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EDUCATION VS TFP: EMPIRICAL EVIDENCE FROM THE
SUB-SAHARAN COUNTRIES

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Education vs TFP: Empirical Evidence from The Sub-Saharan Countries

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Abstract

This paper investigates the “*education-total factor productivity trade-off*” in explaining per worker income differences between Sub-Saharan (unlucky) and G7 (lucky) economies. Following Hall and Jones (1999) and Caselli (2005), on a country basis, I am able to study separately the dynamic of the average years of schooling (i.e. education level), the per worker capital, the per worker income, and the total factor productivity (TFP). I confirm that physical capital and education levels partially explain income differences between unlucky and lucky economies. In a time-series setup I create, on a country-by-country basis, *ad hoc* TFP shock times series. The main result of this paper is that the impact of TFP shocks on per worker income is larger in unlucky economies than in lucky ones. The result holds both for negative and positive shocks. I show that average TFP volatility in the “unlucky world” is 8 times higher than the “G7 world” average TFP volatility. I argue that the order of magnitude of the impact heavily depends on the level of the TFP volatility. It turns out also that the effect of a TFP shock on a relative low per worker income growth rate is higher. I conclude by arguing that the presence of low levels of per worker capital and of human productivity pushes the unlucky economies into a poverty trap. (**JEL:** *I24, I25, O10, O11, O16, O47, O55.* **Keywords:** *Education, TFP Shocks, Poverty Trap*)

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1 Introduction

It is commonly believed that cross-country differences in per worker income are huge. Differences across countries can be attributed to differences in human capital, physical capital, and TFP. It is also largely accepted that standard production functions may fail in capturing cross countries income differences. For example, Pritchett (1996) argues that data (i.e. Barro-Lee) on the growth of years of schooling provide no support at all for the proposition that more rapid rates of growth of education capital produce greater output growth. He shows that the estimated impact of educational capital accumulation on a widely accepted, growth accounting, definition of TFP growth is large, negative, and statistically significant. He provides three possible explanations for this puzzling result: 1. perhaps schooling has, on average in the sample, created no skills; 2. perhaps the rate of expansion of schooling has greatly increased the supply of educated labor; 3. perhaps schooling has created cognitive skills but the typical institutional environment was sufficiently bad that these skills were devoted to privately remunerative but socially wasteful, or even counter-productive, activities relative to demand so that the rate of return has fallen over time. In showing that education is not a sufficient condition for growth, Pritchett (1996) does not support the idea that education is powerless, but he points out that this intuitively results raises the importance of identifying and undertaking those complementary reforms in the non-education sector that will lead education to pay off.

The Pritchett's (1996) empirical result reflects recent empirical regularities supporting the poor role played by education in explaining cross-country income differences. It is common believed that institutions stand behind the "rules of the games" of a society. Hall and Jones (1999) and Caselli (2005) argue that differences in output per worker are fundamentally related to differences in social infrastructures across countries.

North (1994) indicates that institutions embody the incentive structure of a society and are the underlying determinants of economic performance. Shleifer and Vishny (1993), Mauro (1995), and Ehrlich and Lui (1999) argue that corruption hampers economic growth. Hall and Jones (1999) and Acemoglu et al. (2002) both demonstrate the importance of an institutional environment in explaining economic growth. Thus, countries with different levels of institutional quality have different economic growth rates. Using geographic information system (GIS) mapping, Sachs (2001) presents evidence that production technology in the tropics has lagged behind temperate zone technology in the two critical areas of agriculture and health, and this in turn opened a substantial income gap between climate zones. He argues that the difficulty of mobilizing energy resources in tropical economies is emphasized as another significant contributor to the income gap. Mazur (2000) argues that the globalization has dramatically increased inequality between and within nations. Kremer and Maskin (2006), supporters of the anti-globalization movement argue that globalization has marginalized the poor in developing countries and left behind the poorest countries. Clinton (2000), during a session on the Indian parliament, argues that the poor must invest in education to take advantage of globalization.¹

The empirical evidence suggest that, although the average years of schooling, both in primary and secondary school (i.e. higher investments/aids in education), sharply increased in several poor economies during the last 20 years, income inequalities are still high.

¹See Clinton (2000). Address to a Joint Session of the Indian Parliament, March 2000.

It has been already proved that, and will be found again to be true here, output per worker varies enormously across countries. Hall and Jones (1999), on an accounting basis, show that differences in physical capital and educational attainment can only partially explain the variation in output per worker. Differently, they find a large amount of variation in the level of the TFP (i.e. Solow residual/technological progress) across countries. At a deeper level, they also document that the differences in capital accumulation, productivity, and therefore output per worker are driven by differences in institutions and government policies, which they call social infrastructure. Caselli (2005) argues that the observed differences in the factors employed in production do not totally explain most of the cross-country variation in income. He claims that human capital measures should account for differences in the quality of schooling and in health status of the population; the age composition of the capital stock. For example he finds that, disaggregating the government sector out of the data may also potentially reduce the unexplained component of total output.

The empirical part of these two seminal contributions combines variables from two main dataset, the PENN WORLD TABLES and the Barro-Lee educational attainment data set.

The empirical part of this paper is most closely related to Hall and Jones (1999) and Caselli (2005). Thanks to this empirical scheme, education, capital and technological progress can be separately treated and analyzed. I confirm that differences in physical capital and education between Sub-Saharan and G7 economies do not fully explain the huge gap in per worker income. As expected the TFP plays a crucial role in understanding the existence of a cross-country income puzzle. The unlucky economies average TFP accounts only for 27% of the US TFP.

The key contributions compared to those papers are the analysis of the capital, education, TFP and output in a time series framework, the analysis of the dynamic of capital accumulation, the construction of ad hoc tech shocks and the study of the difference impacts of these shocks on per worker output.

The paper is organized as follows. Section 2 describes data. Section 3 discusses empirical results on output, education and technological progress, and studies the impact of TFP shocks on per worker income growth rates. Section 4 provides theoretical supports for the poor conditions of the Sub-Saharan countries. Section 5 concludes.

