UNITED NATIONS UNIVERSITY

UNU-WIDER

World Institute for Development Economics Research

Research Paper No. 2006/26

Decomposing Growth: Do Low-Income and HIPCs Differ from High-Income Countries?

Growth, Technological Catch-up, Technological Change and Human and Physical Capital Deepening

Pertti Haaparanta and Heli Virta*

March 2006

Abstract

This paper studies the distribution of output per worker between the years 1980 and 2000 in different country groups. The study uses data envelopment analysis (DEA) to decompose the changes in the distribution of labour productivity into changes in productive efficiency, changes in best practice technology, accumulation of physical capital, and accumulation of human capital. The study focuses on low-income countries and within them on highly indebted poor countries (HIPCs), which has not been possible in earlier studies.

Keywords: productivity, efficiency, developing countries

JEL classification: O11, O47, O57

---

*Both authors Helsinki School of Economics

This study is a revised version of the paper presented at the 17-18 June 2005 UNU-WIDER anniversary conference, 'WIDER Thinking Ahead: The Future of Development Economics', directed by George Mavrotas and Anthony Shorrocks.

UNU-WIDER gratefully acknowledges the financial contributions to the research programme by the governments of Denmark (Royal Ministry of Foreign Affairs), Finland (Ministry for Foreign Affairs), Norway (Royal Ministry of Foreign Affairs), Sweden (Swedish International Development Cooperation Agency—Sida) and the United Kingdom (Department for International Development).

ISSN 1810-2611 ISBN 92-9190-794-4 (internet version)

Acknowledgements

This work is part of the project no. 206014 financed by the Academy of Finland. Heli Virta thanks also Yrjö Jahnsson Foundation for financial support. In addition, we would like to thank Merja Halme for advice in DEA, and the referees and participants both in the WIDER Jubilee Conference and the Nordic Conference in Development Economics 2005.

UNU World Institute for Development Economics Research (UNU-WIDER)
Katajanokanlaituri 6 B, 00160 Helsinki, Finland

Camera-ready typescript prepared by Lorraine Telfer-Taivainen at UNU-WIDER

Introduction

Widespread and persisting international income differences have motivated ample research on the underlying factors. Aided by the developments in both growth theory and empirics, international differences in growth in per capita incomes or labour productivity have been decomposed in various fashions.[1] Hall and Jones, among others, find that many of the disparities are explained by differences in (labour-augmenting) technology instead of differences in factor availability. According to their interpretation, this reflects international differences in the quality of social infrastructure or, more generally, in institutions. Recent research has further strengthened the case for the role of institutions.[2] There is also evidence that geographical factors can account for poor performance (Sachs et al. 2004). Human capital may also be the deep determinant of economic growth, explaining also the institutional change (Glaeser et al. 2004).

One problem with these studies is that they cannot properly differentiate the impact of institutions: if the institutions affect for example the incentives to adopt new technology or divert resources to unproductive activities, one should have a measure both for the potential of the economy and the extent to which this potential is used. We take first steps to fill this gap: labour productivity can be augmented by accumulation of physical and human capital, improvements in technologies (technological change) and the extent to which these improvements are actually utilized (productive efficiency or catch-up). We decompose the change in labour productivity in 83 countries into these four categories with a special emphasis on low-income countries and among them on highly-indebted countries.

This decomposition can shed light on the causes of international income differences. Artadi and Sala-i-Martin (2003) find that African problems can be traced to high price of capital goods, geographical factors, closedness to trade and too large public expenditures, as well as to conflicts. If geographical factors are very important by facilitating or delaying international trade and flow of information, one expects that the lack of technological catch-up plays a large role in the poor performance of geographically disadvantaged countries. Similarly, poor institutions can damage both the catch-up and accumulation of all types of capital and, hence, the various determinants of growth cannot be assigned uniquely to only one element in our decomposition. Yet, the decomposition gives some idea of the relative importance of the channels through which they have had an influence.

---

[1] See, for example, Hall and Jones (1999); Mankiw et al. (1992).

[2] Pande and Udry (2005); Acemoglu et al. (2002); Rodrik (2003); and Collier and Gunning (1999) for Africa.

The decomposition helps also to understand the impacts of the debt crisis. High debt reduces incentives to invest, as the returns from investment must be used for servicing the debt creating the debt Laffer curve (Krugman 1988). At the same time, high indebtedness increases the bargaining power of the debtor countries vis-a-vis the creditors allowing them to escape from reforms necessary for long-run growth (Birdsall et al. 2003). The relative importance of these two channels can be assessed by looking at the relative contributions of factor accumulation and catch-up in the highly indebted countries.

The decomposition is based on constructing a world production possibility frontier using data envelopment analysis (DEA),[3] as in our data it turns out that all the countries share the same technology. Productive efficiency is measured by the distance of a country's production from the world production possibility frontier.[4] We follow here Kumar and Russell (2002) with two crucial differences. While Kumar and Russell base their analysis on the basic Solow growth model framework, we use the Mankiw et al. (1992) framework, as the Solow model augmented with human capital accumulation fits the cross-country data very well.[5] We analyse data from 83 countries, which is a much larger data set than in Kumar and Russell (2002) and Henderson and Russell (2004). We therefore get a much better focus on the low-income countries. Moreover, our data ranges from 1980 to 2000, while both Kumar and Russell and Henderson and Russell study the period 1965-1990.

We find that developing countries, especially highly indebted poor countries (HIPC), have experienced large improvements in productive efficiency during the last two decades. This positive effect has been washed out by problems in capital accumulation with the result that the overall income distribution in these countries has remained stagnant. Also, production in these countries has shifted to sectors with below average productivity growth and/or it has used old technology more efficiently. Thus, it is inaccurate to assign the stagnation to institutions providing bad incentives. Institutional factors should rather be viewed in association with other factors, such as lack of finance for basic infrastructure. The theory of debt overhang seems also to be more relevant than the theory emphasizing bad incentives to account for the stagnation in HIPC countries.

---

[3] We discuss the choice of the methodology in section 2.1.

[4] Recently Acemoglu et al. (2003) have proposed a model of growth in which the distance is determined endogenously. They apply the model to India. A classic model was built by Nelson and Phelps (1966).

[5] This idea has been picked up also by Henderson and Russell (2004). They use the restriction that human and physical capital are substitutes while in our work such a restriction is not used. In our framework, human capital and physical capital can be complements. This seems to be the empirically relevant alternative given the evidence for capital-skill complementarity.

The change in world distribution of income has been driven also by technological change, not only by capital accumulation as in earlier periods (Kumar and Russell 2002). A natural interpretation is that the information and communication technology has shaped the international income distribution.

1 Analytical framework and data

1.1 Analytical framework

Production in year t in each country is given by the aggregate production function

$$Y_t = F(E_t, L_t, H_t, K_t) \tag{1}$$

where E = efficiency (catch-up) which measures how far from the efficient world production frontier the production is, L = labour force, H = human capital stock, and K = physical capital stock. Production is assumed to exhibit constant returns to scale with respect to L, H, and K. This naturally gives average labour productivity as a function of efficiency and capital stocks per worker:

$$\frac{Y_t}{L_t} = F\left(E_t, 1, \frac{H_t}{L_t}, \frac{K_t}{L_t}\right) \tag{2}$$

The country-specific efficiency scores are calculated by data envelopment analysis (DEA),[6] which assigns a score of one to efficient countries situated at the world production frontier. Inefficient countries receive a score below one. Another option would have been to use some parametric frontier approach, such as stochastic frontier analysis. The main disadvantage of DEA is its deterministic nature and the resulting inability to distinguish between technical inefficiency and statistical noise. On the other hand, DEA does not require any functional specification for the relationship between inputs and outputs or for the inefficiency error term. Using it therefore means escaping various specification and estimation problems.[7] An additional benefit of a DEA decomposition is that it can catch at least some of the implications of factor biased technological change. Caselli (2005) has argued that it can possibly explain much of the income differential between rich and poor countries.

[6] Färe et al. (1994) is a good reference for those interested in the use of the method in the context of economics, while Charnes et al. (1978, 1979) are more known in the management-science literature. Yet another source is Lovell (1994).

[7] Murillo-Zamorano (2004) discusses the differences between parametric and non-parametric frontier methods in more detail.

1.2 The data

Countries

The availability of data between years 1980 and 2000 restricts the number of countries that can be included in the analysis to 83. Although developing economies tend to have measurement errors in statistics, it can be hoped that 'the strong signal from the diversity of the experience dominates the noise' (Barro 2000).

Output

Output is measured by GDP (constant 1995 US$) from the World Bank (2004) *World Development Indicators Online*.

Labour force

As it is not straightforward to choose a proxy for labour force in empirical analysis with both developed and developing nations, we use two different measures to assure the robustness of the results. First, the official labour force statistics from WDI are relatively accurate as to developed countries, but are likely to underestimate the size of the actual labour force in many developing economies, where the size of the informal economy is larger. As the citizens entering the labour market in developing economies are typically younger than in developed economies, a second possible proxy for labour force is the population aged between 15 and 64 years, also from WDI.[8]

Capital stock

Capital stock estimates originate from Ruotinen (2005), who uses the perpetual inventory method to generate them (see also Henry et al. 2003; and Caselli 2005). He uses WDI data on gross fixed capital formation (constant 1995 US$) for investment, and sets the depreciation rate at 10 per cent in accordance with Henry et al. (2003). The formulas for capital stocks are

$$K_{it} = (1-\delta)K_{it-1} + I_{it-1} \text{ and}$$

$$K_{i0} = \frac{I_o}{(g^K + \delta)},$$

where K = the capital stock, δ = the depreciation rate, I = the gross fixed capital investment, and g^K = the annual average growth rate of the investments. Subscript i indexes country and t indexes time.

[8] It is promising that both proxies produce relatively similar results.

Human capital stock

The total human capital stock H_{it} for country i at time t is often calculated as $H_{it} = S_{it} \times L_{it}$, where S_{it} and L_{it} indicate average years of educational attainment and the stock of individuals engaged in productive activity, respectively. This is the approach also we follow.

One of the most recent and widely used measures for E_{it} is that of Barro and Lee (2001).[9] In accordance with the nature of the labour market in developing countries, we use their series of average years of schooling (including primary, secondary, and tertiary levels) for population over 15 years of age. It is also compatible with our second proxy for labour force, namely that of population aged between 15 and 64 years.

When constructing the data set to be used at the efficiency analysis, the same proxy was used both as the labour force proxy and when calculating the total stock of human capital. Thus there were two data sets to begin with:

1) Y (total GDP), L (total labour force), K (total capital stock), H (Barro and Lee average years of schooling for population over 15 years of age x total labour force)
2) Y, L (population 15-64), K, H (Barro and Lee average years of schooling for population over 15 years of age x population 15-64).

2 Efficiency scores

2.1 Efficiency scores for labour productivity

Since we are particularly interested in changes in labour productivity, we concentrate on the case where inputs used to produce GDP per labour are physical and human capital per labour (equation (2)). The results for aggregate output are available upon request.

With official labour force statistics as the proxy for labour (Table 1), France and Sierra Leone[10] are the only countries that are efficient with an efficiency score of one over the whole period. The group of the least-efficient countries is composed of Malawi, Guyana, Lesotho, and the Democratic Republic of the Congo. These have the lowest scores. China starts at the bottom of the list in 1980 and manages to climb only few

---

9 Cohen and Soto (2001) provide an alternative data set for human capital based on some differences in sources and methodology. Correlation between their estimates and those of Barro and Lee (2001) is fairly high in levels, which implies that our overall results are not that dependent on the data set chosen, even if the correlation of the human capital estimates is significantly lower in first difference.

