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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, we are 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). We confirm, according to the related literature, that physical capital and education levels partially explain income differences between unlucky and lucky economies. We show, however, that the impact of *ad hoc* TFP shocks on per worker income is larger in the unlucky economies than in the lucky ones. The result holds both for negative and positive shocks. In particular, we find that average TFP volatility in the "unlucky world" is eight times higher than the "G7 world" average TFP volatility. As a result we argue that the order of magnitude of the impact heavily depends on the level of the TFP volatility. It turns out that the effect of a TFP shock on a relative low per worker income growth rate is higher. We conclude by arguing that the presence of low levels of per worker capital and of human productivity push the unlucky economies into a poverty trap.

Keywords:
Education, Average Years of Schooling, TFP Shocks, Poverty Trap
JEL Codes
I24, I25, O10, O11, O16, O47, O55

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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 on the growth of years of schooling provide no support at all for the proposition that more rapid rates of growth of educational 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 the 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 these intuitive results raise the importance of identifying and undertaking those complementary reforms in the non-education sector that will lead to education in order 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 also largely accepted the idea that institutions stand behind the ``rules of the game'' 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) stress the fact that corruption hampers economic growth. Hall and Jones (1999) and Acemouglu et al. (2002) 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 the 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 focus on the difficulty of mobilizing energy resources in tropical economies and emphasize how such a problem constitutes another significant cause to the income gap.

Mazur (2000) shows that the globalization has dramatically increased the inequality between and within Nations. Kremer an Maskin (2006), supporters of the anti-globalization movement, on the other hand, put forward the idea that globalization has marginalized the poor in developing countries and left behind the poorest countries. Clinton (2000), during a session on the Indian Parliament, said 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 though income inequalities are still high. It has been already proved that, and will be found again to be true in this paper, 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. the 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 if one disaggregates the government sector out of the data, the outcome may be the source of a potential reduction the unexplained component of total output.

The empirical part of these two seminal contributions combines variables from two main data set, 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 studied separately. We 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 contribution of the present paper consists the analyzing capital, education, TFP and output in a time series framework, the study of the dynamic of capital accumulation, the construction of ad hoc technological shocks and the study of the difference impacts of these shocks on per worker output.

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

2. Data Description and Preliminary Analysis

In 2010, the thirty-two Sub-Saharan countries on which we focus on had a combined population of 516 million and an average annual per capita income of $3,270.00 (i.e. $9 per day). To exploit cross-country income differences, we use the G7 economies as a benchmark. The complete list of countries is presented in Table 2.1. In 2010, the G7 had a population of 735 million an average annual per capita income of $35,278.00 (i.e. $98 per

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

day). Average savings to GDP ratios over the sample 1980-2011 are 14.87% and 20.69% for the Sub-Saharan and G7 countries, respectively. Data source is from IMF and include all countries listed in Table 2.1.[2]

Sub-Saharan Africa Economies				**Advanced Economies**
Benin	Gabon	Mauritania	South Africa	Canada
Botswana	Gambia	Mauritius	Sudan	France
Burundi	Ghana	Mozambique	Swaziland	Germany
Cameroon	Kenya	Namibia	Tanzania	Italy
Central African Rep.	Lesotho	Niger	Togo	Japan
Congo, Rep. The	Liberia	Rwanda	Uganda	United Kingdom
Cote d'Ivoire	Malawi	Senegal	Zambia	United States
Dem. Rep. of Congo	Mali	Sierra Leone	Zimbabwe	

Table 2.1. Unlucky and Lucky Economies.

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

$$Y = AK^{\alpha}(Lh)^{1-\alpha} \tag{2.1}$$

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, while A corresponds to the Total Factor Productivity (TFP). Throughout the paper we use the terms total factor productivity, Solow's residual, or technological progress interchangeably. In per capita terms the production function can be written as follows:

$$Y = Ak^{\alpha}h^{1-\alpha} \tag{2.2}$$

where k is the capital labor ratio.

As investigated by Hall and Jones (1999), and by Caselli (2005), we are initially 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, we use the following set of info: a) the output per-worker (i.e. y); b) the capital labor ratio (i.e. k); c) the total average years of schooling (i.e. h); d) the value for the capital share α.

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, we extract output, capital and the number of workers. The second is the Barro-Lee educational attainment data set. The latter is used to find data at educational level. Data run from 1950 or later to 2007.[3] The variable y is measured from PWT63 as the real GDP per worker in

[2] Savings 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.

[3] PENN 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), Swaizland (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).

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), we use the International Monetary Fund Database.

The capital stock, *K*, is estimated using the standard perpetual inventory equation

$$K_t = I_t + (1-\delta)K_{t-1} \tag{2.3}$$

where I_t is investment and δ is the depreciation rate (assumed to be equal to 0.06).[4] We compute the investment series as real aggregate investment in PPP. In practice, $I = rgdpl \cdot pop \cdot ki$, where *rgdpl*, *pop* and *ki* represent, the real income per capita, the population (in thousands) and the investment share of PPP converted GDP per capital at 2005 constant prices (i.e. investment share in total income), respectively.

We estimate that the initial value of capital stock K_0 is $\frac{I_0}{(\delta+g)}$ where I_0, the value of the investment series in the first year, is available (i.e. in our 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 compute *k*, we divide *K* by the number of workers. The latter is obtained as *rgdpch·pop/rgdpwok*, where *rgdpch* is real GDP per capita computed with the chain method.

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

$$h = e^{\theta(s)} \tag{2.4}$$

where *s* represents the average years of schooling and $\theta(s)$ is piecewise a linear function.[5]

Notice that *s* is observed in the data every 5 years (i.e. 1950 - 1955 - 1960 etc…).[6] As stated by 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 the literature, or the so-called stylized facts, we assume that the capital share is 1/3.

The TFP *A* is obtained formally as:

$$A = \frac{y}{k^{\alpha}h^{1-\alpha}}. \tag{2.5}$$

We also construct country-by-country *ad hoc* TFP shock series. To measure shocks, we use an indicator series that takes value 1, once an "extraordinary event" occurs, either

[4] See Caselli (2005).