2 Data Description and Preliminary Analysis

In 2010, the thirty-two Sub-Saharan countries on which I focus had a combined population of 516 million and an average annual per capita income of \$3.270 (i.e. \$9 per day). To exploit cross-country income differences the G7 Economies are used as benchmark. In 2010 the G7 had a population of 735 million an average annual per capita income of \$35.278 (i.e. \$98 per day). Average savings to GDP ratios over the sample 1980-2011 are 14.87% and 20.69% respectively for the Sub-Saharan and G7 sets of countries. Data are from IMF and include all countries listed in Table 1.² Most of the studied unlucky economies are geographically represented in Fig. 1.

The time series are obtained using the empirical procedure developed by Hall and Jones (1995), and Caselli (2005). I assume that output Y is produced according to the following production function

²Savings to GDP ratio data for Liberia and Zimbabwe are not available. Per capita GDP are based on purchasing-power-parity (PPP) in current international dollar.

$$Y = AK^\alpha(Lh)^{1-\alpha} \quad (1)$$

where K is the aggregate capital stock and Lh is the quality adjusted workforce, namely the number of workers L multiplied by the average human capital h and A corresponds to the Total Factor Productivity (TFP). Throughout the paper I use the terms total factor productivity, Solow's residual, or technological progress interchangeably. In per worker terms the production function can be written as follows:

$$y = Ak^\alpha h^{1-\alpha} \quad (2)$$

where k is the capital labor ratio.

As investigated by Hall and Jones (1999), and by Caselli (2005), I am interested in studying how much of the per worker income gap across countries can be described by each production factor (i.e. A , h and k), as defined in Eq. 2. To address the issue, I use the following set of info: a. y (i.e. per-worker output); b. k (i.e. capital labor ratio); c. h (i.e. total average years of schooling); d. the value for the capital share α

Figure 1: The Sub-Saharan Countries

In line with the Caselli's work the data set combines variables from two sources. The first is version 7.0 of the PENN WORLD TABLES. From PENN TABLES, I extract output, capital and the number of workers. The second is the Barro-Lee educational attainment dataset. The latter used to find data at educational level. Data run from

1950 or later to 2007.³ The variable y is measured from PWT63 as real GDP per worker in international dollars (i.e. in PPP, this variable is called *rgdpwok* in the original data set). For more recent data on real GDP per worker in international dollars (e.g. 2010), I use the International Monetary Fund Database.

Capital stock, K , is estimated using the perpetual inventory equation

$$K_t = I_t + (1 - \delta)K_{t-1}$$

where I_t is investment and δ is the depreciation rate. I compute the investment series as real aggregate investment in PPP (i.e. compute as *rgdpl* · *pop* · *ki*, where *rgdpl* is real income per capita).

I estimate the initial value of capital stock K_0 as $\frac{I_0}{(\delta+g)}$ where I_0 is the value of the investment series in the first year it is available (i.e. in my dataset the initial investment value ranges from 1950 to 1970), and g represents the average geometric growth rate for the investment series computed over the first twenty years of available data.

To construct human capital h I take from Barro-Lee data set the average years of schooling in the population over 25 years old. According to Hall and Jones (1999) h can be computed as follows:

$$h = e^{\theta(s)}$$

where s is the average years of schooling and $\theta(s)$ is piecewise linear function.⁴

Notice that s is observed in the data every 5 years (i.e. 1950 - 1955 - 1960 etc).⁵ Caselli (2005): “since s moves slowly over time, a five-years observation can plausibly be employed for nearby dates as well”. The last parameter to be determined is α . As suggested by literature, I assume capital share to be 1/3.

The TFP (i.e. A) is obtained as residual of Eq. 2, formally:

$$A = \frac{y}{k^\alpha h^{1-\alpha}} \quad (3)$$

Ad hoc TFP shocks are also constructed. As shock measure I adopt an indicator that takes value 1 for each “extraordinary event”, either positive or negative. An extraordinary event is chosen as that with TFP growth rate below (above) 1.43 standard deviation minus (plus) the mean of the Hodrick-Prescott filtered TFP growth rate series. To each extraordinary event, either positive or negative, corresponds a 1, otherwise I assign a zero.⁶ Formally, a 1 is assigned if the rate of growth of A is below or above the following threshold

$$TFP Shock_t = \mu_A^{hp} \pm 1.43\sigma_A \quad (4)$$

where μ_A^{hp} represents the mean of the Hodrick-Prescott filtered TFP growth rate series and σ_A is the standard deviation of the TFP growth rate. In Table 4, I present

³PENN TABLE starting dates (in brackets): Benin (1959), Botswana (1960), Burundi (1960), Cameroon (1960), Central Afr. Rep. (1960), Congo (1960), Cote d’Ivoire (1960), Dem. Rep. of Congo (1950), Gabon (1960), Gambia (1960), Ghana (1955), Kenya (1950), Lesotho (1960), Liberia (1970), Malawi (1954), Mali (1960), Mauritania (1960), Mauritius (1950), Mozambique (1960), Namibia (1960), Niger (1960), Rwanda (1960), Senegal (1960), Sierra Leone (1961), South Africa (1950), Sudan (1970), Swaziland (1970), Tanzania (1960), Togo (1960), Uganda (1950), Zambia (1955), Zimbabwe (1954), Canada (1950), France (1950), Germany (1970), Italy (1950), Japan (1950), UK (1950) and USA (1950).

⁴Following Hall and Jones (1999), $\theta(s)$ is defined as follows: $\theta(s) = 0.134 \cdot s$ if $s < 4$, $\theta(s) = 0.134 \cdot 4 + 0.101 \cdot (s - 4)$ if $4 < s \leq 8$ and $\theta(s) = 0.134 \cdot 4 + 0.101 \cdot 4 + 0.068 \cdot (s - 8)$ if $s > 8$

⁵See Barro and Lee website: <http://www.barrolee.com/>.