10 Sierra Leone with its exceptionally low capital per labour ratio affects the scores of other low-income countries. In 1980, 54 countries, mostly developing economies, have Sierra Leone as their benchmark technology and in 2000, still 44 countries. Kumar and Russell (2002) find it possible that DEA might fail to identify the true production frontier especially at low capital-labour ratios. We check the sensitivity of results with a data set without Sierra Leone.

positions by 2000. If the population aged between 15 and 64 years of age is used as the proxy for individuals engaged in productive activity (the results are available upon request), Sierra Leone and Switzerland are the only efficient countries every year. The other countries on the frontier, although not every year, include United States, Sweden, Uruguay, France, Denmark, and Japan. The least efficient countries are the same as above. Thus, the results are not sensitive to the variable used to measure the labour input. Hence, in the following only the results based on data set 1 are used.

Table 1: Efficiency scores based on the use official labour force statistics: labour productivity

	1980	1985	1990	1995	2000
Algeria	0.50	0.43	0.39	0.38	0.42
Argentina	0.74	0.64	0.65	0.78	0.73
Australia	0.80	0.77	0.75	0.77	0.68
Austria	0.85	0.87	0.89	0.96	1.00
Bangladesh	0.34	0.38	0.42	0.53	0.61
Belgium	0.96	0.97	0.98	0.97	0.95
Bolivia	0.56	0.52	0.57	0.68	0.69
Botswana	0.68	0.76	0.73	0.60	0.59
Brazil	0.77	0.68	0.66	0.71	0.67
Cameroon	0.60	0.59	0.45	0.43	0.62
Canada	0.98	0.91	0.84	0.82	0.78
Chile	0.78	0.77	0.87	0.85	0.76
China	0.10	0.16	0.20	0.37	0.46
Colombia	0.80	0.72	0.78	0.73	0.73
Congo, Dem. Rep.	0.38	0.32	0.28	0.26	0.32
Costa Rica	0.87	0.82	0.84	0.80	0.83
Denmark	0.86	0.95	0.89	0.97	0.91
Dominican Rep.	0.71	0.64	0.57	0.58	0.72
Ecuador	0.63	0.62	0.67	0.69	0.75
Egypt, Arab Rep.	0.61	0.51	0.53	0.60	0.73
El Salvador	0.87	0.78	0.80	0.84	0.85
Finland	0.78	0.80	0.77	0.80	0.85
France	1.00	1.00	1.00	1.00	1.00
Gambia, The	0.87	0.67	0.61	0.59	0.73
Germany	0.78	0.79	0.84	0.85	0.80
Ghana	0.32	0.31	0.39	0.51	0.61
Greece	0.76	0.71	0.71	0.72	0.69
Guatemala	0.89	0.80	0.88	0.90	0.91
Guyana	0.16	0.16	0.18	0.26	0.35
Honduras	0.57	0.50	0.54	0.52	0.52
Hong Kong, China	0.82	0.77	0.83	0.82	0.68
Hungary	0.60	0.64	0.63	0.53	0.61

table continues…

Iceland	0.90	0.87	0.87	0.87	0.83
India	0.23	0.27	0.33	0.44	0.55
Indonesia	0.43	0.45	0.53	0.57	0.52
Iran, Islamic Rep.	0.44	0.49	0.53	0.54	0.61
Ireland	0.84	0.80	0.91	1.00	1.00
Israel	0.86	0.87	0.99	0.94	0.82
Italy	0.92	0.91	0.91	0.93	0.85
Jamaica	0.50	0.52	0.70	0.52	0.52
Japan	0.85	0.90	1.00	1.00	1.00
Jordan	0.63	0.57	0.46	0.47	0.53
Kenya	0.24	0.28	0.35	0.42	0.51
Korea, Rep.	0.77	0.77	0.75	0.66	0.60
Lesotho	0.23	0.24	0.28	0.25	0.26
Malawi	0.11	0.13	0.15	0.22	0.34
Malaysia	0.76	0.64	0.69	0.60	0.55
Mali	0.58	0.47	0.48	0.46	0.57
Mauritius	0.60	0.69	0.72	0.63	0.62
Mexico	0.85	0.75	0.72	0.62	0.71
Mozambique	0.53	0.38	0.46	0.53	0.57
Netherlands	0.81	0.83	0.85	0.89	0.89
New Zealand	0.80	0.81	0.75	0.80	0.72
Nicaragua	0.45	0.41	0.33	0.37	0.47
Niger	0.26	0.26	0.36	0.45	0.67
Norway	0.75	0.74	0.65	0.80	0.80
Pakistan	0.47	0.57	0.47	0.61	0.75
Panama	0.85	0.80	0.74	0.68	0.64
Papua New Guinea	0.50	0.45	0.43	0.56	0.65
Paraguay	0.73	0.61	0.61	0.58	0.59
Peru	0.81	0.74	0.62	0.66	0.64
Philippines	0.48	0.39	0.46	0.49	0.57
Portugal	0.84	0.79	0.84	0.76	0.64
Rwanda	0.52	0.46	0.42	0.35	0.58
Senegal	0.57	0.64	0.67	0.69	0.83
Sierra Leone	1.00	1.00	1.00	1.00	1.00
Singapore	0.82	0.66	0.78	0.86	0.94
South Africa	0.88	0.72	0.78	0.75	0.79
Spain	0.89	0.89	0.89	0.83	0.74
Sri Lanka	0.30	0.32	0.35	0.44	0.51
Swaziland	0.54	0.47	0.69	0.63	0.65
Sweden	0.97	1.00	0.97	0.92	0.90
Switzerland	1.00	1.00	0.99	0.96	0.97
Syrian Arab Rep.	0.32	0.28	0.30	0.41	0.48

table continues…

Thailand	0.44	0.44	0.53	0.47	0.48
Togo	0.33	0.31	0.32	0.37	0.47
Tunisia	0.61	0.55	0.58	0.55	0.61
United Kingdom	0.92	0.94	0.94	0.94	0.84
United States	1.00	1.00	1.00	0.99	0.84
Uruguay	0.9998	0.80	1.00	1.00	1.00
Venezuela	0.61	0.56	0.66	0.65	0.68
Zambia	0.21	0.26	0.34	0.36	0.52
Zimbabwe	0.50	0.53	0.43	0.45	0.57

Source: The efficiency scores and decomposition of the labour productivity were obtained by OnFront Version 2.02. The scores were calculated with five-year intervals beginning from 1980 and ending with the year 2000.

2.2 Do high-income countries and developing economies share the same technological knowledge?[11]

The groups of high-income and developing countries may differ with respect to the availability of technology, invalidating the calculations above. We therefore use a method presented by Charnes et al. (1981) and discussed by Lovell (1994)[12] to take the categorical environmental variable into account: the observations are first divided into two mutually exclusive groups. After the efficiency scores have been calculated for each group separately, the scores are used to scale the individual outputs to the efficient frontier in the respective group. New efficiency scores are then calculated for the combined group of all countries so that the scaled GDP figures are used as the output.

The scaling of the countries to the efficient frontier in the country's group results in much smaller differences in the final efficiency scores.[13] The group of the most efficient countries comprises now of Austria, Belgium, France, and Sierra Leone closely tailed by Ireland, Spain, and Switzerland as well as a large number of other countries. At the other extreme, Brazil, Algeria, Argentina, Malaysia, South Africa, Venezuela, Tunisia, Iran, and the Republic of Korea fare less well. These results imply that the assumption of equal access to the same technology is reasonable.

[11] In accordance with the World Bank convention, we use the term developing economies to denote low- and middle-income countries.

[12] The method was originally developed for separating management efficiency from programme efficiency. See Charnes et al. (1981).

[13] The results are available upon request.

3 Productivity distributions: how has the world of 1980 changed into the world of 2000?

3.1 Average performance in country groups

We decompose labour productivity in a manner analogous to Kumar and Russell (2002). Unlike them, we incorporate changes in human capital in the spirit of Mankiw et al. (1992). The technical details of the decomposition are presented in Appendix 1, whereas this section concentrates on the empirical results. The decomposition results are in Table 2. The percentage change in labour productivity between 1980 and 2000 is displayed in column 2 (y%). Columns 3-6 display the effects that changes in efficiency (EC%), technology (TC%), physical capital (K%), and human capital (H%) have had on labour productivity development in each country.

Table 2: Decomposition of changes in labour productivity (L=official labour force statistics)

	y%	EC%	TC%	K%	H%
Algeria	-26.3	-16.1	10.3	-28.0	10.7
Argentina	-4.6	-1.0	9.2	-14.5	3.1
Australia	31.7	-15.7	19.2	29.9	1.0
Austria	45.2	17.9	6.6	5.9	9.1
Bangladesh	34.0	78.8	-44.1	16.5	15.0
Belgium	39.7	-0.4	9.1	18.4	8.6
Bolivia	-14.2	24.0	-31.8	-5.2	7.0
Botswana	137.2	-13.7	-2.6	145.7	14.9
Brazil	-8.9	-12.4	12.1	-13.4	7.1
Cameroon	-5.5	3.7	-24.2	6.8	12.7
Canada	28.1	-19.9	11.2	41.3	1.7
Chile	67.3	-3.6	-3.9	75.0	3.2
China	352.9	349.1	-56.9	98.5	18.0
Colombia	-6.8	-8.0	-8.9	7.0	3.9
Congo, Dem. Rep.	-62.1	-17.4	-55.4	-18.6	26.4
Costa Rica	9.5	-4.3	-1.0	12.4	2.9
Denmark	35.9	4.7	11.4	13.4	2.9
Dominican Rep.	30.1	1.7	-12.8	37.4	6.7
Ecuador	-23.3	18.6	-16.6	-23.4	1.3
Egypt, Arab Rep.	52.8	20.2	-19.1	24.2	26.6
El Salvador	-12.7	-3.0	-13.6	-7.1	12.1
Finland	53.8	8.3	13.1	8.6	15.7
France	37.0	0.0	7.8	14.0	11.5
Gambia, The	-0.4	-16.8	-40.0	33.3	49.8
Germany	39.0	3.1	10.5	14.9	6.2

table continues..

Ghana	6.0	93.3	-51.4	6.0	6.5
Greece	11.0	-9.6	20.2	-1.1	3.3
Guatemala	-9.1	3.0	-6.1	-10.5	5.0
Guyana	-13.7	123.3	-7.3	-59.8	3.7
Honduras	-13.9	-9.1	-21.5	3.4	16.7
Hong Kong, China	103.6	-17.4	12.4	110.0	4.4
Hungary	29.0	0.4	-4.0	33.6	0.1
Iceland	26.3	-7.8	14.7	11.0	7.5
India	99.1	140.4	-53.0	39.8	26.1
Indonesia	64.6	22.6	-35.8	85.7	12.7
Iran, Islamic Rep.	16.5	37.4	2.4	-24.9	10.3
Ireland	122.4	18.8	22.9	42.4	6.9
Israel	29.1	-5.6	14.9	18.6	0.4
Italy	28.6	-7.8	13.1	13.6	8.5
Jamaica	-2.5	4.9	-4.5	-7.3	5.0
Japan	44.5	17.2	7.7	6.3	7.7
Jordan	-28.6	-15.6	-1.3	-21.2	8.9
Kenya	-11.1	111.9	-49.5	-24.8	10.5
Korea, Rep.	166.5	-22.5	1.4	218.5	6.5
Lesotho	60.8	15.9	-18.7	66.2	2.7
Malawi	9.4	208.5	-42.4	-43.1	8.2
Malaysia	94.8	-28.5	-1.8	163.1	5.4
Mali	1.2	-2.6	-7.8	1.7	10.7
Mauritius	96.0	3.1	-2.9	90.8	2.6
Mexico	-8.2	-16.6	0.5	1.6	7.7
Mozambique	27.2	7.7	-45.6	82.8	18.8
Netherlands	26.9	9.9	6.1	2.2	6.5
New Zealand	9.2	-10.8	10.1	10.8	0.3
Nicaragua	-36.8	3.4	-26.6	-25.6	11.8
Niger	-34.8	160.2	-10.9	-75.7	15.7
Norway	55.2	6.5	8.3	3.8	29.7
Pakistan	53.3	59.6	-38.9	21.3	29.7
Panama	6.5	-24.9	-9.9	47.6	6.6
Papua New Guinea	9.2	30.7	-9.3	-17.9	12.1
Paraguay	-7.8	-19.6	-12.7	25.3	4.8
Peru	-24.9	-20.4	-9.1	-1.0	4.8
Philippines	-7.4	18.5	-34.4	9.1	9.2
Portugal	62.5	-24.0	23.3	53.5	13.0
Rwanda	-21.4	12.9	-54.8	23.9	24.3
Senegal	14.5	45.1	-32.5	10.2	6.0
Sierra Leone	-54.4	0.0	-97.3	1380.8	15.1
Singapore	137.7	14.4	16.4	55.4	14.8

table continues..