[5] The structure of the piecewise linear function $\theta(s)$: $\theta(s) = 0.134 \cdot s$ if $s \le 4$, $\theta(s) = 0.134 \cdot 4 + 0.101 \cdot (s-4)$ if $4 < s \le 8$ and $\theta(s) = 0.134 \cdot 4 + 0.101 \cdot 4 + 0.068 \cdot (s-8)$ if $s > 8$ (see Hall and Jones, 1999 and Caselli, 2005).

[6] See Barro and Lee website: http://www.barrolee.com/.

positive or negative, and 0 otherwise. An extraordinary event is chosen as that with a TFP growth rate below (above) 1.43 standard deviation minus (plus) the mean of the Hodrick-Prescott filtered TFP growth rate series. Formally, 1 is assigned if the rate of growth of A is below or above the following threshold

$$TFP\ Shock_t = \mu_t^{hp} \pm 1.43\sigma_A \tag{2.6}$$

where μ_t^{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 2.2, we present the average contribution of each input to income (see appendix A) . The decomposition is the result of the log version of Eq. 2.2, and takes the form:

$$\log(y) = \log(A) + \alpha \log(k) + (1-\alpha)\log(h)\,. \tag{2.7}$$

Eq. 2.7 allows us to capture one of the key factors of the growth accounting literature. Our numbers suggest that income is mostly determined by capital (i.e. $\alpha \log(k)$) and technological factors (i.e. $\log(A)$). Over the 32 Sub-Saharan countries the fraction $\frac{(1-\alpha)\log(h)}{\log(y)}$ is on the average equal to 3.18%. The average contribution of capital per-worker and TFP is respectively equal to 55.28% and 41.54%. Similar results are obtained for the G7 economies. We argue that education, here captured by the average years of schooling, contributes marginally to the per-worker income wealth. The preliminary results of Table 2.2 pave the way to study the dynamics of the per-worker capita, education and TFP in as well as their implications for the huge income differences between Sub-Saharan and G7 economies.

3. Cross-Country Income Differences: An Empirical Review

3.1 Output, Education and TFP: Some Stylized Facts

Output per worker varies enormously across countries. If rich and poor economies are compared, the gap becomes huge. 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 the differences in social infrastructure across countries.

Caselli (2005), using the benchmark Hall and Jones' (1999) production function, comes into the conclusion 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. This empirical regularity supports our curiosity to study deeply the impact of TFP shocks on income. Hall and Jones (1999) provide additional support. They argue that 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.

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
Zimbawe	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
Mean (32 Sub-Saharan)	55.28	3.18	41.54

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[7] Formally, Caselli (2005) uses the following measure of success: $success_1 = \frac{var[\log(y_{hk})]}{var[\log(y)]}$ where $y_{hk} = k^{\alpha}h^{1-\alpha}$. He refers to y_{hk} as the factor-only model.

Mean (7 Developed)	49.99	5.76	44.25

Table 2.2. The elements of this table represent the average contribution of each input to total per-worker 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.

In Table 3.1, we report the summary statistics of the population, per-worker income, education level and per-worker capital. The time series are obtained following the procedure described in Section 2. In addition, we show the average values of the population growth rate and of the 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 3.1 confirm the Hall and Jones' (1999) main results. The numbers presented in these columns show that the average growth rate of per-worker income is lower across unlucky economies than that across lucky economies (i.e. 1.060% vs 2.280%).

Country	Pop.	y	*k*	h	k (per capita)	A	Var(A)
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
Mauritius	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
Mean(32 Sub-Saharan)	2.549	1.060	2.339	2.735	1,113,663.6	-0.053	0.729
Sd (32 Sub-Saharan)	0.444	1.673	3.279	1.397	. . .	0.895	0.941

Mean (7 Advanced)	0.742	2.280	3.381	8.149	10,760,895.7	0.686	0.098
Sd (7 Advanced)	0.448	0.972	2.032	1.816	. . .	0.457	0.094

Table 3.1. The elements of this table represent the mean values of the rate of growth of the population (*pop*), per-worker real GDP ($\bar{y}_t$), per-worker capital ($\bar{k}_{t(\%)}$), the human capital ($\bar{h}_t$) 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 or later to 2009. Sources: PENN WORLD Tables, Barro-Lee Data Set.

As expected, according to the neoclassical growth theory, this long-run result appear to be unfair and counterintuitive. Why? The comparison of the average per-worker capital and average TFP growth rate among unlucky and lucky economies provides a clear answer. Unlucky economies' average per worker capital growth rate and average TFP growth rate are 2.339% and -0.053%, respectively. For lucky economies we have 3.381% and 0.686% respectively.

Summary statistics' heterogeneity exhists also within the Sub-Saharan area. For example, 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. 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) as far as per worker capital concerns.[8]

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

We obtain four main empirical facts: 1) the absolute convergence theory does not apply;[9] 2) the rate of growth of the technological progress across unlucky economies is on the 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); 4) the ratio between lucky and unlucky economies of the average per-worker capital stock is equal to ten.

Our results largely support past empirical evidence stating 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 3.2, we report country-by-country empirical counterparts of Eq. 2.2. More precisely, we weight the average production input of each economy *i* over the average production component of the US. Formally,

$$y_i^w = \frac{\bar{y}_i}{\bar{y}_{US}}; \quad k_i^w = \frac{\bar{k}_i^\alpha}{\bar{k}_{US}^\alpha}; \quad h_i^w = \frac{\bar{h}_i^{1-\alpha}}{\bar{h}_{US}^{1-\alpha}}; \quad A_i^w = \frac{\bar{A}_i}{\bar{A}_{US}} \tag{3.1.1}$$

where the bar variables define average values. Data suggests that, under this benchmark production function, the TFP plays a crucial role in explaining why unlucky

[8] The minimum and maximum values are country specific sample averages. Data run from 1950 or later to 2009.

[9] A detailed discussion is provided in Section 4.

[10] Negative 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.

economies are not able to emerge. The average TFP weighs only 27%. Education and per worker capital appear to weigh more, respectively 60% and 40%.