⁶A similar procedure can be found in Bloom (2009), and Cazzavillan and Donadelli (2010).

the average contribution of each input to income (see appendix A) . The decomposition is the result of the log tranformation of Eq. 2, and takes the form

$$\log(y) = \log(A) + \alpha \log(k) + (1 - \alpha) \log(h)$$

This very simple trick allows us to capture the major issue of this part of the growth accounting literature. My numbers suggest that income is mostly determined by capital (i.e. $\alpha \log(k)$) and technological factors (i.e. $\log(A)$). In the 32 Sub-Saharan countries the quantity $\frac{(1-\alpha)\log(h)}{\log(y)}$ is on average equal to 3.18%. The average contribution of capital and TFP is respectively equal to 55.28% and 41.54%. Similar results are obtained for the G7 economies.

I conclude that education, here captured by the average years of schooling, contributes marginally to per capita income wealth. The naive results illustrated in Table 4 force us to study in more details the role of capital, education and TFP in understanding income differences between Sub-Saharan and G7 countries. Next sections are devoted to capture the reasons behind the huge gap, in terms of standards of living, between unlucky and lucky economies.

3 Income Differences: An Empirical Review

3.1 Output, Education and Total Factor Productivity

Output per worker varies enormously across countries. The gap is huge as soon as poor and rich economies are compared. Hall and Jones (1999), on an accounting basis, show that differences in physical capital and educational attainment can only partially explain the variation in output per worker. Instead, they find a large amount of variation in the level of the Solow residual across countries. Their main hypothesis is that differences in capital accumulation, productivity, and therefore output per worker are fundamentally related to differences in social infrastructure across countries.

Caselli (2005), using the benchmark Hall and Jones' (1999) production fuction, argues that only a small fraction of cross-country income variance can be attributed to differences in (physical and human) capital. In particular, he finds that the fraction of the variance of income explained by observed endowments is equal to 0.39.⁷ This implies that a large portion of the variance is explained by the Solow's residual. The empirical phenomenom supports our interest in studying deeply the impact of TFP shocks on in income.

A further support is provided by Hall and Jones (1999):

“Countries produce high levels of output per worker in the long run because they achieve high rates of investment in physical capital and human capital and because they use these inputs with a high level of productivity”

In Table 1, I report the summary statistics of the population, income, education level and capital. The time series are obtained following the procedure descibed in Section 2. In addition, I show the average of the population growth rate and of the

⁷Formally, Caselli (2005) uses the following measure of success:

$$success_1 = \frac{var[\log(y_{KH})]}{var[\log(y)]}.$$

Country	$\bar{Pop.}$	$\bar{y}$	$\bar{k}_{\%}$	$\bar{h}$	$\bar{k}_S$	$\bar{A}$	σ_A^2
Sub-Saharan Africa							
Benin	2.854	1.150	1.101	1.579	580,529.9	0.225	0.277
Botswana	2.636	6.508	11.208	4.290	2,722,750.3	1.697	0.752
Burundi	2.399	0.895	2.537	1.400	75,800.3	-0.331	0.580
Cameroon	2.319	1.143	3.780	2.963	785,174.8	-0.869	0.278
Central African Republic	2.273	-0.764	-2.562	1.680	296,073.1	-0.439	0.216
Congo, Republic The	2.716	2.213	-0.437	3.513	1,125,737.8	1.605	0.636
Cote d'Ivoire	3.410	0.700	1.170	2.084	431,322.5	-0.252	0.237
Democratic Republic of Congo	2.797	-1.179	-0.886	1.924	296,502.5	-1.334	1.536
Gabon	2.227	2.298	2.344	3.509	7,436,666.3	0.419	0.683
Gambia	3.173	1.256	4.435	1.276	194,579.3	-0.664	0.455
Ghana	2.591	2.008	-1.164	4.052	1,087,550.4	1.537	1.326
Kenya	3.190	0.379	-0.004	3.732	430,677.6	-0.375	0.244
Lesotho	1.657	2.784	12.666	4.058	494,800.0	-1.418	0.538
Liberia	2.585	-1.470	-4.900	1.995	993,403.5	-0.279	5.415
Malawi	2.886	2.477	3.711	2.207	648,237.1	0.654	0.971
Mali	2.220	-3.418	3.912	0.641	395,543.5	0.097	0.379
Mauritania	1.945	2.407	1.770	2.311	1,021,951.2	1.383	0.873
Mautitius	1.681	1.727	1.176	5.138	3,594,133.1	0.720	0.338
Mozambique	2.160	1.837	3.414	0.022	99,453.8	0.627	0.231
Namibia	2.604	1.104	2.028	4.569	3,497,271.6	-0.063	0.253
Niger	2.677	-0.083	1.930	0.759	354,120.5	-0.919	0.418
Rwanda	2.642	1.304	3.419	1.677	144,542.2	-0.345	1.666
Senegal	2.601	0.242	2.710	2.858	406,108.6	-1.139	0.202
Sierra Leone	1.558	1.204	4.485	1.559	247,637.8	-0.611	0.598
South Africa	2.201	1.149	1.577	5.684	4,255,861.4	0.188	0.109
Sudan	2.875	1.545	3.368	1.447	304,383.5	-0.010	0.924
Swaziland	2.705	2.779	2.820	4.081	1,719,355.8	0.957	0.675
Tanzania	2.825	0.096	4.103	3.107	232,829.8	0.096	0.181
Togo	2.928	-0.055	1.949	2.533	621,269.6	-1.479	0.404
Uganda	3.044	1.370	2.413	2.519	171,091.1	-0.005	0.249
Zambia	2.806	0.826	0.035	4.007	844,676.3	0.136	0.790
Zimbabwe	2.384	-0.512	0.743	4.353	127,199.8	-1.501	0.886
Advanced Economies							
Canada	1.490	1.401	2.118	9.568	9,362,137.2	0.333	0.053
France	0.707	2.588	3.671	6.361	9,739,378.0	0.810	0.066
Germany	0.306	1.359	0.669	6.769	15,704,562.1	0.201	0.100
Italy	0.424	3.240	4.400	6.535	11,348,080.5	1.275	0.057
Japan	0.709	3.850	6.960	9.064	10,997,926.0	1.287	0.308
United Kingdom	0.361	1.871	3.778	7.604	6,932,284.4	0.283	0.039
United States	1.196	1.649	2.068	11.139	11,241,901.5	0.614	0.063
Average (32 Sub-Saharan)	2.549	1.060	2.339	2.735	1,113,663.6	-0.053	0.729
Standard Deviation (32 Sub-Saharan)	0.444	1.673	3.279	1.397	...	0.895	0.941
Average (7 Developed)	0.742	2.280	3.381	8.149	10,760,895.7	0.686	0.098
Standard Deviation (7 Developed)	0.448	0.972	2.032	1.816	...	0.457	0.094