South Africa	-19.9	-10.6	4.5	-20.0	7.2
Spain	35.5	-16.6	22.3	25.8	5.5
Sri Lanka	66.3	73.6	-44.1	56.2	9.8
Swaziland	31.8	20.1	-13.3	13.9	11.1
Sweden	31.9	-7.8	21.4	15.0	2.5
Switzerland	5.6	-2.9	6.1	1.8	0.7
Syrian Arab Rep.	-1.7	48.9	-11.4	-32.8	10.9
Thailand	117.8	8.0	-16.6	118.0	10.9
Togo	-27.6	42.9	-28.7	-36.9	12.6
Tunisia	30.3	0.8	2.2	15.9	9.2
United Kingdom	49.7	-9.0	15.9	39.0	2.1
United States	42.5	-16.2	15.5	46.8	0.2
Uruguay	1.8	0.0	-0.1	-2.0	3.9
Venezuela	-30.9	10.4	2.8	-40.9	3.0
Zambia	-32.3	140.8	-33.8	-62.4	13.0
Zimbabwe	-1.3	13.2	-32.9	-7.0	39.7

Source: Authors' calculations.

The *average* percentage changes between 1980 and 2000 for different country groups are collected in Table 3. Average productivity improvement in the world was mostly due to physical capital deepening, but this result is strongly affected by the presence of Sierra Leone in calculations.[14] Without Sierra Leone, the change in efficiency plays an equally important role.

The averages reveal some interesting differences between the country groups. The average growth in output per worker, i.e. labour productivity, exceeded 45 per cent in high-income countries, but remained below 20 per cent in developing economies. The effect of the change in efficiency is close to 30 per cent in developing economies, while the contribution of the component is negative (-2.8 per cent) in high-income countries. In contrast, the average effect from technological change, i.e. from the movement of the best practice frontier, has been positive at over 10 per cent in high-income countries but is negative -20 per cent in developing economies. This is a major explanation for the divergence in average paths in output per worker.

[14] If Sierra Leone with its exceptionally low capital per labour ratio is excluded from the data envelopment analysis, the efficiency scores of those lower-income countries that originally had Sierra Leone as a part of their reference technology improve. The most dramatic impacts are seen in the decompositions. Although the relative contributions of particularly efficiency change and capital accumulation may change somewhat drastically within a country, the signs of the contributions remain unchanged. These results are available upon request.

Table 3: Mean effects in different groups of countries

	The change in GDP per worker (%)	The contribution to the change in labour productivity of the change in			
		efficiency	technology	physical capital	human capital
Mean, all countries	27.3	19.5	-9.8	35.5	10.0
excluding Sierra Leone	28.3	19.8	-8.8	19.1	10.0
Mean, high-income countries	45.3	-2.8	13.6	24.1	6.8
Mean, developing economies	19.5	29.2	-19.9	40.5	11.4
excluding Sierra Leone	20.8	29.7	-18.6	17.0	11.3
Mean, middle-income countries	28.4	15.3	-9.0	23.4	7.9
Mean, upper-middle-income countries	38.3	-8.9	0.3	49.8	5.3
Mean, lower-middle-income countries	22.4	30.0	-14.6	7.4	9.5
Mean, low-income countries	3.9	53.5	-39.3	70.5	17.5
excluding Sierra Leone	6.9	56.2	-36.4	5.0	17.6
Mean, not classified by debt	45.3	-2.8	13.6	24.1	6.8
Mean, less-indebted countries	58.8	38.2	-17.0	40.8	11.0
Mean, moderately-indebted countries	15.0	12.7	-17.6	22.0	11.0
Mean, severely-indebted countries	-13.3	43.3	-26.2	66.3	12.3
excluding Sierra Leone	-10.7	46.0	-21.7	-15.9	12.1
Mean, HIPCs	-15.0	51.8	-36.7	66.5	15.0
excluding Sierra Leone	-12.7	54.8	-33.2	-10.8	15.0

Note: These are non-weighted arithmetic means. Country classifications presented in Appendix 2 are the World Bank classifications for the year 2000. These were chosen because the results can now be analysed from the end-of-the-period point of view and because similar classifications are unavailable for the beginning of the period.

Source: Authors' calculations.

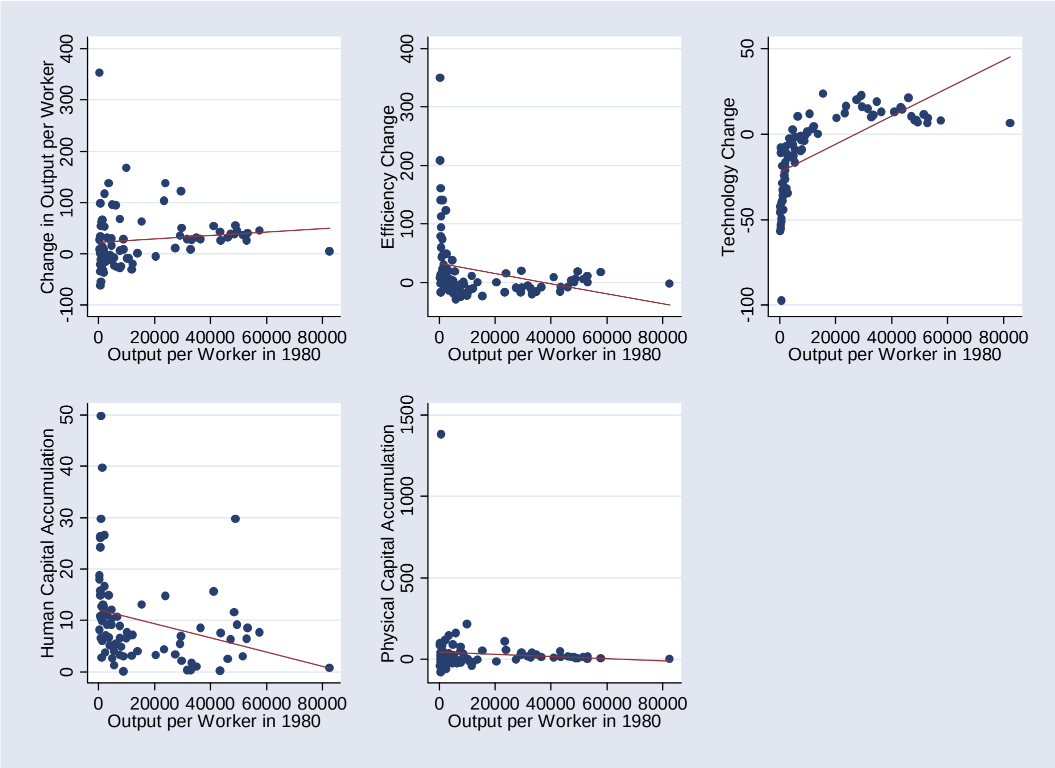
How can one explain this technological implosion? One answer is that at the same time as these countries have improved their efficiency, their production structure has concentrated more in activities with relatively slow technological change. Secondly, some developing economies may be liquidity constrained for example due to high debt, and cannot afford to buy the latest technologies but are, however, able to improve the efficiency at which they are using their old equipment.[15] The accumulation of physical capital seems to play an important role in sustaining average international income differentials. The contribution of human capital accumulation displays less variation although it has generally been a little higher in the developing economies. The striking

[15] Henderson and Russell (2004) rule out the possibility of technological implosion. We did not want to follow them for the reasons just given.

observation is that improvements in efficiency seem to have been largest in the countries with either severe or low levels of debt.[16] The interpretation of this result will be given below.

The group average changes can be produced by large changes in just few countries. To begin with the analysis of changes in the entire distribution of labour productivity, we plot the growth rates of labour productivity and its components against the income per capita in 1980 in Figure 1. The first diagram gives the changes in output per worker over 1980-2000, the next ones changes in efficiency, technical change, human capital accumulation and physical capital accumulation. The figures also display the trends (basically reproducing the same information as Table 3).

Figure 1: Percentage changes in output per worker, efficiency, technology, human capital and physical capital between 1980 and 2000



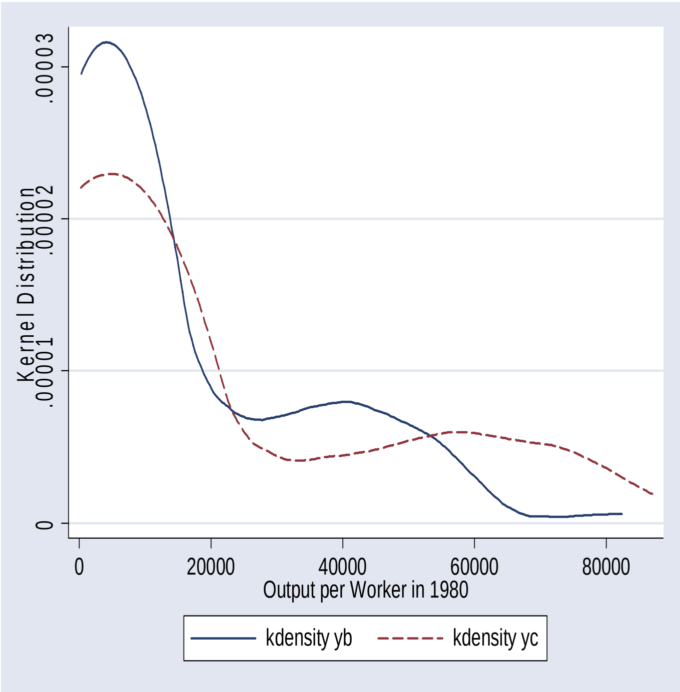
The dispersion among low-income countries is huge in comparison to high-income countries. Secondly, there is some non-linearity: the poorest countries have gained most from efficiency improvements, but the medium-income countries the least. This contrasts with Kumar and Russell (2002: figure 4b), who find that all countries benefited equally (little) from efficiency improvements.

16 The differences between debtor country groups are sensitive to the year on which the classification is based, because movements from one indebtedness group to another are not rare. The basic result of large efficiency improvements in debtor countries is not sensitive to this problem.

3.2 Productivity distributions in country groups

We next examine the distribution dynamics of output per worker to get an idea of how individual countries and country groups performed, and how the distribution of labour productivity changed between 1980 and 2000. The distributions of labour productivity in these two years are in Figure 2 (the dotted line refers to the distribution in 2000 identified by c in the figure legend). These are kernel estimates of the distributions.

