCH * POP/RGDPWOK, where RGDPCH is per capita GDP computed via the chain method, POP is the population and RGDPWOK is real GDP per worker. The measure of output is calculated as RGDPWOK multiplied by the number of workers; the resulting output is in 2005 international dollars. Real aggregate investment in 2005 international dollars is computed as RGDPL * POP * KI, where RDGPL is real GDP computed via the Laspeyres index, and KI is the investment share of real GDP. We follow Caselli and Feyrer (2007) and apply the perpetual inventory method to the real investment series to construct the physical capital stock. We follow HR and adopt the Hall and Jones (1999) construction of human capital using an updated education database (Barro and Lee, 2010), whereby we use the average (African) returns for each level of education found in Table A1 of Psacharopoulos and Patrinos (2004).

4 (In)significant results

Here we present our main results. First, we look for significance of the average estimates, both weighted and unweighted, from the decomposition. Second, we focus on the estimates for specific countries and pay attention to countries that deviate from average behavior. Our sole table (Table 1) contains five columns: productivity change (in percent) and the percentage contributions of the four components of labor productivity growth. The significant components are in bold. All significant components turn out to be so at the 1% level.

As we believe that African countries may belong to a different frontier than the rest of the world, we expect that only using African countries might have an effect on the estimates (both in terms of absolute values and significance). We therefore also performed the same analysis on a much wider sample of countries during the same time period. With respect to the estimates for the African countries, while the absolute value of the components of the decomposition sometimes change, we generally find that the significance does not.[4]

[3] We use Version 6.3 since it is arguably more reliable than the new version 7.0 (see Breton, 2012).

[4] These results are available from the authors upon request.

4.1 Average estimates

The final two lines of Table 1 list the average and weighted average of each particular column over the 35 economies.[5] The row labeled "Average" is the simple arithmetic average and the "Weighted Average" weights each of the estimates by their relative 2007 output, similar to Zelenyuk (2011).

The average productivity growth in Africa over the 1970-2007 period is 54%. While this number may not seem small, note that this same percentage is nearly four times as large for Ireland and nearly twenty times as large for China over the same time frame. Note that the statistical inference cannot be provided for productivity measures since they are actual data points, not point estimates.

The average EFF, $TECH$, $KACC$, and $HACC$ components are -38.21, 1.53, 67.35 and 60.19%, respectively.[6] Ignoring statistical significance, these results suggest that capital deepening is the primary driver of labor productivity growth in Africa followed by human capital accumulation. Technological change is essentially nonexistent and efficiency changes actually led to regress.

Of the four components, only efficiency changes and human capital accumulation are *significant* on average. Thus, if we ignore statistical inference, we would falsely conclude that the physical capital accumulation is the major driving force behind productivity growth. A possible explanation for the insignificance of physical capital contribution is that the value of capital stock in developing countries does not necessarily reflect its public investment cumulated at cost (Pritchett, 2000). Further, if government investment spending has created little useful capital, its contribution to productivity growth will likely be insignificant. Besides, certain norms may generate inefficiencies by discouraging effort (see Platteau, 2009) encourage a misallocation of resources or encourage people to hide their wealth (Baland et al., 2011).

The weighted averages, ignoring statistical significance, show that human capital accumulation plays a larger role than physical capital accumulation, but we still see that physical capital accumulation and technology changes are insignificant on average. We should note that when we look at the (unreported) extended sample of countries that

[5] We note that bootstrap techniques have been applied for inference regarding aggregate efficiencies of countries (see Henderson and Zelenyuk, 2007), but not with respect to the components of decomposition.

[6] Percentages are obtained by subtracting 1 from the index and multiplying by 100. Because of compounding, the average contributions of individual components do not, of course, sum to the average productivity change.

the average contribution of physical capital (weighted or unweighted) is statistically significant, but still insignificant for Africa on average.

4.2 Individual estimates

Many of the individual results mimic the averages. The majority of efficiency components are negative and significant. The characterization of the African inefficiency may be related to the effect of genetic diversity recently advanced by Ashraf and Galor (forthcoming). Virtually all technology components are near zero and none are significant. The interesting results are with respect to physical capital accumulation. Although most are insignificant, we find several (8/35) which are positive and significant. Finally, most $HACC$ components are positive and significant.

We now turn our attention to observations which differ from the averages. With respect to efficiency change, Malawi and Mauritius are the only two countries that have positive and significant efficiency components. This finding for Mauritius is consistent with the widely held view that it is a successful African story with successful development strategies (e.g., their import substitution investment and export processing zone strategies). This success story deserves particular attention because initial conditions were weak in Mauritius even compared to other African nations, which led some economists to ponder whether or not that country would fail to develop (Meade, 1961). Similarly, Malawi achieved impressive productivity growth in recent years thanks to better governance and a development strategy based on improvement in land and labor productivity. As such, the country is currently a net food exporter in contrast to its earlier years of food insecurity.