Table 1: The elements of this table represent the mean values of the rate of growth of the population ($\bar{Pop.}$), per worker real GDP ($\bar{y}$), per worker capital ($\bar{k}_{\%}$), the human capital ($\bar{h}$) and Solow's residual ($\bar{A}$). The 5th column represents the mean of the *per worker capital* stock (measured in millions of US dollars). The last column display the variance of the TFP (σ_A^2). Numbers are all expressed in percentage points. Data run from 1950 to 2009. Sources: PENN WORLD Tables, Barro-Lee Data Set.

per worker capital stock, as well as the variance of the TFP. Statistics are computed on a country-by-country basis. Columns three, four and six of Table 1 are enough, obviously in the opposite way, to support the Hall and Jones' conclusion. Numbers presented in these columns show that the average growth rate of per worker income is lower across unlucky economies than across lucky economies (i.e. 1.060% vs 2.280%). As expected, according to neoclassical growth theory, this long-run result appear to be pretty unfair and counterintuitive. Why?

The comparison of the average per worker capital and average TFP growth rate between unlucky and lucky economies provides a pretty clear answer. Unlucky economies' average per worker capital growth rate and average TFP growth rate are respectively 2.339% and -0.053%. For lucky economies I have 3.381% and 0.686% respectively.

Summary statistics' heterogeneity is present also with in the Sub-Saharan area. For example, the per worker income ranges from \$728.57 (Burundi) to \$ 23,066.90 (Gabon), and the per worker capital ranges from \$ 75,800.33 (Burundi) to \$ 7,436,666.28 (Gabon). The gap with the G7 economies is still significantly high. The per worker income interval goes from a min of \$ 38,014.08 (Japan) to a max of \$ 56,281.49 (USA); and goes from a min of \$ 6,932,284.44 (UK) to a max of \$ 15,704,562.07 (Germany) for the per worker capital.⁸ Average years of schooling min-max intervals are [0.02 (Mozambique) - 5.68 (South Africa)] and [6.36 (France) - 11.14 (USA)].

I emphasize the following empirical issues:

1. the absolute convergence theory does not apply;⁹
2. the rate of growth of the technological progress across unlucky economies is on average negative;¹⁰
3. the rate of growth of per worker capital is negative in 6 out of 32 unlucky economies (i.e. average negative capital accumulation).¹¹

The results mostly support the past empirical evidence that differences in physical capital intensity and differences in educational attainment explain only a small fraction of the differences in output per worker across countries. In Table 2, I report country-by-country empirical counterparts of Eq. 2. All countries' (unlucky and lucky) production inputs are weighted over the US. Formally:

$$y = \frac{y_i}{y_{US}}; \quad k = \frac{k_i^\alpha}{k_{US}^\alpha}; \quad h = \frac{h_i^{1-\alpha}}{h_{US}^{1-\alpha}}; \quad A = \frac{A_i}{A_{US}} \quad (5)$$

Data suggests that, under this benchmark production function, the TFP plays a crucial role in explaining why unlucky economies are not able to emerge. The average TFP weighs only 27%. Education and per worker capital seem to weigh more, respectively 60% and 40%.

Hall and Jones (1999) argue that one possible interpretation of this result is that I must consider other differences, such as the quality of human capital, on-the-job

⁸Min and max values are country specific sample averages, and data run from 1950 or later to 2009.

⁹A detailed discussion is provided in Section 4.

¹⁰Negative average TFP growth rates are found in the following unlucky economies: Burundi, Cameroon, Central African Republic, Cote d'Ivoire, Dem. Rep. of Congo, Gambia, Kenya, Lesotho, Liberia, Niger, Namibia, Rwanda, Senegal, Sierra Leone, Sudan, Togo, Uganda, Zimbabwe (i.e. $\sim 50\%$).

¹¹

Country	Productivity Factors: Contribution			
	y	k^α	$h^{1-\alpha}$	$A = \frac{y}{y_{kh}}$
Advanced Economies				
United States	1.000	1.000	1.000	1.000
Canada	0.874	0.942	0.931	0.996
France	0.793	0.934	0.776	1.093
Germany	0.948	1.132	0.836	1.002
Italy	0.791	0.974	0.785	1.035
Japan	0.675	0.918	0.892	0.825
United Kingdom	0.760	0.835	0.839	1.084
Sub-Saharan Africa				
Benin	0.043	0.376	0.541	0.213
Botswana	0.175	0.568	0.697	0.441
Burundi	0.013	0.187	0.533	0.130
Cameroon	0.081	0.405	0.624	0.320
Central African Republic	0.031	0.297	0.551	0.191
Congo, Republic The	0.079	0.470	0.656	0.255
Cote d'Ivoire	0.068	0.338	0.571	0.354
Democratic Republic of Congo	0.034	0.300	0.551	0.204
Gabon	0.410	0.869	0.656	0.719
Gambia	0.035	0.255	0.527	0.257
Ghana	0.036	0.460	0.673	0.116
Kenya	0.045	0.341	0.640	0.205
Lesotho	0.035	0.319	0.674	0.162
Liberia	0.047	0.438	0.586	0.182
Malawi	0.023	0.378	0.569	0.109
Mali	0.038	0.323	0.493	0.241
Mauritania	0.057	0.452	0.577	0.218
Mautitius	0.189	0.687	0.713	0.386
Mozambique	0.016	0.206	0.507	0.154
Namibia	0.231	0.681	0.704	0.482
Niger	0.037	0.318	0.499	0.232
Rwanda	0.029	0.232	0.551	0.225
Senegal	0.054	0.331	0.609	0.267
Sierra Leone	0.039	0.279	0.544	0.254
South Africa	0.309	0.727	0.742	0.572
Sudan	0.085	0.300	0.549	0.514
Swaziland	0.141	0.536	0.722	0.365
Tanzania	0.024	0.273	0.624	0.143
Togo	0.046	0.378	0.600	0.202
Uganda	0.028	0.249	0.578	0.193
Zambia	0.074	0.422	0.663	0.264
Zimbabwe	0.014	0.227	0.677	0.093
Average (6 Developed)	0.807	0.956	0.843	1.006
Standard Deviation (6 Developed)	0.086	0.090	0.055	0.089
Average (32 Sub-Saharan)	0.080	0.394	0.606	0.271
Standard Deviation (32 Sub-Saharan)	0.089	0.161	0.070	0.142