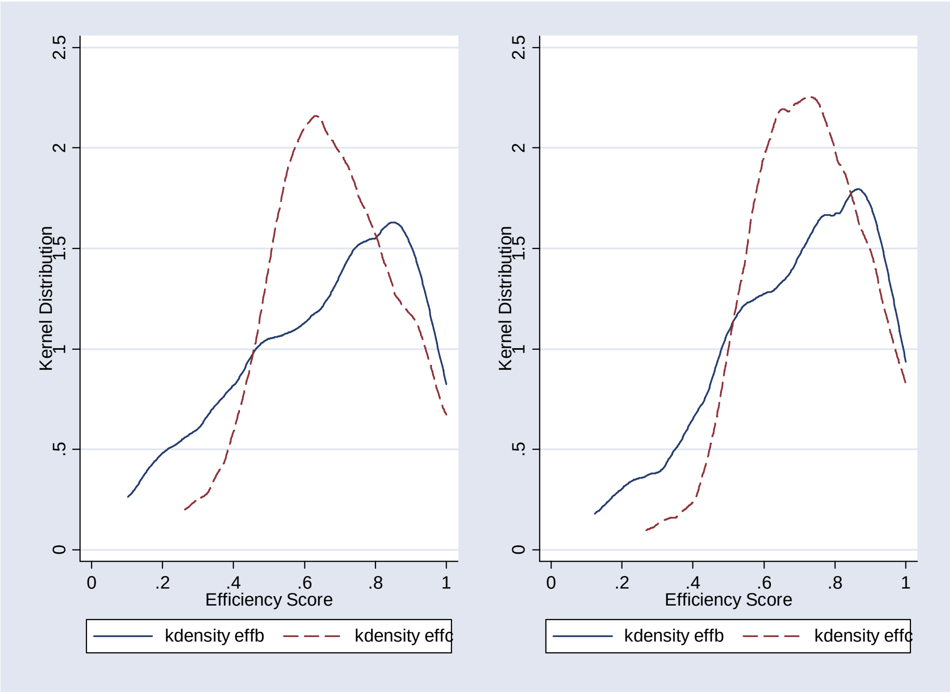
Figure 2: Distributions of output per worker, 1980 and 2000



The usual story is that the world income per capita distribution has two peaks (Jones 1997), which was confirmed by Kumar and Russell (2002). Our results for the year 1980 imply likewise a bimodal distribution, but the evidence for 2000 is weaker. This may naturally be partly due to differences in data sets, but one cannot rule right away out the possibility that the world is not as polarized as it used to be.

The kernel estimates of distributions of the efficiency scores (or catch-up measures) for years 1980 (label kdensity effb) and 2000 (label kdensity effc) are in Figure 3. The first panel depicts the efficiency scores calculated with the data comprising Sierra Leone, while the right-hand figure is based on a data set without Sierra Leone. The figures imply that the same discussion holds for both cases. The density concentrated at the lowest efficiency scores is smaller in 2000 than in 1980. The second more striking feature is that the poorest countries, which had the lowest scores in 1980, have gained a lot in efficiency while rich countries have been losing.

Figure 3: Distributions of efficiency index, 1980 and 2000 (with and without Sierra Leone)



To study how the labour productivity distribution of 1980 was transformed into the distribution of 2000, we analyze how the individual components of the decomposition (A6) presented in Appendix 1 change the distribution of 1980. We first show the transformation for all countries, then for developing economies, then for different income and debt classes within developing economies, and finally for heavily indebted poor countries.[17] In Figure 4, the first diagram reproduces Figure 2. The second diagram shows the kernel estimate of the distribution in 2000 (depicted by the dash line) together with the estimate of distribution of

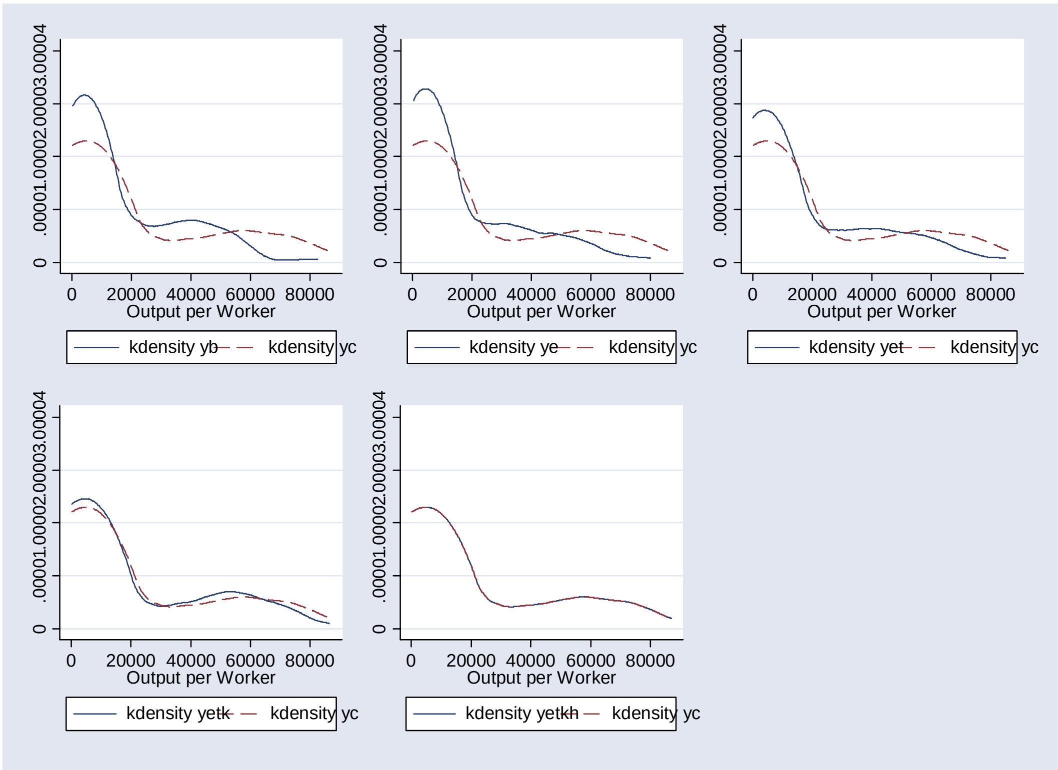
$$\frac{e_c}{e_b} y_b$$

where b = 1980 and c = 2000. Like in Kumar and Russell (2002), the latter and its equivalents will be called counterfactual distributions in the text below. The third diagram gives the impact of the cumulative changes in efficiency and technological change on 1980 labour productivity, the fourth the combined impact of efficiency, technological change and physical capital accumulation and the last diagram (producing the first) the combined impact of all the underlying changes, including human capital

[17] We use the test devised by Li (Pagan and Ullah 1999: 68-9, test statistic given by their equation 2.144) to test for the significance of the distribution change. The test is valid also when x and y are dependent. Test results are presented in Appendix 5.

accumulation.[18] The order of presentation does not influence the results (transformations using other representative orders of presentation are given in Appendix 3).

Figure 4: Counterfactual distributions of labour productivity: all countries



All countries

The distributions of labour productivity in 1980 and in 2000 are statistically different. There is no single driver of the change in the distribution. Statistically,[19] the most significant driver of change has been technological change together with physical and human capital accumulation. Changes in efficiency have also contributed to the transformation of the labour productivity distribution by taking away the other peak from the distribution of 1980 (Figure 4).

---

18 Letter *e* in the legend of the next figures and diagrams refers to efficiency, *t* to technological change, *h* to the contribution of human capital, and *k* to the contribution of physical capital.

19 See the Table in Appendix 5.

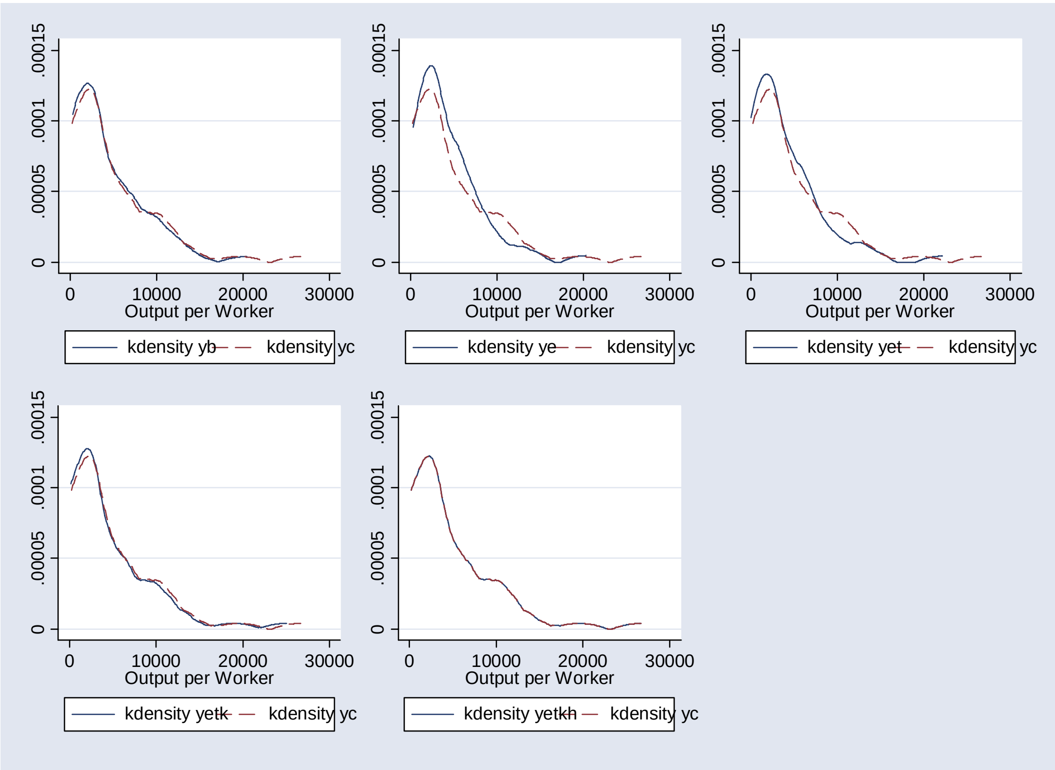
High-income countries

In high-income countries, the distribution has been altered jointly by technological change and physical capital accumulation.[20] This holds irrespective of the order in which the components are taken into account (Figure A4 in Appendix 4). Statistically the distributions of labour productivity in 1980 and in 2000 are different.

Developing economies

Figure 5 displays the results for developing economies, the first diagram giving again the kernel estimates of the actual distributions. Statistically, the distributions of 1980 and 2000 are identical. Yet, there has been a significant improvement in efficiency, which has, jointly with human capital, increased developing country income (*ceteris paribus*). The positive effect has been nullified by technological change and lack of capital accumulation.

Figure 5: Counterfactual distributions of labour productivity: developing economies



Is it possible to analyze the improvement in developing countries' efficiency (technological catch-up) in terms of the theories reviewed in the introduction? Geography cannot matter much, as the efficiency gain has been widespread (see

[20] Exactly, the Li-test indicates that the distribution of labour productivity obtained from the distribution of 1980 by taking into account the changes in efficiency and physical capital stock is the same as the actual year 2000 distribution. For other combinations of underlying changes this does not hold.

Table 2). Similarly, it is hard to make a case for a change in institutions in this period as the single major factor causing the stagnation of developing country incomes. Such a result would have to be based on a more detailed analysis on the common (institutional) features of those countries that have gained in efficiency.

There thus seems to be a puzzle, which is even larger when we look at the debtor countries. The phenomenon is consistent with the Nelson-Phelps model, which implies the catch-up rate is an increasing function of human capital intensity. The model also helps to understand why the contribution of human capital, for given catch-up, seems to be small. In addition finance constraints may explain the result.