We find very small changes in technology across the countries and none of them are significant. In fact, only 11 countries have components different from zero (of course none in a statistical sense). This result is perhaps expected as HR and others have shown that there is little to no technological improvement for Africa. The difference here is that we are able to show this with statistical evidence.

While many countries have large components for physical capital accumulation, it is only statistically significant for 8 countries: Botswana, Egypt, Lesotho, Liberia, Mali, Mauritius, Sudan, and Swaziland. Consider for example the case of Liberia. The colonial history of Liberia is very different from other African countries. In particular, while others have been colonized by Europeans, Liberia was founded and colonized by freed American slaves. As such, Liberia has strong historically ties with the United

States. These ties encouraged FDI inflows to the country. A main source of income was mining iron, a sector that is capital intensive.

It is also interesting to see losers in terms of human capital accumulation. Only two countries have insignificant $HACC$ terms. Specifically, Lesotho and Mozambique have small positive, but insignificant components. This result may reflect the damaging effect that HIV has had on human capital development in these countries (Channing, 2006).

5 Conclusion

Studying growth patterns and determinants of African economies is essential for understanding what can be done to reduce the gap between the performance of the continent and the rest of the world. Using bootstrap method originally designed for Malmquist indices we introduce statistical inference into the quadripartite decomposition of labor productivity growth developed by HR to analyze the components of growth in Africa. The results identify human capital accumulation as a major and the only positive and significant (in a statistical sense) driving force behind labor productivity growth in Africa. The study also shows that productivity growth is significantly hampered by efficiency losses. Technological change is nonexistent in the sample. Finally, and most importantly, ignoring statistical inference would lead us to falsely conclude that physical capital accumulation is a major economic engine in Africa when it is not.

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Table 1: Statistical significance of the Productivity and Percentage contributions to labor productivity change, 1970−2007, (all values in bold are significant at the 1% level)

#	Country	PROD	EFF	TECH	KACC	HACC
1	Algeria	−14.49	**-74.895**	4.40	3.511	**215.169**
2	Benin	23.52	**-32.623**	0.00	22.725	**49.375**
3	Botswana	579.91	0.005	3.34	**143.083**	**170.639**
4	Burundi	−23.15	**-73.618**	0.00	149.136	**16.919**
5	Cameroon	50.61	**-43.991**	0.00	64.191	**63.778**
6	Central African Republic	−29.44	**-47.11**	0.00	-11.763	**51.204**
7	Congo	60.70	**-19.213**	0.00	27.152	**56.437**
8	Cote d'Ivoire	−7.20	**-28.289**	0.00	-0.943	**30.642**
9	Egypt	164.72	**-24.51**	0.00	**61.485**	**117.151**
10	Gabon	1.74	**-63.586**	0.00	33.793	**108.837**
11	Gambia	2.74	**-59.383**	0.00	71.171	**47.776**
12	Ghana	20.87	-5.534	0.00	-17.288	**54.693**
13	Kenya	7.45	**-39.79**	0.00	4.874	**70.164**
14	Lesotho	180.57	**-34.101**	0.00	**261.398**	17.811
15	Liberia	−78.52	**-91.709**	0.00	**82.779**	**41.701**
16	Malawi	134.71	**42.138**	0.00	5.713	**56.201**
17	Mali	110.75	-8.64	0.00	**89.471**	**21.75**
18	Mauritania	21.15	**-37.679**	0.00	42.056	**36.849**
19	Mauritius	214.61	**73.75**	6.77	**22.257**	**38.718**
20	Morocco	40.11	**-49.317**	8.07	32.951	**92.412**
21	Mozambique	89.87	2.015	0.00	80.339	3.203
22	Namibia	14.86	**-40.175**	5.58	12.536	**61.596**
23	Niger	−34.84	**-51.333**	0.00	15.213	**16.211**
24	Rwanda	−2.83	**-67.047**	0.00	132.888	**26.611**
25	Senegal	−6.88	**-57.969**	0.00	66.992	**32.671**
26	Sierra Leone	−25.18	**-48.805**	0.00	9.515	**33.442**
27	South Africa	29.82	**-31.37**	5.06	9.168	**64.929**
28	Sudan	88.98	**-72.323**	4.14	**392.219**	**33.21**
29	Swaziland	198.25	**-62.614**	2.15	**406.362**	**54.239**
30	Tanzania	56.00	**-36.551**	0.00	95.486	**25.772**
31	Togo	−34.69	**-64.78**	0.00	5.916	**75.067**
32	Tunisia	139.61	-21.468	7.36	7.821	**163.587**
33	Uganda	12.41	**-42.081**	0.00	41.835	**36.839**
34	Zambia	−32.52	**-45.493**	2.58	-11.721	**36.702**
35	Zimbabwe	−57.92	**-79.109**	3.99	5.06	**84.358**
	Average	54.18	**-38.206**	1.53	67.354	**60.19**
	Weighted Average	68.91	**-36.276**	3.07	47.551	**92.48**