Hall and Jones (1999) argue that one possible interpretation of this result may rely on other differences, such as the quality of human capital, on-the-job training, or vintage effects. These inputs might be considered directly in the production function. They finally 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 provide the main explanation. 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.

Country		Productivity Factors: Contribution		
Advanced Economies	y	k^{α}	$h^{1-\alpha}$	A
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 Economies				
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
Zimbawe	0.014	0.227	0.677	0.093
Mean (6 Developed)	0.807	0.956	0.843	1.006
Sd (6 Developed)	0.086	0.090	0.055	0.089
Mean (32 Sub-Saharan)	0.080	0.394	0.606	0.271
Sd (32 Sub-Saharan)	0.089	0.161	0.070	0.142

Table 3.2 . The elements of this table are the empirical counterparts to the components of Eq. 2.2, 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.

We find that the following inequalities hold:

$$\frac{\bar{k}_i^{\alpha}}{\bar{k}_{US}^{\alpha}} < \frac{\bar{h}_i^{1-\alpha}}{\bar{h}_{US}^{1-\alpha}} \quad \cup \quad \frac{\bar{A}_i}{\bar{A}_{US}} < \frac{\bar{h}_i^{1-\alpha}}{\bar{h}_{US}^{1-\alpha}} \tag{3.1.2}$$

The second and last columns of Table 3.2 support the inequalities in (3.1.2). These results suggest carrying out an analysis on the cross-country income differences by emphasizing only the role of TFP and per-worker capital gaps rather than the education gap. Since differences in technologies appear to be critical, 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 the average years of schooling in understanding cross-country per-worker income differences as well as in exacerbating output instability. While abstracting from the political or social instability issues, we focus, instead, via time series analysis, on the magnitude of the impact of TFP shocks on per-worker income. The time series environment allows us to conduct the analysis on a country-by-country basis. The TFP shock series is derived from the 1.43 standard deviations from the mean of the TFP growth rate Hodrick-Prescott filtered series (see Section 2). For each country we produce two series: one collects positive shocks and one collects negative shock. Shock series appear as 0/1 indicator variables.

Our *ad hoc* shocks are indicated, 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. We 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 by adopting a vector autoregression (VAR) analysis. A simple *VAR*(*p,k*) equation can be written formally as

$$X_t = A_1 X_{t-1} + \cdots\cdots + A_k X_{t-k} + W_t \tag{3.2.1}$$

where $W_t \sim WN(0,\Omega)$. In (3.2.1) x_t is a $(p \cdot 1)$ vector of variables and k represents the numbers of lags. To evaluate the impact of TFP shocks on per-worker income, we estimate a country-by-country bivariate VAR. The full set of variables used in our VARs are: per-worker income growth rate (Δy_t) and TFP Shock series (TFP^{Shock}). In our specific case, the VAR specification in (3.2.1) is given by

$$\underbrace{\begin{bmatrix} TFP_t^{Shock} \\ \Delta y_t \end{bmatrix}}_{X_t} = \underbrace{\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}}_{A_1} \underbrace{\begin{bmatrix} TFP_{t-1}^{Shock} \\ \Delta y_{t-1} \end{bmatrix}}_{X_{t-1}} + \underbrace{\begin{bmatrix} w_{TFP\,t} \\ w_{\Delta y_t} \end{bmatrix}}_{W_t} \tag{3.2.1}$$

where A_1 is the matrix of coefficients and k is assumed to be 1. Our VARs' estimates are computed by using robust standard errors (i.e. HAC procedure). Lags k are chosen according to the standard AIC, BIC and HQC lag selection criteria. To compute IRFs, the 1/0 TFP shock series is ordered last in a Cholesky decomposition. This specification implies that the second shock does not affect the first variable contemporaneously, but both shock have a contemporaneous effect on the second variable.

The main result we achieved 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 (3.2.1), are collected, thus presented, on a country-by-country basis, in Fig. A4-A7. For space reasons, we 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 Swaizland are not shown. The 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. We 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.

We argue that the high order of magnitude of 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. Fig. A.1-A.3 show that in the unlucky world the TFP growth rate fluctuates on the 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 4.1 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 4.1 suggest that the percentage of population living on less than $2.00 per day in Sub-Saharan countries is remained constantly high (i.e. around 70%) for the last 30 years.

Country Name	1981	1984	1987	1990	1993	1996	1999	2002	2005	2008
East Asia & Pacific	92.4	88.3	81.6	81	75.8	64	61.7	51.9	39	33.2

Europe & Central Asia	8.32	6.68	6.33	6.87	9.18	11.2	12.1	7.92	4.6	2.2
Latin America & Caribbean	23.8	26.8	22.4	22.4	21.7	21	22	22.2	16.7	12.4
Middle East & North Africa	30.1	27.1	26.1	23.5	22.1	22.2	22	19.7	17.4	13.9
South Asia	87.2	85.6	84.5	83.6	82.7	80.7	77.8	77.4	73.4	70.9
Sub-Saharan Africa	72.2	74.7	74.3	76	78.1	77.5	77.4	76.1	74.1	69.2

Table 4.1. 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. Source: WORLD BANK.

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.[11]

Using the 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 roods, the local level of literacy, etc.). Kraay and Raddatz (2007) study 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) focus on the evidence that the level of per capita GDP, the quality of governance and the public capital stock are found to influence private capital accumulation. Our empirical results seem to fit well this last argument. According to their empirical results we also show that a low (or negative) average per worker capital stock accumulation, in the relatively low-income group economies, tends to push them into a poverty trap.

Sach et al. (2004) claim that Africa's extreme poverty leads to low national saving rates. They underline 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.