Table 2: The elements of this table are the empirical counterparts to the components of equation $y = Ak^\alpha h^{(1-\alpha)}$, all measured as ratios to the U. S. values. The first column is the product of the other three columns. Data run from 1950 or later to 2009. Sources: PENN WORLD Tables, Barro-Lee Data Set.

training, or vintage effects. These inputs might be considered directly in the production function. They ultimately claim that a theory of productivity differences is needed.

For example, Parente and Prescott (1994) propose a theory of economic development in which technology adoption and barriers to such adoptions are the focus. Based on the fact that the size of these barriers differs across countries and time, Parente and Prescott (1994) construct a theory where it is shown that the larger these barriers, the greater the investment a firm must make to adopt a more advanced technology. The second and last columns of Table 2 suggest that I need to pay much more attention to TFP and capital gaps rather than to education gaps. Formally I have

$$\frac{\bar{k}_i^\alpha}{\bar{k}_{US}^\alpha} < \frac{\bar{h}_i^{1-\alpha}}{\bar{h}_{US}^{1-\alpha}}$$

and

$$\frac{\bar{A}_i}{\bar{A}_{US}} < \frac{\bar{h}_i^{1-\alpha}}{\bar{h}_{US}^{1-\alpha}}$$

where the bar variables denote the average values. The benchmark economy is the US. Since differences in technologies appear to be crucial, the rest of the paper is devoted to study the impact of total factor productivity shocks on output per worker.

3.2 TFP Shocks: Do They Matter?

As discussed in Section 3.1, the TFP component results to be much more important than education in understanding cross-country per worker income differences, as well as in exacerbating output instability. In this work, I abstract from the political or social instability issues and I focus, via time series analysis, on the magnitude of the impact of TFP shocks on per worker income. The time series environment allows me to conduct the analysis on a country-by-country basis. The series of the TFP shock is the 1.43 sd deviation from the mean of the TFP Hodrick-Prescott filtered series (see Section 2). For each country I produce two series: one collects positive shocks and one collects negative shock. Shock series appear as 0/1 indicator variables. My *ad hoc* shocks are reported, on yearly basis, in Table 5 (see Appendix B). Positive or negative signs, reported in parentheses, confirm the presence of extreme movements, either positive or negative, in the TFP growth rate series. I assume that, in many economies, to each extreme event corresponds a financial, political or social shock.

The effects of TFP shocks on per worker income are studied via vector autoregression (VAR) analysis. A $VAR(p, k)$ can be written formally as

$$X_t = A_1 X_{t-1} + \dots + A_k X_{t-k} + W_t$$

where $W_t \sim WN(0, \Omega)$, and the $MA(\infty)$ representation $x_t = \sum_{j=0}^{+\infty} c_j W_{t-j}$, which holds under well-known assumptions. In general x_t is a vector $(p \cdot 1)$ and k represents the number of lags. In this simple world the x_t vector is

$$X_t = \begin{bmatrix} TFP \text{ Shocks}_t \\ \Delta y_t \end{bmatrix} \quad (6)$$

hence, the VAR estimation replicates

$$\underbrace{\begin{bmatrix} TFP\ Shock s_t \\ \Delta y_t \end{bmatrix}}_{X_t} = \underbrace{\begin{bmatrix} a & c \\ b & d \end{bmatrix}}_{A_1} \underbrace{\begin{bmatrix} TFP\ Shock s_{t-1} \\ \Delta y_{t-1} \end{bmatrix}}_{X_{t-1}} + \underbrace{\begin{bmatrix} w_{TFP,t} \\ w_{\Delta Y,t} \end{bmatrix}}_{W_t} \quad (7)$$

where a , b , c and d are coefficients and k is assumed to be 1. My *VAR* estimates are computed using robust standard errors (i.e. HAC procedure). Lags k are chosen according to AIC, BIC and HQC lag selection criteria. To conclude, I use the Cholesky decomposition as identification scheme.

The main result here is that the impact of the *ad hoc* TFP shock series on per worker income is larger in the unlucky world rather than in the lucky one. Impulse response functions (IRFs), computed via the estimation of (7), are collected, thus presented, on a country-by-country basis, in Fig. 5 - 8 (see Appendix B). For space reasons, I report IRFs to negative TFP shocks only. Once positive TFP shocks are considered, symmetric results, in terms of magnitude, are obtained. IRFs of Mauritania and Swaziland are not shown. Obviously, IRFs have a negative impact on the per worker income growth rate. As pointed out above, the impact is much higher in unlucky economies rather than in lucky ones. In the unlucky world, the collapse of the per worker income ranges from -2% to -8%, and from -0.1% to -3% in the lucky world. I notice also that for some economies the impact is not statistically significant. Where significant it lasts on average for 1.5 years. For lucky economies, statistical results are less robust

I argue that the high order of magnitude of the the impact is mostly driven by the presence of a high TFP volatility level. Not surprisingly, the average TFP volatility across unlucky countries is roughly 8 times higher than the average volatility computed across lucky economies (i.e. 0.729% vs 0.098%). The presence of high TFP volatility across unlucky economies is confirmed by Fig. 2 and 3. In the unlucky world the TFP growth rate fluctuates on average around a wider band.