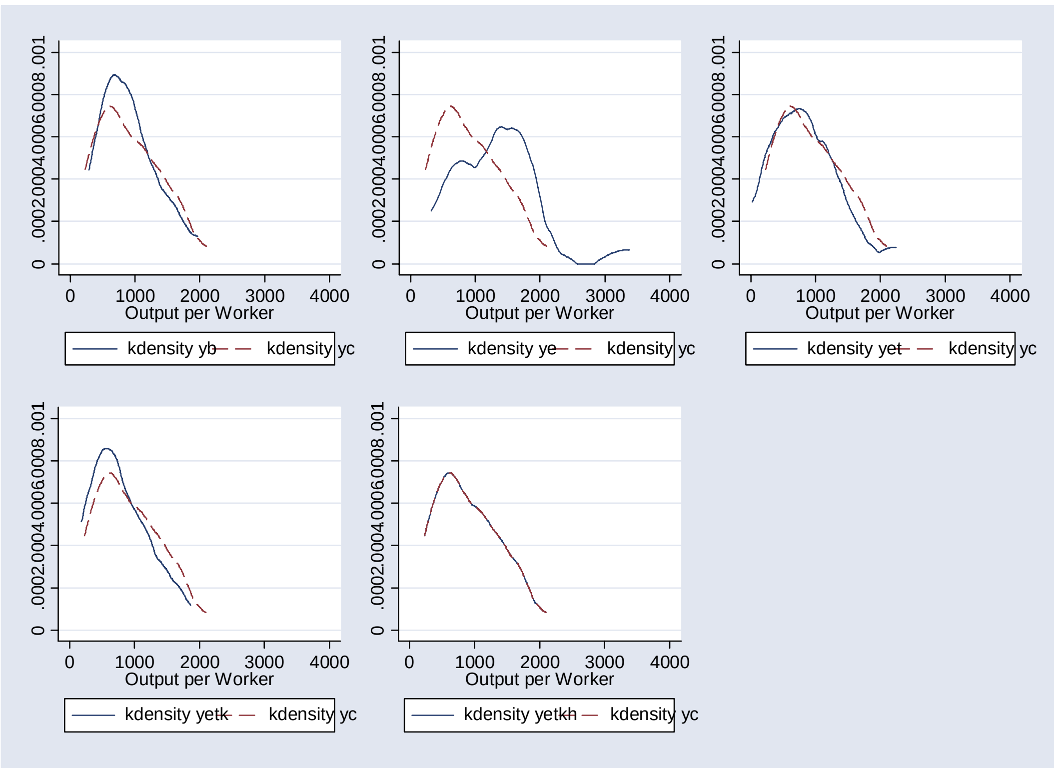
Middle-income countries

In middle-income countries (see Figure A5 in Appendix 4), the distributions of labour productivity in 1980 and 2000 are the same. The counterfactual 1980 distribution combining the effects of changes in efficiency and human and physical capital stocks differs significantly from the distribution of 2000.

Low-income countries

In low-income countries of Figure 6, changes in efficiency (jointly with human capital) and technology are statistically significant drivers of change, but netting each other out. Changes in efficiency improve incomes.

Figure 6: Counterfactual distributions of labour productivity: low-income countries (with Sierra Leone)



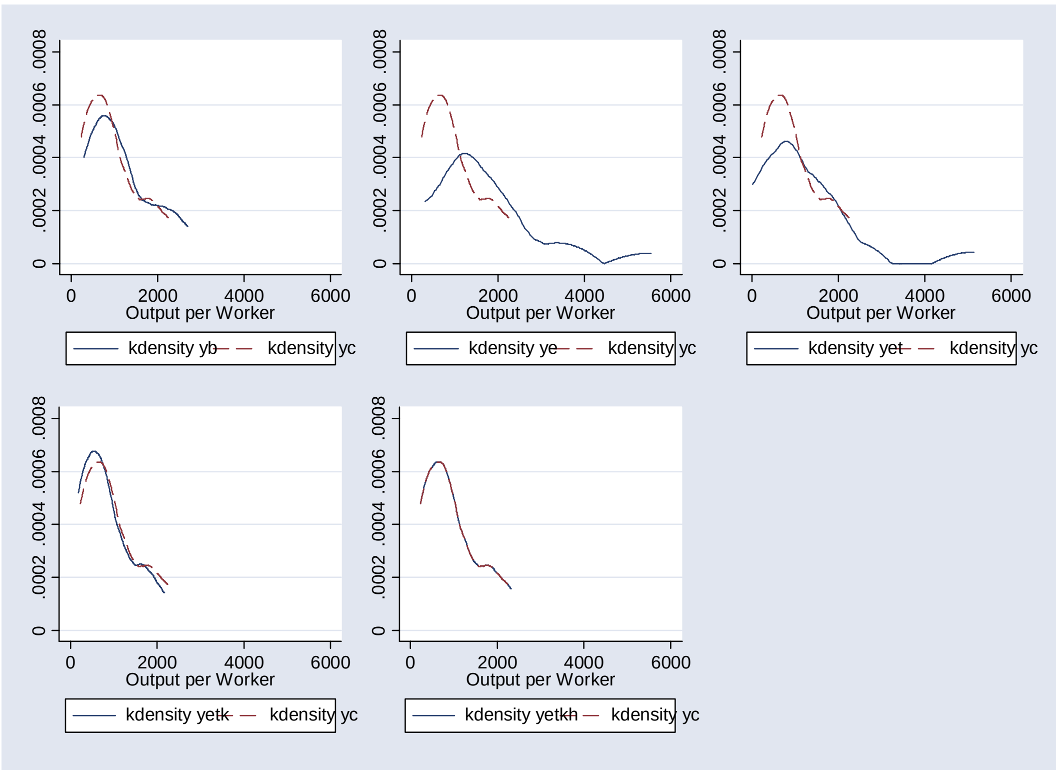
Debtor countries

In all three debtor country groups from severely-indebted to less-indebted countries, the actual 1980 distribution and all counterfactual distributions are statistically identical with the 2000 distribution (see also Figures A6-A8). This means that the component changes have been too small and too diverse, perhaps also to different directions, to have had a statistically significant impact.

HIPCs

Again, in the aggregate there has not been any statistically significant change in the distribution between 1980 and 2000 (Figure 7). Changes in productive efficiency have, however, had a large, statistically significant impact on the distribution of labour productivity in HIPCs: improvements in efficiency have tended to reduce the proportion of countries at low productivity levels and increased the proportion of countries at relatively high output per worker levels. Hence, efficiency improvements have tended to benefit the highly-indebted countries. These benefits have been taken away by the technological implosion and contraction in physical capital accumulation.

Figure 7: Counterfactual distributions of labour productivity: HIPCs



The result[21] gives fairly strong support for the reasoning behind the debt Laffer curve: high indebtedness reduces incentives to invest in productive capital. Hansen (2004) finds also that high indebtedness reduces growth by reducing investment. Our data does not support the possibility that high indebtedness allows debtor countries to escape the necessary policy reforms. If the implication of the hypothesis is that the lack of reforms increases the waste of resources, then exactly the opposite has happened according to our data. Since most of the HIPCs are in sub-Saharan Africa, the results are in line with Artadi and Sala-i-Martin (2003), who find that the high price of capital goods significantly reduces income there.

4 Conclusions

We studied the world distribution of output per worker between the years 1980 and 2000. We used data envelopment analysis to decompose the changes in the distribution of output per worker into changes in productive efficiency (which can be interpreted to measure the degree of technological catch-up), changes in best practice technology (technological change), accumulation of human capital, and accumulation of physical capital. The most significant results are:

a) The distribution of income in developing and HIPC countries has not changed between 1980 and 2000. This stagnation has been created by decline in capital accumulation, as at the same time improvements in production efficiency have been remarkable. In HIPCs, resources have been shifted to sectors with below average productivity growth and/or production has been using old technology more efficiently, while at the same time investments in new technology have remained very low. This implies that one should not focus on institutions alone to explain stagnation, as institutional explanations usually emphasize the inefficiencies created by bad institutions. Instead, one should look for factors working together with institutional factors. The result also supports the reasoning behind the debt Laffer curve, as it implies that excessive debt creates a tax on investment. The analysis does not support the view that high indebtedness allows countries to escape reforms.

b) The world distribution of output per worker since 1980 until 2000 has been altered *jointly* by technological change and accumulation of physical and human capital. Technological change together with changes in productive efficiency has had some effect, too. No single factor can explain the change since 1980s. This is in contrast with studies focusing on earlier periods: they have found the deepening of physical capital to be the major factor.

[21] To check the robustness of the results we have made the decompositions based on the efficiency scores calculated without Sierra Leone With some minor exceptions all the results hold. The results are available upon request.

c) Developed and developing countries share the same frontier technology.

A look at the distributions can thus clarify some of the issues related to the problems of development. To get further, it is necessary to model explicitly for example the determinants of efficiency. In the context of DEA this requires special care (for example Simar and Wilson 2003), but the benefits may be large. This is left for future work.

Appendix 1

Decomposition of output/worker

We decompose labour productivity in a manner analogous to Kumar and Russell (2002) but incorporating also changes in human capital.[22] For any country for *b*(ase) and *c*(urrent) periods change in labour productivity can be decomposed into changes in efficiency and potential output:

$$\frac{y_c}{y_b} = \frac{e_c \times \bar{y}_c(k_c, h_c)}{e_b \times \bar{y}_b(k_b, h_b)} \tag{A1}$$

where k_t, h_t are the physical capital and human capital stocks per capita for period t. Similarly, e_t is the efficiency score for period t. The potential output for the economy in period t is by definition $\bar{y}_t(k_t, h_t) = y_t / e_t$. Change in potential output can be decomposed into changes in technology and inputs. The problem is that it matters in which order decompositions are made. One decomposition is:

$$\frac{y_c}{y_b} = \frac{e_c}{e_b}\frac{\bar{y}_c(k_c, h_c)}{\bar{y}_b(k_c, h_c)}\frac{\bar{y}_b(k_c, h_c)}{\bar{y}_b(k_b, h_b)} = \frac{e_c}{e_b}\frac{\bar{y}_c(k_c, h_c)}{\bar{y}_b(k_c, h_c)}\frac{\bar{y}_b(k_c, h_c)}{\bar{y}_b(k_c, h_b)}\frac{\bar{y}_b(k_c, h_b)}{\bar{y}_b(k_b, h_b)} \tag{A2}$$

The first ratio measures the change in efficiency, the second ratio the impact of technological change, the third the impact of human capital accumulation and the fourth the impact of physical capital accumulation. This is the other possible decomposition:

$$\frac{y_c}{y_b} = \frac{e_c}{e_b}\frac{\bar{y}_c(k_c, h_c)}{\bar{y}_b(k_c, h_c)}\frac{\bar{y}_b(k_c, h_c)}{\bar{y}_b(k_b, h_c)}\frac{\bar{y}_b(k_b, h_c)}{\bar{y}_b(k_b, h_b)} \tag{A3}$$

[22] Our approach differs from Henderson and Russell (2004), who decompose the growth of labour productivity into the growth of output per efficiency unit of labour and the growth of human capital.

The third ratio measures the impact of physical capital accumulation, and the last the impact of human capital accumulation. The problem is solved by taking the geometric average and weighing the changes equally:

$$\frac{y_c}{y_b} = \frac{e_c}{e_b}\frac{\bar{y}_c(k_c,h_c)}{\bar{y}_b(k_c,h_c)}\left[\frac{\bar{y}_b(k_c,h_c)}{\bar{y}_b(k_c,h_b)}\frac{\bar{y}_b(k_b,h_c)}{\bar{y}_b(k_b,h_b)}\right]^{\frac{1}{2}}\left[\frac{\bar{y}_b(k_c,h_c)}{\bar{y}_b(k_b,h_c)}\frac{\bar{y}_b(k_c,h_b)}{\bar{y}_b(k_b,h_b)}\right]^{\frac{1}{2}} \qquad \text{(A4)}$$

The first ratio is again the change in efficiency, the second component is the technological change, the third measures the impact of human capital accumulation and the fourth the impact of physical capital accumulation.