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

To stress this crucial problem, we 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 the 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 acheiving 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 uncertain individual behavior. We claim that bad borrowing conditions, mainly characterized by an underdeveloped financial system, for unlucky people exacerbate the excess capital accumulation phenomenom. Since the capital level of unlucky people is much lower than that of lucky people, the *saving for rainy days* does not apply. 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.[12] The failure of the precautionary savings motive confirms that unlucky people have nothing to save (i.e. they cannot accumulate resources for the future). In this simple mechanism, 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.[13] We show that income inequalities are still very high between advanced and poor economies. We add that such inequalities are present also within the Sub-Saharan area.[14] 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 minimum of $ 38,014.08 (Japan) to a maximum of $56,281.49 (USA). Differences in average years of schooling are also captured.[15] We show that the average per-worker income growth rate is negative in 7 Sub-Saharan countries (i.e. Central African Republic, Democratic Republic of Congo, Liberia, Mali, Niger, Togo, Zimbabwe).

[12] Recall 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%.

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

[14] The 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.

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

In this simple work, we 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. We 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 the 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, we argue that huge differences in per-worker capital and very low level in human capital productivity justify the presence of the poverty trap.

Appendix A: The TFP Shocks

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 African Republic	1969(+), 1980(-), 1983(-), 1984(+), 1990(-), 1996(-), 1997(+), 2003(-), 2007(+)
Congo, Republic 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(+)
Mauritius	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(+)
Zimbabwe	1969(+), 1970(+), 1981(+), 1984(-), 1989(+), 1992(-), 2003(-), 2004(-)

Table A.1. 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 $\textit{TFP Growth Rate} > \mu_A^{hp} + 1.43\sigma_A$ and a (-) is assigned when $\textit{TFP Growth Rate} > \mu_A^{hp} - 1.43\sigma_A$. 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 Dataset.

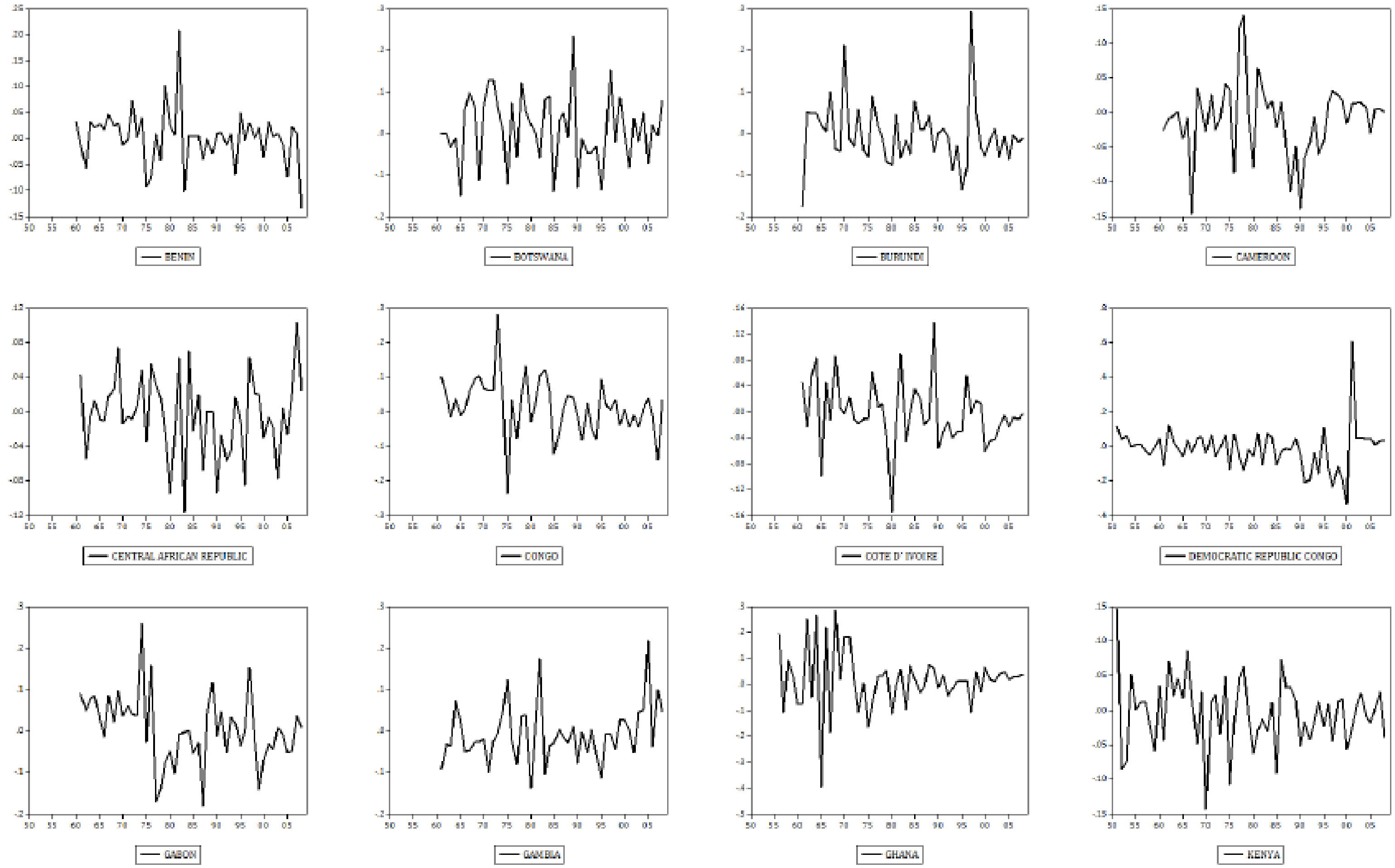

Figure A.1: The Dynamic of the TFP Growth Rate (a)