4 The Impossible Story of Capital Accumulation

The Sub-Saharan Africa's underdevelopment is well known. Bayraktar and Fofack (2011) notice that Sub-Saharan Africa is classified as the poorest region of the world, one that is getting poorer in the face of sustained growth and significant improvements of living standards in the rest of the world. They claim that this general characterisation of the region almost implies uniform and widespread poverty, and homogenous and stagnant economic growth rates. Table 4 shows the percentage of population living on less than \$2.00 a day in the major emerging and poor macro areas. The Sub-Saharan Africa, second only to South Asia, is the poorest area of the world, as of 2008. In contrast to all the other macro areas, Table 3 suggest that the percentage of population living on less than \$2.00 a day in Sub-Saharan countries is remained costantly high (i.e. around 70%) for the last 30 years.

Sach et al. (2004) point out that it is the only major developing region with negative growth in income per capita during 1980-2000. They argue that African countries have the worst health condition of the planet and suffer government crisis. Many parts of Africa are well governed even though stuck in poverty. Their explanation is that Africa is stuck in a poverty trap, too poor to achieve robust, high levels of economic growth and, in many places, simply too poor to grow at all.

There is also an abundance of empirical evidence that most countries that were poor in the 50's remain so today. A large part of the literature support the idea that if poverty traps are an important feature of growth dynamics, than over time one would expect a bimodal distribution of per capita income, in which I have a group of poor countries clustered around the low-level poverty trap equilibrium and a group rich countries clustered around the high equilibrium.¹²

Country Name	1981	1984	1987	1990	1993	1996	1999	2002	2005	2008
East Asia & Pacific	92.41	88.25	81.59	80.97	75.76	63.97	61.74	51.93	39.03	33.24
Europe & Central Asia	8.32	6.68	6.33	6.87	9.18	11.23	12.13	7.92	4.6	2.2
Latin America & Caribbean	23.77	26.84	22.35	22.36	21.72	21.04	21.99	22.23	16.69	12.38
Middle East & North Africa	30.06	27.13	26.14	23.46	22.13	22.22	21.96	19.73	17.37	13.9
South Asia	87.2	85.55	84.48	83.58	82.67	80.71	77.83	77.41	73.36	70.88
Sub-Saharan Africa	72.2	74.7	74.29	75.95	78.12	77.51	77.42	76.11	74.08	69.2

Table 3: Poverty headcount ratio at \$2 a day (PPP) (% of population). Population below \$2 a day is the percentage of the population living on less than \$2.00 a day at 2005 international prices. As a result of revisions in PPP exchange rates, poverty rates for individual countries cannot be compared with poverty rates reported in earlier editions. Source: WORLD BANK.

Using data from microenterprises in Mexico, McKenzie and Woodruff (2008) argue that poverty traps might exist if there are a large fixed costs to starting a business. Jalan and Ravallion (2002) find that consumption growth at the household level increases with the local availability of geographical capital (e.g. availability of roads, the local level of literacy, etc.) Kraay and Raddatz (2007) examines the empirical relevance of the poverty trap view of underdevelopment. They focus on the quantitative implications of two leading mechanisms generating poverty traps in aggregate growth models: low saving and low productivity at low levels of development. They argue that in such situations countries will converge to an equilibrium with low capital and output per capita, but they find little evidence of the existence of poverty traps based on these two broad mechanisms.

Bayraktar and Fofack (2011) argue that the level of GDP per capita, quality of governance and public capital stock are found to influence private capital accumulation. Our empirical results seem to fit well this last argument. In line with their empirical results I also show that a low (or negative) average per worker capital stock accumulation, in the relatively low-income group economies, tend to push them into a poverty trap. Sacht et al. (2004) claim that Africa's extreme poverty leads to low national saving rates. They argue that low domestic saving is not offset by large inflows of private foreign capital (e.g. FDI), because Africa's poor infrastructure and weak (productive) human capital discourage such inflows.

To stress this crucial problem, I discuss here below a well-known theoretical economic results. Suppose to introduce in this unlucky environment uninsured idiosyncratic shocks. Specifically, assume that unlucky people, different from lucky ones, receive idiosyncratic labor income shocks which are uninsured, as in a standard Bewley's economy. In our specific environment the uninsurable labor income shock reflects the fact that unlucky people are uncertain about the future return of the number of years invested in education, that is, about the chance to find a stable job after the diploma. According to Bewley (1986) and Aiyagari (1994), market incompleteness in combination with the possibility of being borrowing constrained in the future should push agents to accumulate excess capital in order to smooth consumption in the face of

¹²See Azariadis and Stachurski (2004a, b) and Quah (1993, 1996, 1997) among others.

uncertain individual behaviour. I argue that bad borrowing conditions, mainly characterized by an underdeveloped financial system, for unlucky people should exacerbate the excess capital accumulation phenomenon. Since the capital level of unlucky people is much lower than that of lucky people, the cool idea of *saving for rainy days* does not apply at all. Aggregate Sub-Saharan data on savings also suggest that the contribution of uninsured idiosyncratic risk to aggregate wealth accumulation is quite modest, supporting Aiyagari's (1994) seminal contribution.¹³

The failure of the precautionary savings framework simply confirms that unlucky people have nothing to save (i. e. they cannot accumulate resources for the future). In this simple story, to avoid labor income shocks, human capital has to be wisely invested. Unlucky governments need to create an environment where educated people receive a compensation reflecting their qualifications. Empirical data on the average years of schooling show that an increase in the average education level took place in the last 20 years. But a lack in the productivity of human capital is still taking place.