In (A4) it still matters which capital stocks and techniques are used as the base, as the change can be decomposed as follows:

$$\frac{y_c}{y_b} = \frac{e_c}{e_b}\frac{\bar{y}_c(k_b,h_b)}{\bar{y}_b(k_b,h_b)}\frac{\bar{y}_c(k_c,h_c)}{\bar{y}_c(k_c,h_b)}\frac{\bar{y}_c(k_c,h_b)}{\bar{y}_c(k_b,h_b)} \qquad \text{(A5)}$$

In addition, (A5) has the problem that the order in which the impacts of the capital accumulation is calculated matters. Putting all things together leads to the solution:

$$\frac{y_c}{y_b} = \frac{e_c}{e_b}\left[\frac{\bar{y}_c(k_c,h_c)}{\bar{y}_b(k_c,h_c)}\frac{\bar{y}_c(k_b,h_b)}{\bar{y}_b(k_b,h_b)}\right]^{\frac{1}{2}}\left\{\left[\frac{\bar{y}_b(k_c,h_c)}{\bar{y}_b(k_c,h_b)}\frac{\bar{y}_b(k_b,h_c)}{\bar{y}_b(k_b,h_b)}\right]^{\frac{1}{2}}\left[\frac{\bar{y}_c(k_c,h_c)}{\bar{y}_c(k_c,h_b)}\frac{\bar{y}_c(k_b,h_c)}{\bar{y}_c(k_b,h_b)}\right]^{\frac{1}{2}}\right\}^{\frac{1}{2}} \times$$
$$\left\{\left[\frac{\bar{y}_b(k_c,h_c)}{\bar{y}_b(k_b,h_c)}\frac{\bar{y}_b(k_c,h_b)}{\bar{y}_b(k_b,h_b)}\right]^{\frac{1}{2}}\left[\frac{\bar{y}_c(k_c,h_c)}{\bar{y}_c(k_b,h_c)}\frac{\bar{y}_c(k_c,h_b)}{\bar{y}_c(k_b,h_b)}\right]^{\frac{1}{2}}\right\}^{\frac{1}{2}} \qquad \text{(A6)}$$

where the first ratio measures the change in productive efficiency, the second technological change, the third the impact of human capital accumulation, and the last the impact of physical capital accumulation.

Appendix 2

Table A1: Country classifications for 2000

BY INCOME LEVEL

High income	**Developing economies**		
Australia	**Upper middle income**	**Lower middle income**	**Low income**
Austria	Argentina	Algeria	Bangladesh
Belgium	Botswana	Bolivia	Cameroon
Canada	Brazil	China	Congo, Dem. Rep.
Denmark	Chile	Colombia	Gambia, The
Finland	Costa Rica	Dominican Republic	Ghana
France	Hungary	Ecuador	India
Germany	Korea, Rep.	Egypt, Arab Rep.	Indonesia
Greece	Malaysia	El Salvador	Kenya
Hong Kong, China	Mauritius	Guatemala	Lesotho
Iceland	Mexico	Guyana	Malawi
Ireland	Panama	Honduras	Mali
Israel	South Africa	Iran, Islamic Rep.	Mozambique
Italy	Uruguay	Jamaica	Nicaragua
Japan	Venezuela, RB	Jordan	Niger
Netherlands		Papua New Guinea	Pakistan
New Zealand		Paraguay	Rwanda
Norway		Peru	Senegal
Portugal		Philippines	Sierra Leone
Singapore		Sri Lanka	Togo
Spain		Swaziland	Zambia
Sweden		Syrian Arab Republic	Zimbabwe
Switzerland		Thailand	
United Kingdom		Tunisia	
United States			

BY INDEBTEDNESS

Not classified	**Less indebted**	**Moderately indebted**	**Severely indebted**
Australia	Bangladesh	Algeria	Argentina
Austria	Botswana	Bolivia	Brazil
Belgium	China	Chile	Cameroon
Canada	Costa Rica	Colombia	Congo, Dem. Rep.
Denmark	Dominican Republic	Gambia, The	Ecuador
Finland	Egypt, Arab Rep.	Ghana	Guyana

France	El Salvador	Honduras	Indonesia
Germany	Guatemala	Hungary	Jordan
Greece	India	Jamaica	Malawi
Hong Kong, China	Iran, Islamic Rep.	Kenya	Nicaragua
Iceland	Korea, Rep.	Malaysia	Niger
Ireland	Lesotho	Mali	Pakistan
Israel	Mexico	Mauritius	Peru
Italy	Paraguay	Mozambique	Rwanda
Japan	South Africa	Panama	Sierra Leone
Netherlands	Sri Lanka	Papua New Guinea	Syrian Arab Republic
New Zealand	Swaziland	Philippines	Zambia
Norway		Senegal	
Portugal		Thailand	
Singapore		Togo	
Spain		Tunisia	
Sweden		Uruguay	
Switzerland		Venezuela, RB	
United Kingdom		Zimbabwe	
United States			

Highly indebted poor countries

Bolivia	Mali
Cameroon	Mozambique
Congo, Dem. Rep.	Nicaragua
Gambia, The	Niger
Ghana	Rwanda
Guyana	Senegal
Honduras	Sierra Leone
Kenya	Togo
Malawi	Zambia

Source: the World Bank 2002.

Appendix 3

Decomposition of changes in world distribution of output per worker: alternative orderings

Figure A1: Counterfactual distributions of labour productivity: all countries

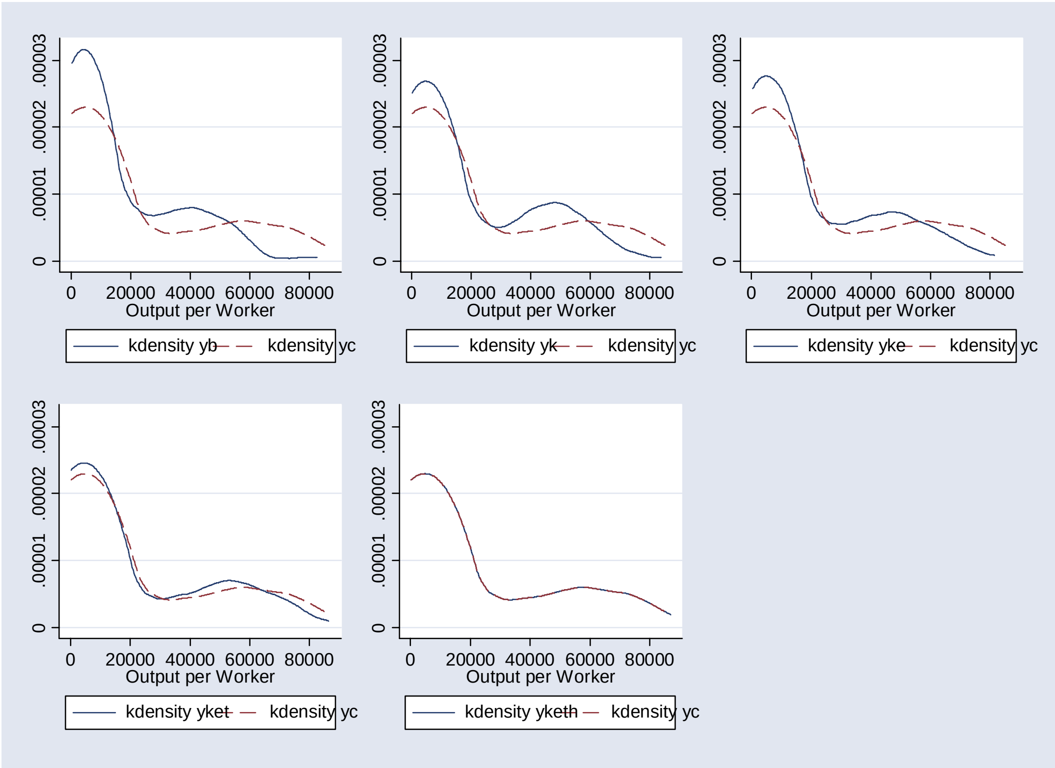


Figure A2: Counterfactual distributions of labour productivity: all countries

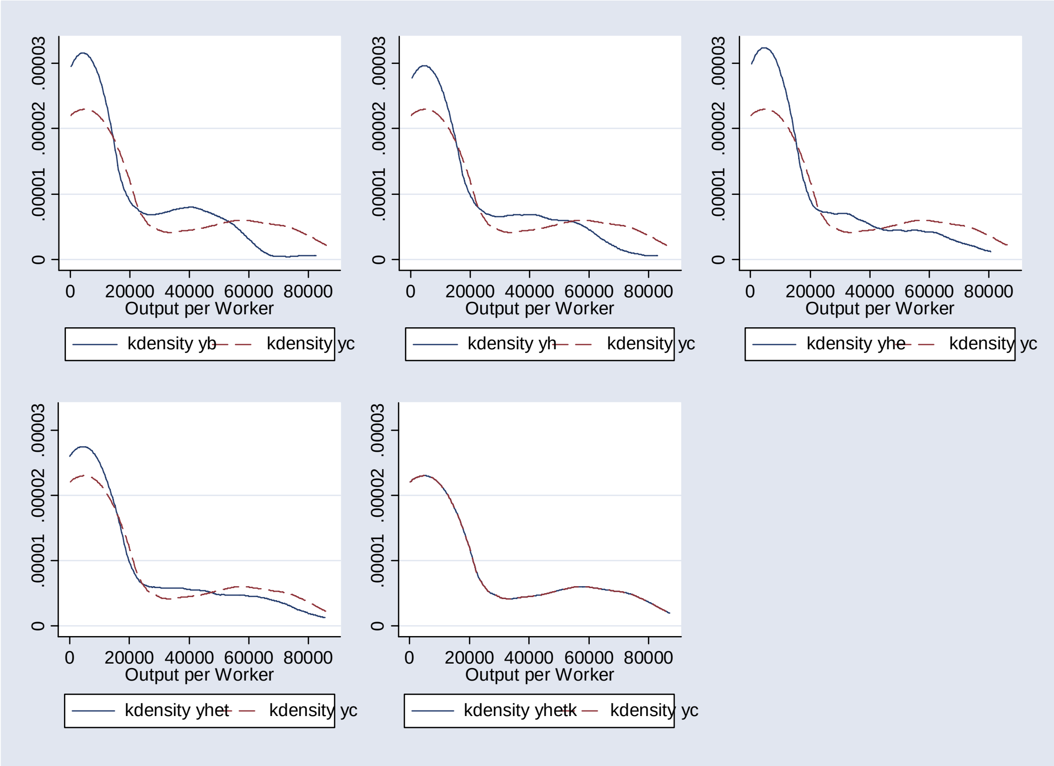
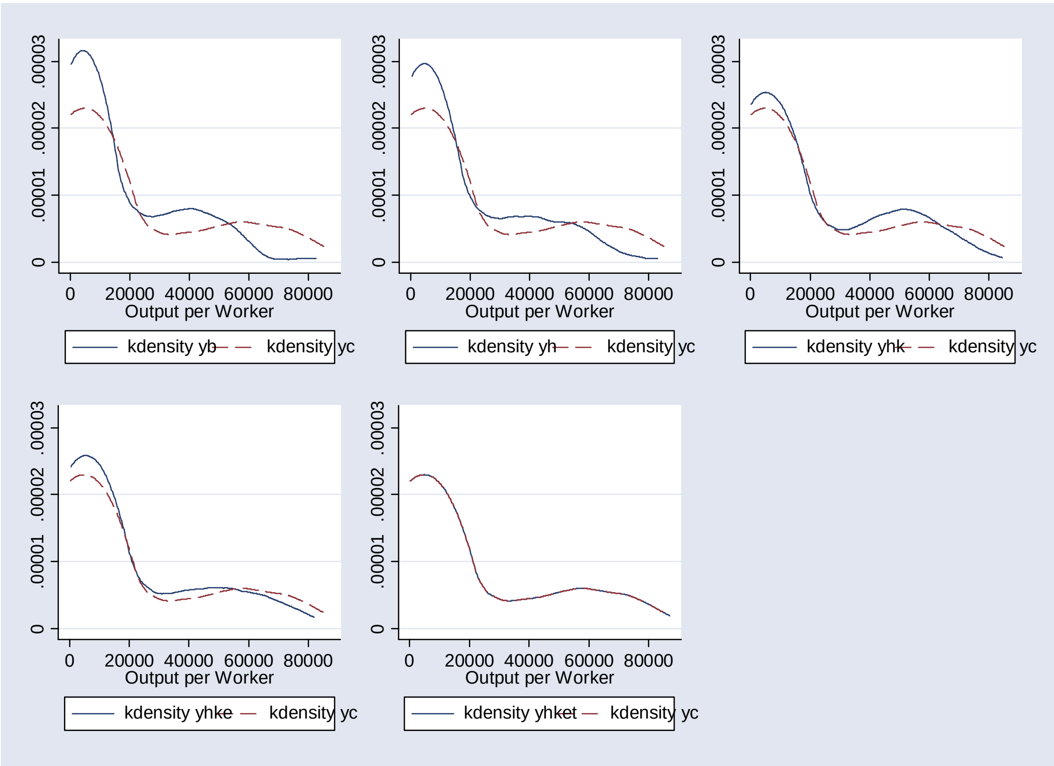