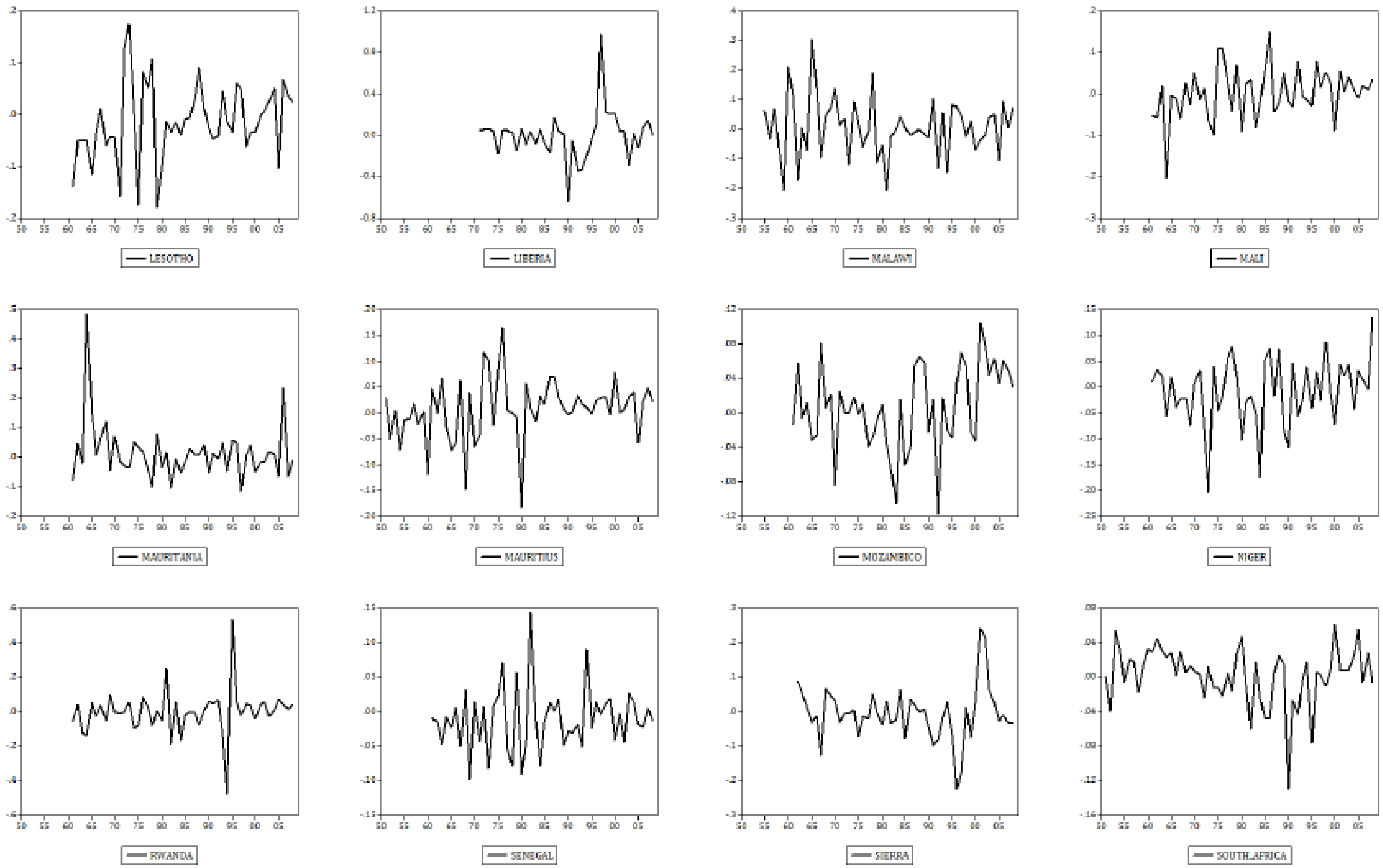

Figure A.2: The Dynamic of the TFP Growth Rate (b)