5 Conclusion

The role of the education and the TFP in explaining cross-country income differences has been widely discussed and documented in the economic growth literature.¹⁴

I show that income inequalities are still very high between advanced and poor economies. I add that such inequalities are present also within the Sub-Saharan area.¹⁵ The per worker income average annual income ranges from a minimum of \$728.57 (Burundi) to a maximum of \$23,006.90 (Gabon). The gap with the G7 economies is significantly high. The per worker income interval goes from a min of \$ 38,014.08 (Japan) to a max of \$ 56,281.49 (USA). Differences in average years of schooling are also captured.¹⁶ I stress that the average per income growth rate is negative in 7 Sub-Saharan countries (i.e. Central African Republic, Democratic Republic of Congo, Liberia, Mali, Niger, Togo, Zimbabwe).

In this simple work I confirm that the TFP (i.e. Solow's residual) explains a larger portion of the per worker income gap between Sub-Saharan and G7 economies than the education (i.e. average years of schooling). On average the TFP in the unlucky world accounts only for 27% of the US TFP. Capital and education account for 39.4% and 60% respectively. Income inequalities are mostly driven by differences in technological progress and capital. Education accounts only residually. I show that the negative TFP shocks further depress the per capita income in the Sub-Saharan zone. The magnitude of the impulse generated by the shock is on average much higher in the unlucky world than in the lucky one. The order of magnitude of the impact is affected by the TFP volatility level, or simply the effect of a TFP shock on a relative low per worker income growth rate is higher than in an economy with high per worker income growth rate. To conclude, I argue that huge differences in per worker capital and very low level in human capital productivity justify the presence of the poverty trap.

¹³Recall that average savings to GDP ratio over the period 1980 - 2011 in the Sub-Saharan zone is approximately equal to 15%. In contrast, the lucky world displays a value around 21%.

¹⁴See Caselli (2005), Hall and Jones (1999) and Sachs (2001), among many others.

¹⁵The average standard deviation of the per worker income growth rate across the 32 Sub-Saharan countries is 1.7% and 0.97% across the G7 economies.

¹⁶Average years of schooling min-max intervals: [0.02 (Mozambique) - 5.68 (South Africa)] and [6.36 (France) - 11.14 (USA)]

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A Decomposition of the Benchmark Technology: Some Empirical Facts

Country	$\frac{\alpha \log(k)}{\log(y)}$	$\frac{(1-\alpha) \log(h)}{\log(y)}$	$\frac{\log(A)}{\log(y)}$
Sub-Saharan Africa			
Benin	56.81	1.94	41.25
Botswana	53.41	4.17	42.42
Burundi	56.43	2.11	41.46
Cameroon	53.32	3.43	43.26
Central African Republic	56.01	2.30	41.69
Congo, Republic The	55.81	4.01	40.19
Cote d'Ivoire	52.25	2.49	45.27
Democratic Republic of Congo	56.92	2.41	40.67
Gabon	52.49	3.31	44.20
Gambia	53.11	1.67	45.23
Ghana	60.81	4.73	34.46
Kenya	55.22	3.96	40.82
Lesotho	55.11	4.92	39.97
Liberia	60.72	3.19	36.09
Malawi	61.79	2.80	35.41
Mali	55.66	0.81	43.53
Mauritania	57.20	2.70	40.09
Mautitius	54.56	4.60	40.85
Mozambique	56.04	1.35	42.61
Namibia	52.92	4.39	42.68
Niger	55.86	0.98	43.16
Rwanda	53.18	2.31	44.52
Senegal	53.50	3.38	43.12
Sierra Leone	53.66	2.07	44.27
South Africa	52.07	4.79	43.14
Sudan	49.53	1.97	48.50
Swaziland	53.29	4.87	41.84
Tanzania	56.69	4.05	39.27
Togo	56.44	3.21	40.35
Uganda	54.61	2.92	42.47
Zambia	54.73	4.29	40.98
Zimbabwe	58.94	5.61	35.46
Advanced Economies			
Canada	49.47	6.46	44.07
France	50.02	4.76	45.22
Germany	50.80	5.33	43.87
Italy	50.58	4.91	44.51
Japan	50.61	6.25	43.14
United Kingdom	49.01	5.57	45.43
United States	49.45	7.03	43.52
Average (32 Sub-Saharan)	55.28	3.18	41.54
Average (7 Developed)	49.99	5.76	44.25

Table 4: The elements of this table represent the average contribution of each input to total output (numbers are expressed in percentage points). According to data availability, mean values might be computed using a different number of years. Series are annually and run from 1950 to 2009. Source: PENN WORLD Tables, Barro-Lee Data Set.