Figure A3: Counterfactual distributions of labour productivity: all countries



Appendix 4

Decomposition of changes in the distribution of output per worker in different groups of countries

Figure A4: Counterfactual distributions of labour productivity: high-income countries

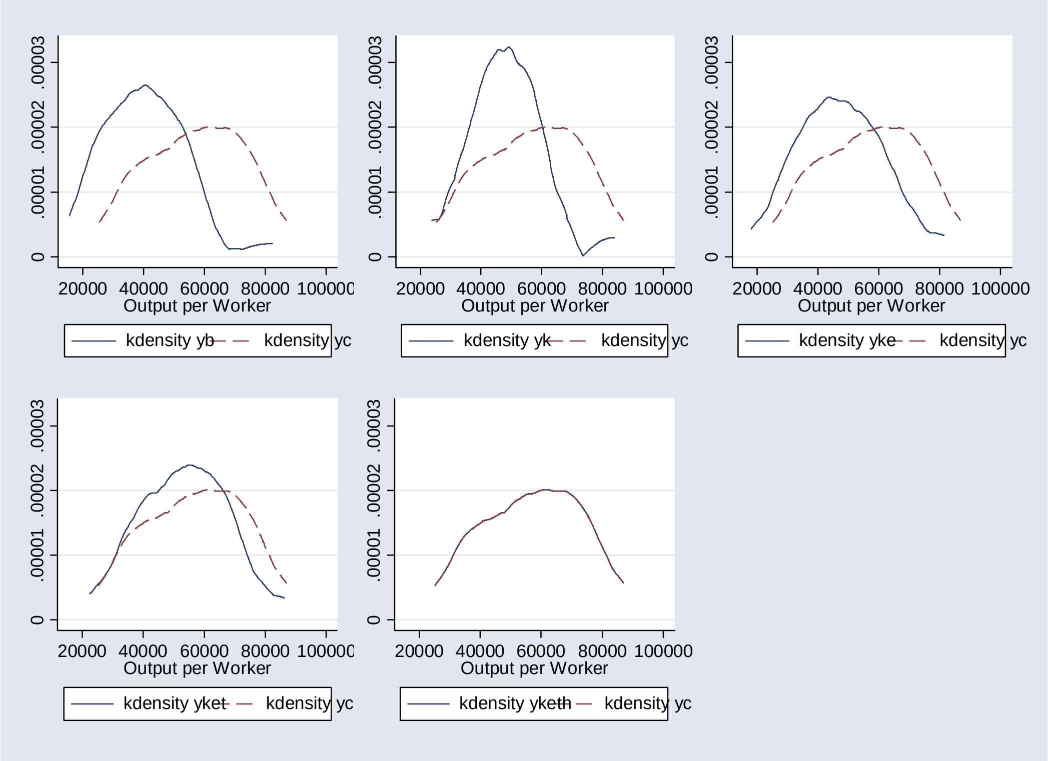


Figure A5: Counterfactual distributions of labour productivity: middle-income countries

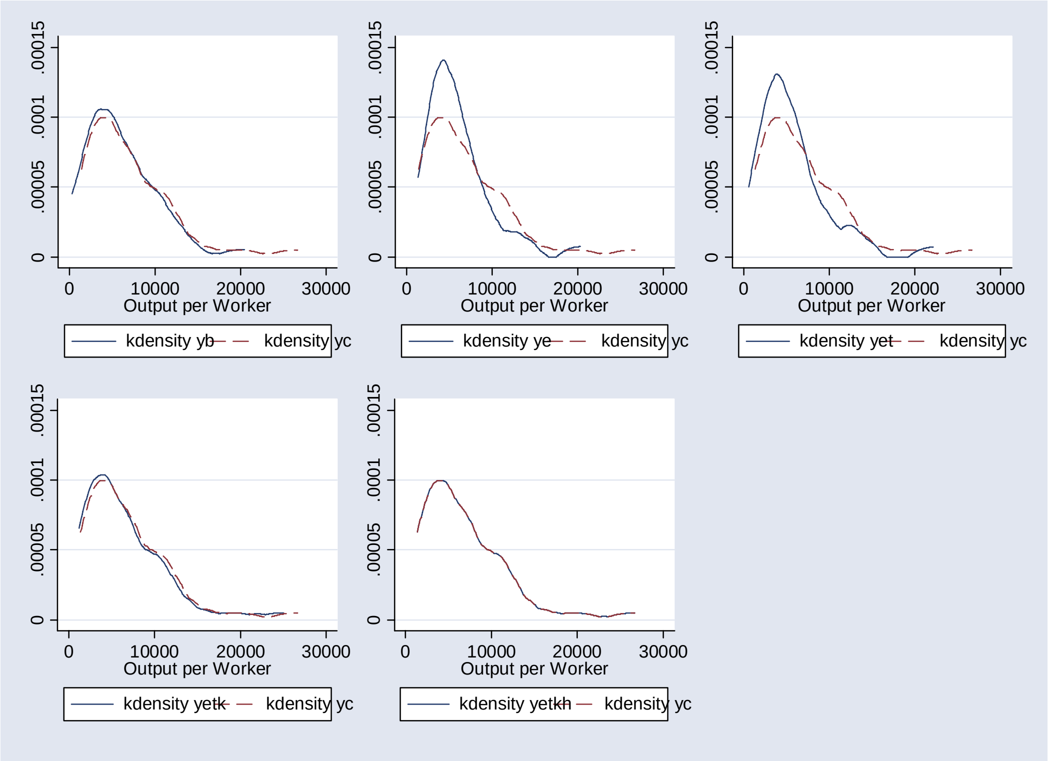


Figure A6: Counterfactual distributions of labour productivity: less-indebted countries

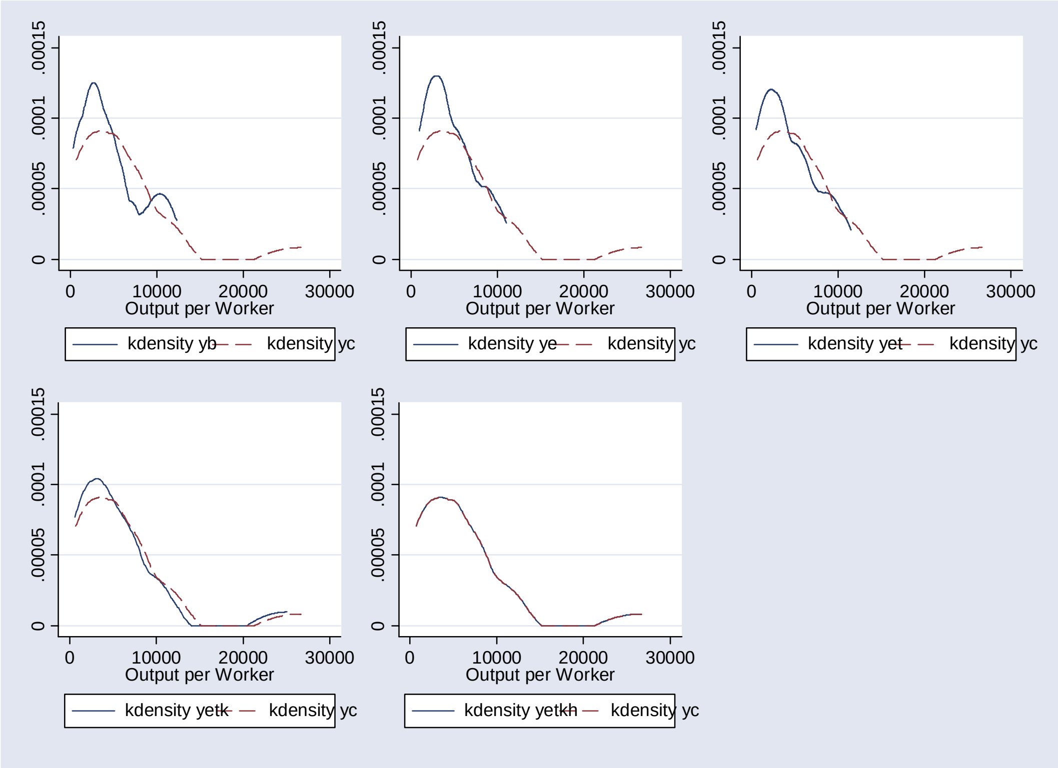


Figure A7: Counterfactual distributions of labour productivity: moderately-indebted countries