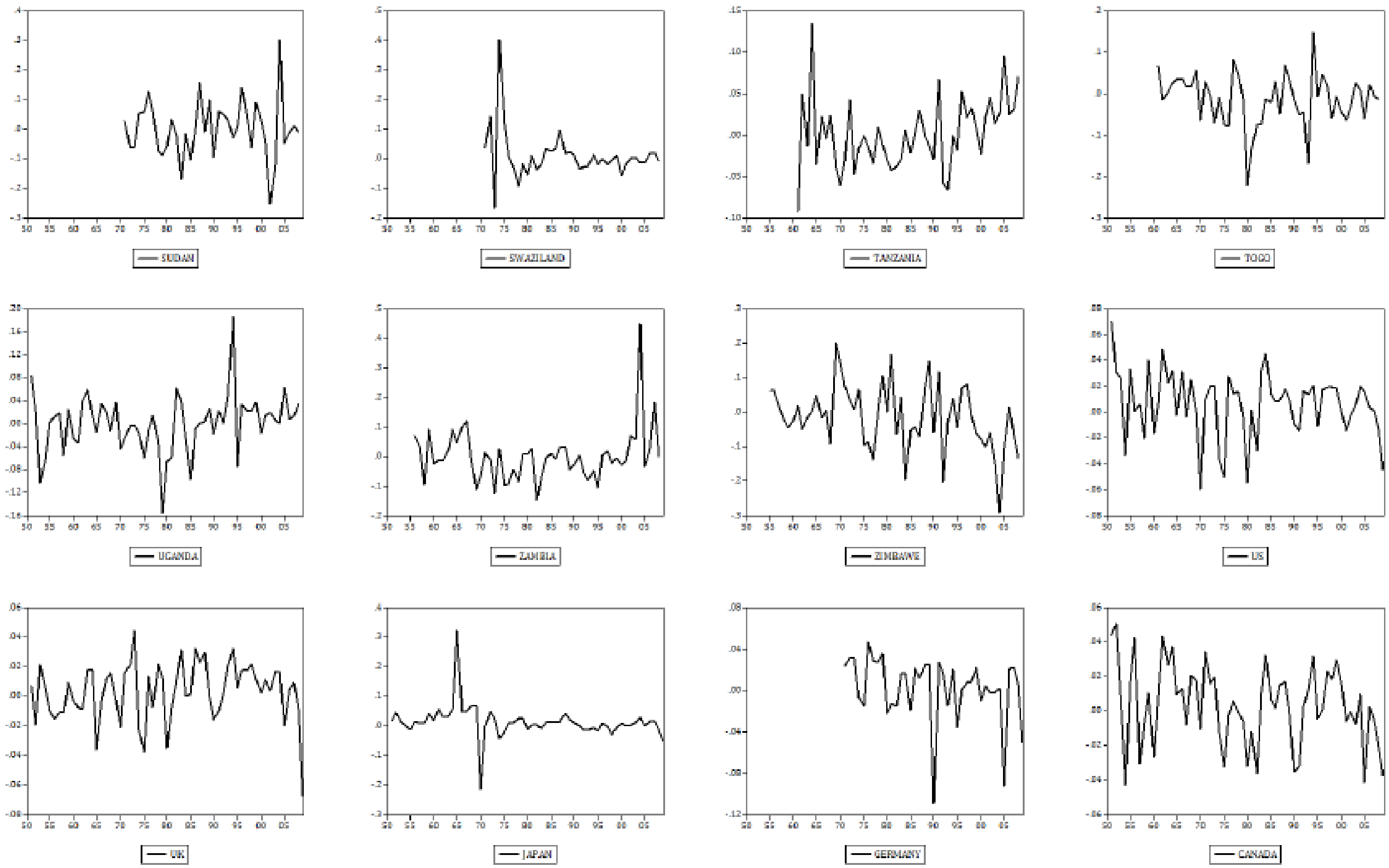

Figure A.3: The Dynamic of the TFP Growth Rate (c)

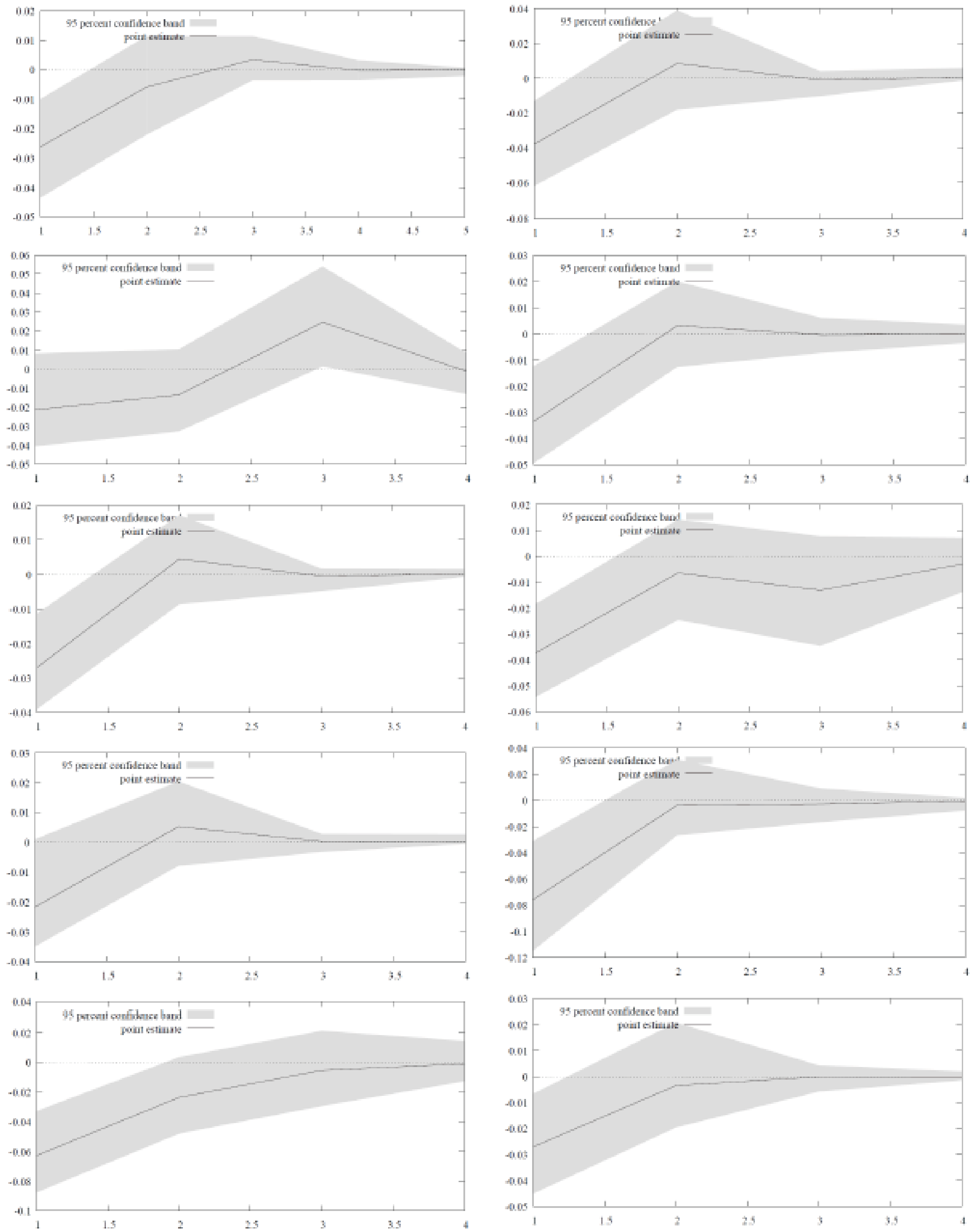

Figure A.4: Sub-Saharan Economies IRFs: VAR estimation of the impact of 1/0 negative TFP shock indicator on per-worker income growth rate. The variable y is from PWT63 PENN TABLE, and represent the real GDP per worker in international dollars (i.e. in PPP, this variable is called *rgdpwok* in the original 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.