B The Total Factor Productivity

Country	Productivity Shocks
United States	1951(+), 1954(-), 1962(+), 1970(-), 1974(-), 1975(-), 1980(-), 1984(+), 2009(-)
Canada	1950(+), 1951(+), 1952(+), 1954(-), 1956(+), 1957(-), 1962(+), 1964(+), 1975(-), 1980(-), 1982(-), 1990(-), 1991(-), 2005(-), 2009(-)
France	1956(+), 1960(+), 1975(-), 1985(-), 1990(-), 1995(-), 2009(-)
Germany	1990(-), 2005(-), 2009(-)
Italy	1951(+), 1961(+), 1966(+), 1968(+), 1975(-), 1990(-)
Japan	1950(+), 1965(+), 1970(-)
United Kingdom	1965(-), 1973(+), 1975(-), 1980(-), 1986(+), 1994(+), 2009(-)
Benin	1975(-), 1979(+), 1982(+), 1983(-), 2005(-), 2008(-)
Botswana	1965(-), 1969(-), 1972(+), 1975(-), 1985(-), 1989(+), 1990(-), 1995(-), 1997(+)
Burundi	1961(-), 1970(+), 1995(-), 1997(+)
Cameroon	1967(-), 1976(-), 1977(+), 1978(+), 1988(-), 1990(-)
Central Afr. Rep.	1969(+), 1980(-), 1983(-), 1984(+), 1990(-), 1996(-), 1997(+), 2003(-), 2007(+)
Congo, Rep. The	1973(+), 1975(-), 1979(+), 1985(-), 2007(-)
Cote d'Ivoire	1964(+), 1965(-), 1968(+), 1980(-), 1982(+), 1989(+)
Dem. Rep. of Congo	1991(-), 1992(-), 1997(-), 1999(-), 2000(-), 2001(+)
Gabon	1974(+), 1976(+), 1977(-), 1978(-), 1987(-), 1997(+), 1999(-)
Gambia	1975(+), 1980(-), 1982(+), 1983(-), 1995(-), 2005(+), 2007(+)
Ghana	1956(+), 1962(+), 1964(+), 1965(-), 1966(+), 1967(-), 1968(+), 1971(+), 1975(-)
Kenya	1951(+), 1952(-), 1962(+), 1966(+), 1970(-), 1975(-), 1985(-), 1986(+)
Lesotho	1961(-), 1971(-), 1972(+), 1973(+), 1975(-), 1978(+), 1979(-)
Liberia	1990(-), 1992(-), 1997(+)
Malawi	1959(-), 1960(+), 1962(-), 1965(+), 1978(+), 1981(-), 1994(-)
Mali	1964(-), 1974(-), 1975(+), 1976(+), 1980(-), 1986(+), 2000(-)
Mauritania	1964(+), 2006(+)
Mautitius	1960(-), 1968(-), 1972(+), 1973(+), 1976(+), 1980(-)
Mozambique	1967(+), 1970(-), 1982(-), 1983(-), 1992(-), 2001(+), 2002(+)
Namibia	1962(+), 1964(+), 1985(-), 1987(+), 1993(-), 2006(+)
Niger	1973(-), 1980(-), 1984(-), 1990(-), 1998(+), 2008(+)
Rwanda	1981(+), 1994(-), 1995(+)
Senegal	1969(-), 1973(-), 1976(+), 1978(-), 1979(+), 1980(-), 1982(+), 1984(-), 1994(+)
Sierra Leone	1967(-), 1996(-), 1997(-), 2001(+), 2002(+)
South Africa	1953(+), 1982(-), 1985(-), 1986(-), 1990(-), 1995(-), 2000(+), 2005(+)
Sudan	1983(-), 1987(+), 1996(+), 2002(-), 2004(+)
Swaziland	1972(+), 1973(-), 1974(+)
Tanzania	1961(-), 1964(+), 1970(-), 1991(+), 1993(-), 2005(+), 2008(+)
Togo	1977(+), 1980(-), 1981(-), 1993(-), 1994(+)
Uganda	1951(+), 1953(-), 1979(-), 1985(-), 1994(+), 1995(-)
Zambia	1982(-), 2004(+), 2007(+)
Zimbawe	1969(+), 1970(+), 1981(+), 1984(-), 1989(+), 1992(-), 2003(-), 2004(-)

Table 5: Total Factor Productivity Shocks: Positive or negative signs (in parentheses) confirm the presence of extreme movements in the TFP growth rate series. A (+) is assigned when $TFP\ Growth\ Rates > \mu_A^{hp} + 1.43\sigma_A$ and a (-) is assigned when $TFP\ Growth\ Rates < \mu_A^{hp} - 1.43\sigma_A$. The variable μ_A^{hp} represents the sample mean of the TFP growth rate Hodrick-Prescott filtered series. Dates. Sources: PENN WORLD Tables, Barro-Lee Data Set.

Figure 2: The Dynamic of the TFP Growth Rate (a)

Figure 3: The Dynamic of the TFP Growth Rate (b)

Figure 4: The Dynamic of the TFP Growth Rate (c)

Figure 5: Sub-Saharan Economies IRFs: VAR estimation of the impact of 1/0 negative TFP shock indicator on per worker income growth rate. The variable y is from PWT63 PENN TABLE, and represent the real GDP per worker in international dollars (i.e. in PPP, this variable is called *rgdpwok* in the original data set). Notes: shaded areas are 95% confidence bands around the response to 1/0 negative TFP shock indicator. From top left: Benin, Botswana, Burundi, Cameroon, Central African Republic, Congo, Cote d' Ivoire, Dem. Rep. Congo, Gabon and Gambia. Data run from 1950 or later to 2009.

Figure 6: Sub-Saharan Economies IRFs: VAR estimation of the impact of 1/0 negative TFP shock indicator on per worker income growth rate. The variable y is from PWT63 PENN TABLE, and represent the real GDP per worker in international dollars (i.e. in PPP, this variable is called *rgdpwok* in the original data set). Notes: shaded areas are 95% confidence bands around the response to 1/0 negative TFP shock indicator. From top left: Ghana, Kenya, Lesotho, Liberia, Malawi, Mali, Mauritius, Mozambique, Namibia and Niger. Mauritania's IRF is not showed (no 1/0 negative shocks). Data run from 1950 or later to 2009.

Figure 7: Sub-Saharan Economies IRFs: VAR estimation of the impact of 1/0 negative TFP shock indicator on per worker income growth rate. The variable y is from PWT63 PENN TABLE, and represent the real GDP per worker in international dollars (i.e. in PPP, this variable is called *rgdpwok* in the original data set). Notes: shaded areas are 95% confidence bands around the response to 1/0 negative TFP shock indicator. From top left: Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia, Zimbabwe. Swaziland IRF is not showed (invertibility condition is not satisfied). Data run from 1950 or later to 2009.

Figure 8: G7 Economies IRFs: VAR estimation of the impact of 1/0 negative TFP shock indicator on per worker income growth rate. The variable y is from PWT63 PENN TABLE, and represent the real GDP per worker in international dollars (i.e. in PPP, this variable is called *rgdpwok* in the original data set). Notes: shaded areas are 95% confidence bands around the response to 1/0 negative TFP shock indicator. From top left: Canada, France, Germany, Italy, Japan, United Kingdom and USA. Data run from 1950 or later to 2009.