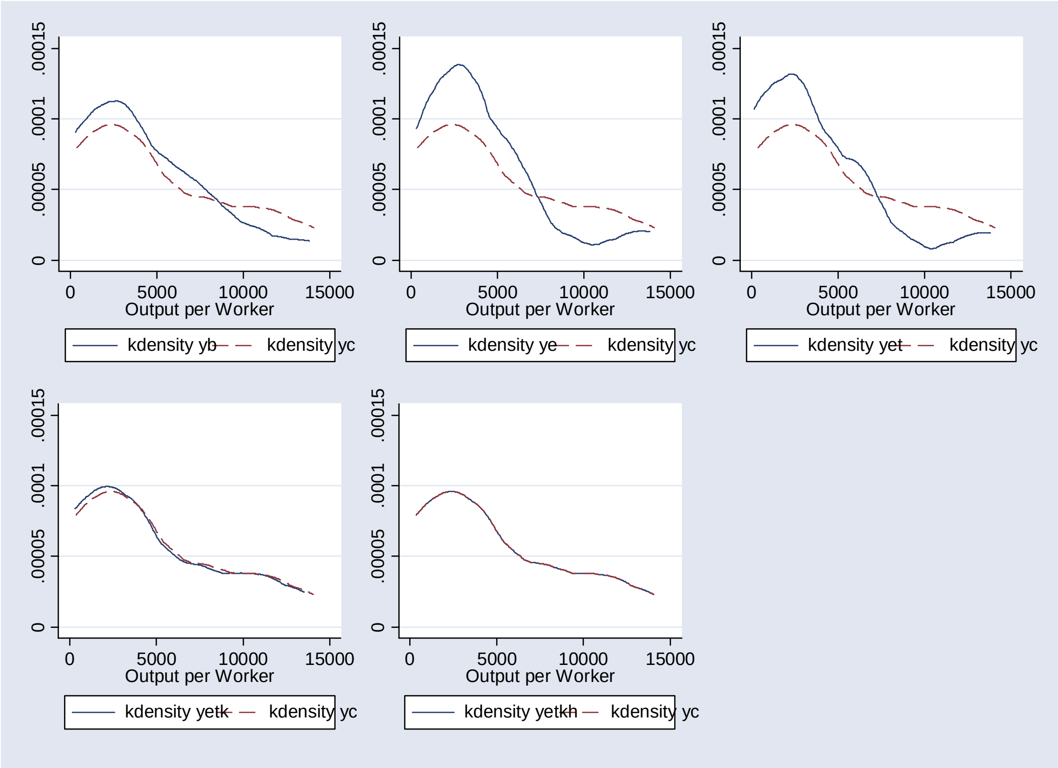
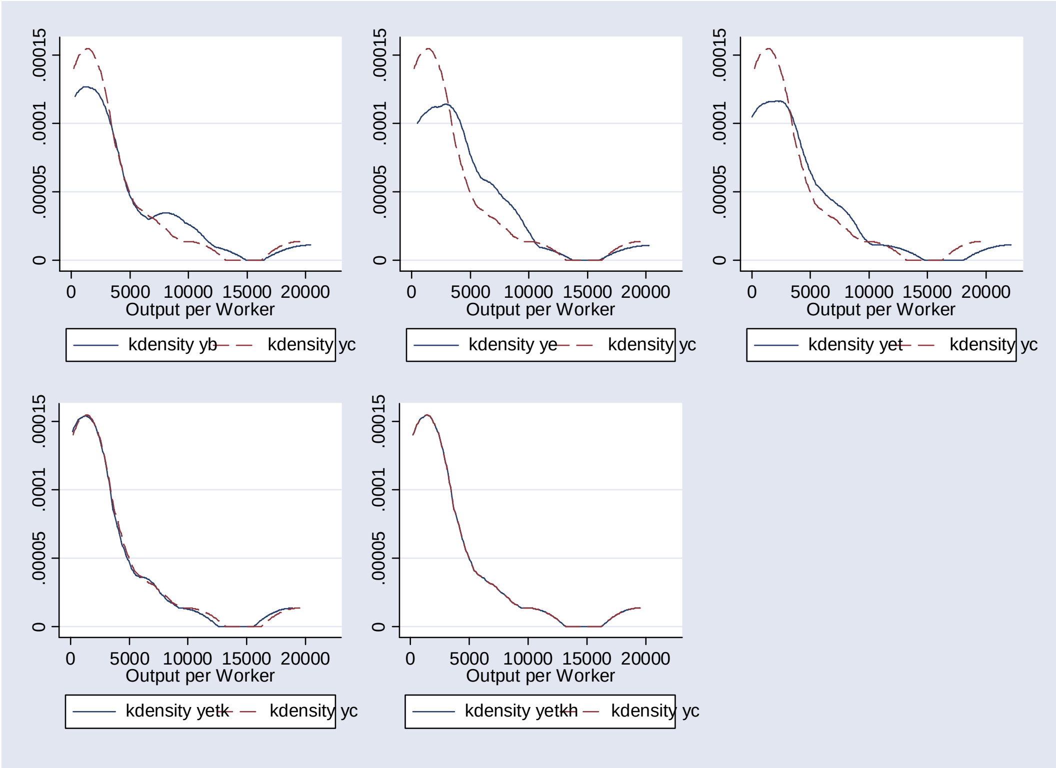


Figure A8: Counterfactual distributions of labour productivity: severely-indebted countries (with Sierra Leone)



Appendix 5

Statistical tests for the change in distribution

We used the bootstrap method to calculate the small sample distributions on which to base our tests. We resampled each country group 1000 times. Table 2A denotes the acceptance of the null-hypothesis indicated in the left most column, and R its rejection. For example in the HIPC case A in the first cell indicates that the null of no change in actual distribution between 1980 and 2000 is accepted. All tests are at 5 per cent significance level.

Table 2A: Test results for the change in distribution

Null hypothesis	All countries	High income	Developing economies	Low income	Middle income	HIPC
f(yc)=g(yb)	R	R	A	A	A	A
f(yc)=g(yE)	R	R	A	A	A	R
f(yc)=g(yT)	R	R	A	R	A	A
f(yc)=g(yK)	R	R	A	A	A	A
f(yc)=g(yH)	R	R	A	A	A	A
f(yc)=g(yET)	R	R	A	A	A	A
f(yc)=g(yEK)	R	R	A	A	A	A
f(yc)=g(yEH)	R	R	R	R	A	R
f(yc)=g(yTK)	A	A	A	R	A	A
f(yc)=g(yTH)	A	R	A	A	A	A
f(yc)=g(yKH)	R	R	A	A	A	A
f(yc)=g(yETK)	A	A	A	A	A	A
f(yc)=g(yETH)	A	R	A	A	A	A
f(yc)=g(yEKH)	R	A	R	R	R	R
f(yc)=g(yTKH)	A	A	A	A	A	A

Null hypothesis	Less-indebted	Moderately-indebted	Severely-indebted
f(yc)=g(yb)	A	A	A
f(yc)=g(yE)	A	A	A
f(yc)=g(yT)	A	A	A
f(yc)=g(yK)	A	A	A
f(yc)=g(yH)	A	A	A
f(yc)=g(yET)	A	A	A
f(yc)=g(yEK)	A	A	A
f(yc)=g(yEH)	A	A	A
f(yc)=g(yTK)	A	A	A
f(yc)=g(yTH)	A	A	A
f(yc)=g(yKH)	A	A	A

f(yc)=g(yETK)	A	A	A
f(yc)=g(yETH)	A	A	A
f(yc)=g(yEKH)	A	A	A
f(yc)=g(yTKH)	A	A	A

Source: Authors' calculations.

References

Acemoglu, D., P. Aghion, and F. Zilibotti (2003). 'Distance to Frontier, Selection, and Economic Growth', mimeo, University College London.

Acemoglu, D., S. Johnson, and J. Robinson (2002). 'Reversal of Fortune: Geography and Institutions in the Making of the Modern World Income Distribution', *Quarterly Journal of Economics* 117: 1369-401.

Artadi E. and X. Sala-i-Martin (2003). 'The Economic Tragedy of XXth Century: Growth in Africa', *NBER Working Papers* 9865, National Bureau of Economic Research: Cambridge MA.

Barro, R.J. (2000). 'Inequality and Growth in a Panel of Countries', *Journal of Economic Growth* 5: 5-32.

Barro, R.J., and J. Lee (2001). 'International Data on Educational Attainment: Updates and Implications', *Oxford Economic Papers* 53(3): 541-63.

Birdsall, N., S. Claessens, and I. Diwan (2003). 'Policy Selectivity Foregone: Debt and Donor Behavior in Africa', *World Bank Economic Review* 17(3): 409-35.

Caselli, F. (2005). 'Accounting for Cross-Country Income Differences', *CEP Discussion Papers* 667, Centre for Economic Policy Research: London.

Charnes, A., W.W. Cooper, and E. Rhodes (1978). 'Measuring the Inefficiency of Decision Making Units', *European Journal of Operational Research* 2(6): 428-49.

Charnes, A., W.W. Cooper, and E. Rhodes (1979). 'Measuring the Inefficiency of Decision Making Units', *European Journal of Operational Research* 3(4): 321-39.

Charnes, A., W.W. Cooper, and E. Rhodes (1981). 'Evaluating Programme and Managerial Efficiency: An Application of Data Envelopment Analysis to Programme Follow Through', *Management Science* 27(6): 668-97.

Cohen, D., and M. Soto (2001). 'Growth and Human Capital: Good Data, Good Results', *CEPR Discussion Papers* 3025, Centre for Economic Policy Research: London.

Collier, P., and J. Gunning (1999). 'Explaining African Economic Performance', *Journal of Economic Literature* 37(1): 64-111.

Färe, R., S. Grosskopf, and C.A.K. Lovell (1994). *Production Frontiers*, Cambridge University Press: Cambridge.

Glaeser, E., R. La Porta, F. Lopez-de-Silanes, and A. Shleifer (2004). 'Do Institutions Cause Growth', *NBER Working Papers* 10568, National Bureau of Economic Research: Cambridge MA.

Hall, R.E., and C.I. Jones (1999). 'Why Do Some Countries Produce So Much More Output Per Worker Than Others?', *Quarterly Journal of Economics* 114(1): 83-116.

Hansen, H. (2004). 'The Impact of External Aid and Debt on Growth and Investment', in T. Addison, H. Hansen, and F. Tarp (eds) *Debt Relief for Poor Countries*, Palgrave Macmillan for UNU-WIDER: Basingstoke and New York.

Henderson, D., and R. Russell (2004). 'Human Capital and Convergence: A Production Function Approach', mimeo, State University of New York, Albany.

Henry, M., R. Kneller, and C. Milner (2003). 'Trade, Technology Transfer and National Efficiency in Developing Countries', *CREDIT Research Papers* 2003/50, Centre for Research in Economic Development and International Trade, University of Nottingham: Nottingham.

Jones, C.I. (1997). 'On the Evolution of the World Income Distribution', *Journal of Economic Perspectives* 11(3): 19-36.

Krugman, P. (1988). 'Financing vs. Forgiving a Debt Overhang', *Journal of Development Economics* 29: 253-68.

Kumar, S., and R.R. Russell (2002). 'Technological Change, Technological Catch-up, and Capital Deepening: Relative Contributions to Growth and Convergence', *The American Economic Review* 92(3): 527-48.

Li, Q. (1996). 'Non-parametric Testing of Closeness between Two Unknown Distribution Functions', *Econometric Reviews* 15(3): 261-74.

Lovell, C.A.K (1994). 'Linear Programming Approaches to the Measurement and Analysis of Productive Efficiency', *Top* 2(2): 175-248.

Mankiw, N., D. Romer, and D. Weil (1992). 'A Contribution to the Empirics of Economic Growth', *Quarterly Journal of Economics* 107(2) 407-37.

Murillo-Zamorano, L.R. (2004). 'Economic Efficiency and Frontier Techniques', *Journal of Economic Surveys* 18(1): 33-77.

Nelson, R., and E. Phelps (1966). 'Investment in Humans, Technological Diffusion, and Economic Growth', *American Economic Review* 56(1/2): 69-75.

Pagan, A., and A. Ullah (1999). *Non-parametric Econometrics*, Cambridge University Press: Cambridge.

Pande R., and C. Udry (2005). 'Institutions and Development: A View from Below', paper presented at the Econometric Society World Congress 2005, August, London.

Rodrik, D. (ed.) (2003). *In Search of Prosperity*, Princeton University: New Jersey.

Ruotinen, J. (2005). 'Technological Diffusion and Trade in Services', mimeo, Helsinki School of Economics: Helsinki.

Sachs J., J. MacArthur, G. Schmidt-Traub, M. Kruk, G. McCord, C. Bahadur, and M. Faye (2004). 'Ending Africa's Poverty Trap', *Brookings Papers on Economic Activity* 1, The Brookings Institution: Washington DC.

Simar L., and P. Wilson (2003). 'Estimation and Inference in Two-Stage, Semi-Parametric Models of Production Processes', *Institut de Statistique Discussion Papers* 0307, Université Catholique de Louvain: Louvain-la-Neuve.

World Bank (2002). *World Development Indicators 2002*, World Bank: Washington DC.

World Bank (2004). *World Development Indicators Online*, retrieved in December 2004 from http://devdata.worldbank.org/dataonline/.