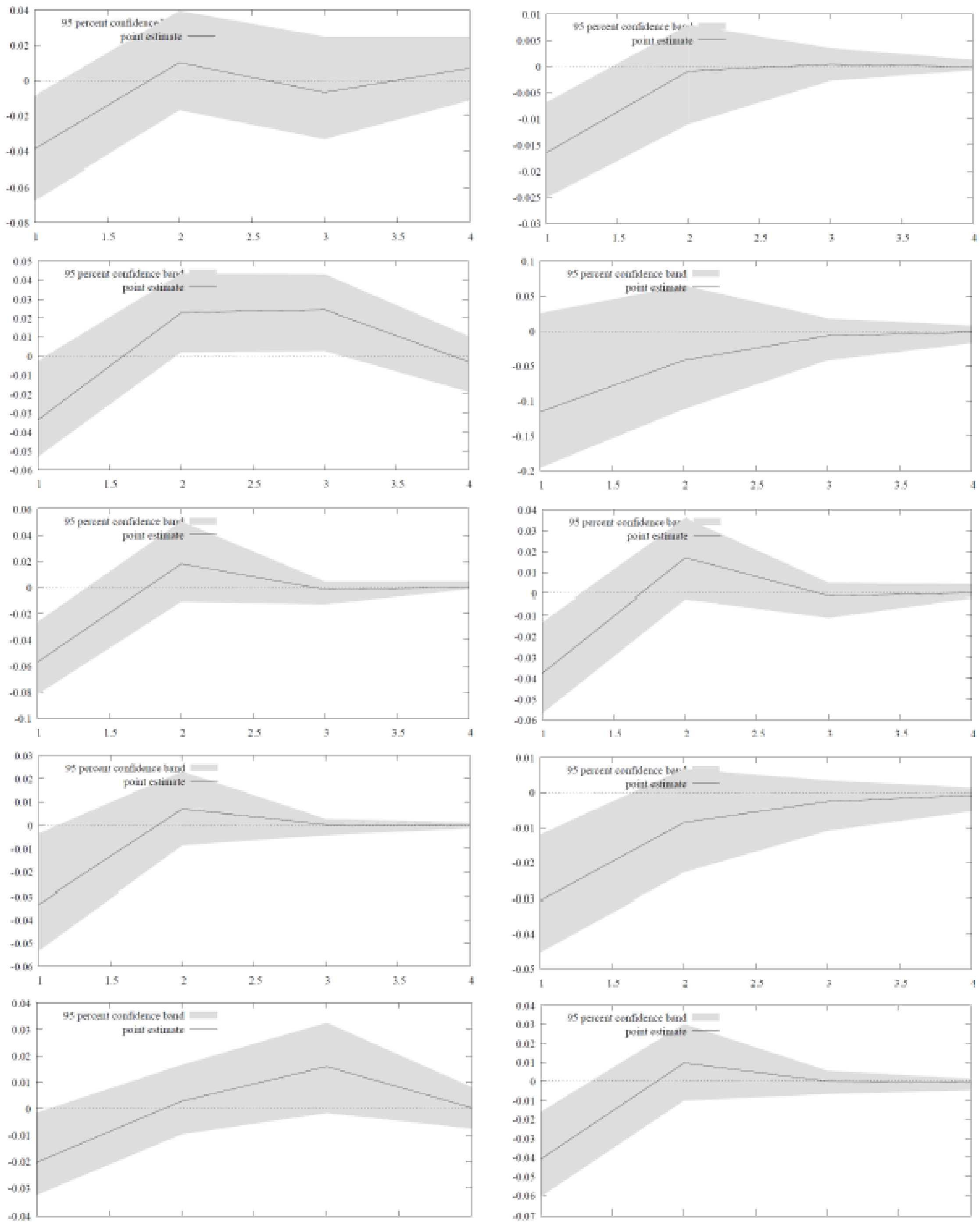

Figure A.5: Sub-Saharan Economies IRFs: VAR estimation of the impact of 1/0 negative TFP shock indicator on per worker income growth rate. The variable *y* is from PWT63 PENN TABLE, and represent the real GDP per worker in international dollars (i.e. in PPP, this variable is called *rgdpwok* in the original data set). Notes: shaded areas are 95% confidence bands around the response to 1/0 negative TFP shock indicator. From top left: 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.

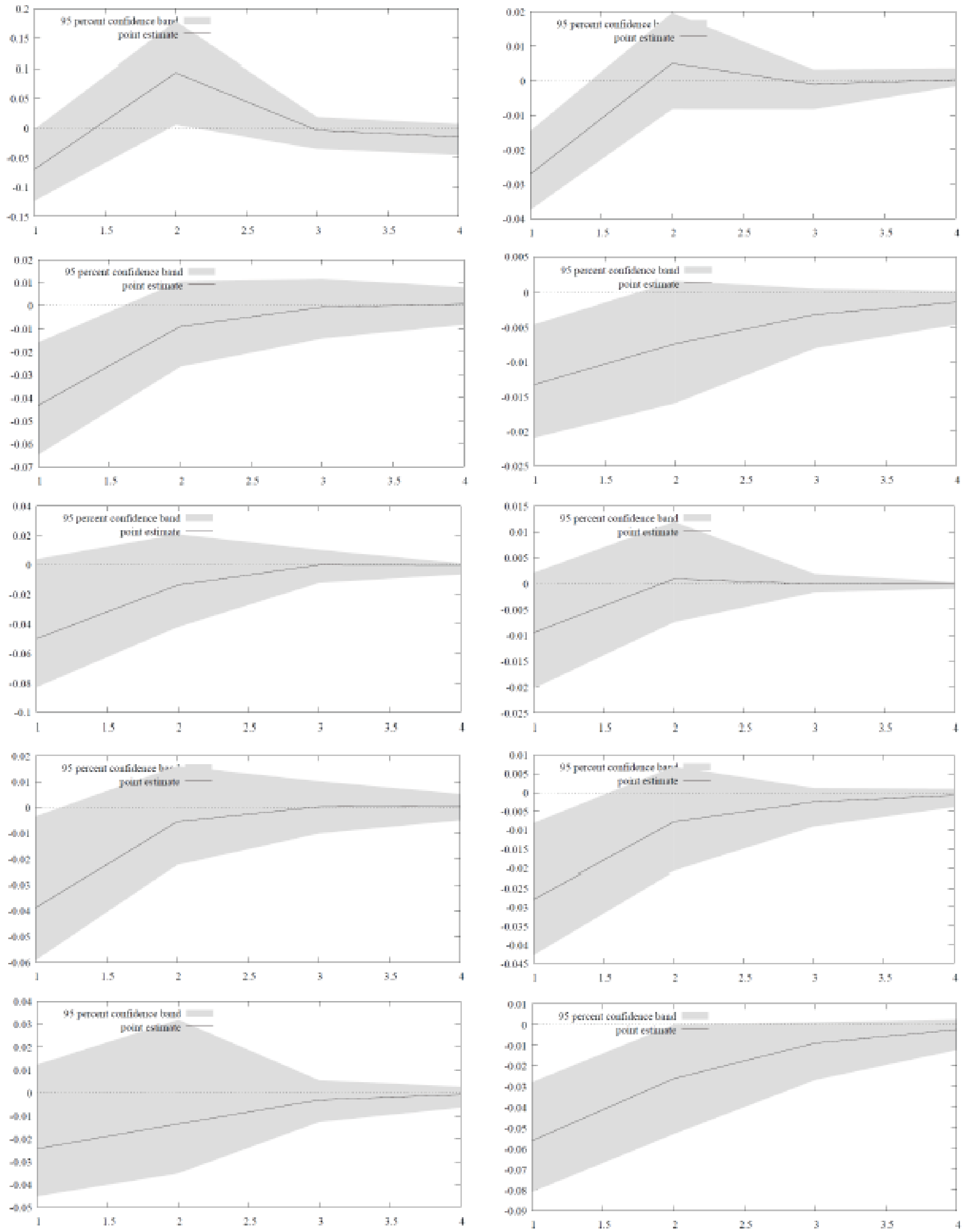

Figure A.6: Sub-Saharan Economies IRFs: VAR estimation of the impact of 1/0 negative TFP shock indicator on per worker income growth rate. The variable *y* is from PWT63 PENN TABLE, and represent the real GDP per worker in international dollars (i.e. in PPP, this variable is called *rgdpwok* in the original data set). Notes: shaded areas are 95% confidence bands around the response to 1/0 negative TFP shock indicator. From top left: Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia, Zimbabwe. Swaizland IRF is not showed (invertibility condition is not satified). Data run from 1950 or later to 2009.

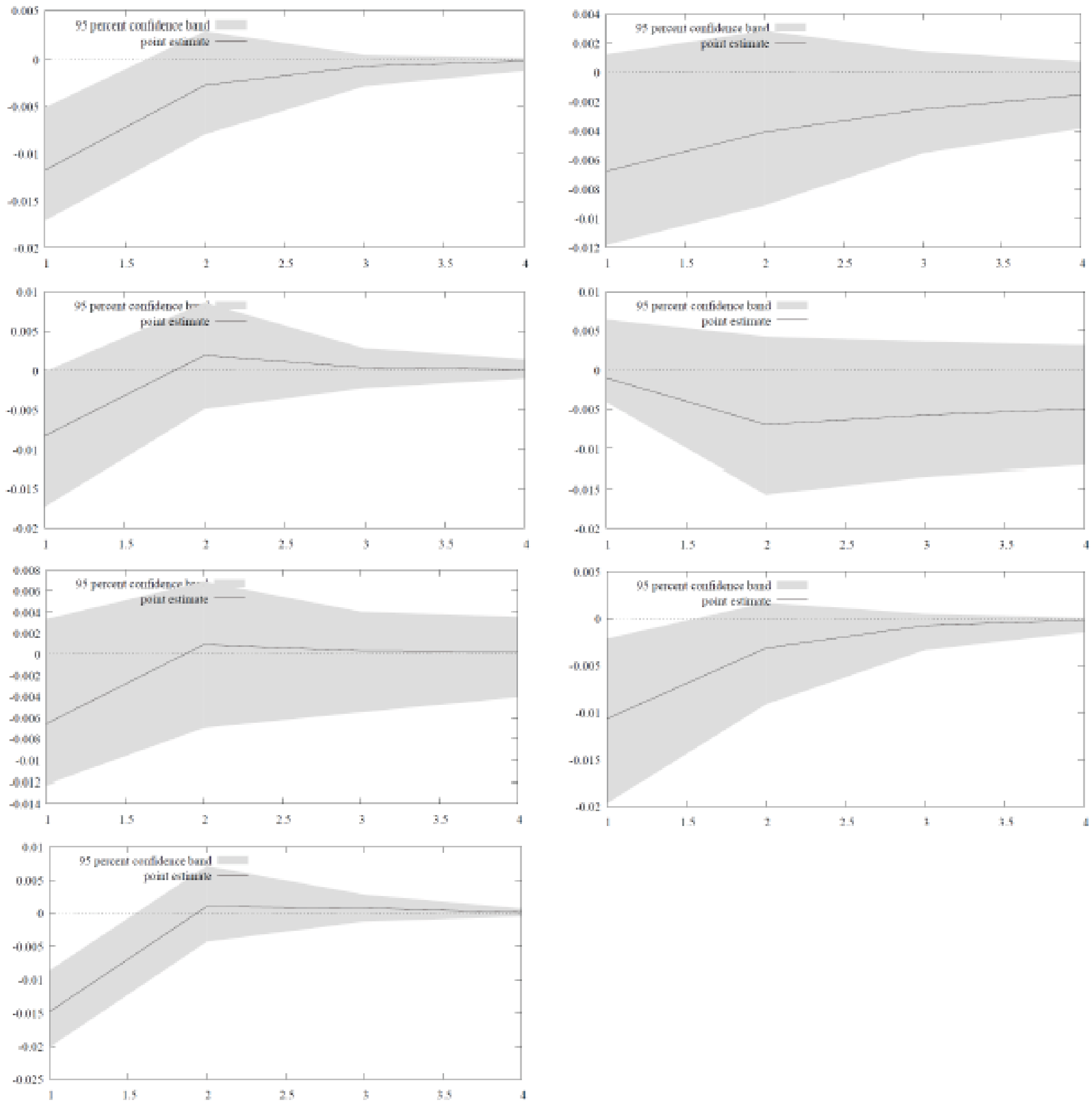

Figure A.7: G7 Economies IRFs: VAR estimation of the impact of 1/0 negative TFP shock indicator on per worker income growth rate. The variable *y* is from PWT63 PENN TABLE, and represent the real GDP per worker in international dollars (i.e. in PPP, this variable is called *rgdpwok* in the original data 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.

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