Growth Accounting for Some Selected Developing, Newly Industrialized and Developed Nations from 1966-2000: A Data Envelopment Analysis

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Key Words: Data envelopment analysis, growth accounting, technical efficiency, efficiency change, technological change, capital accumulation, human capital accumulation, kernel smoothing, cross country labor productivity distribution and counterfactual distributions

Abstract

We work out technical efficiency levels of 29 countries consisting of some selected South Asian, East Asian and EU countries using data envelopment analysis. Luxembourg has an efficiency score of one(most efficient) in all the years .Netherlands also has an efficiency score of one in 1966,1971,1976 and 1981.Japan,UK,Belgium,Ireland,Indonesia,Spain and Germany has an efficiency score of one in at least one of the years from 1966 to 2000.In the year 2000 though mean efficiency levels(without including life expectancy as input) of South Asian countries is higher than the European Union Countries and East Asian countries. Japan has the highest average efficiency followed by Hong Kong in the East Asian region in the period 1966-2000.

We also decompose labor productivity growth into components attributable to technological changes (shifts in the overall production frontier), technological catch up or efficiency changes(movement towards or away from the frontier),capital accumulation(movement along the frontier) and human capital accumulation(proxied by life expectancy).The overall production frontier is constructed using deterministic methods requiring no specification of functional form for the technology nor any assumption about market structure or the absence of market imperfections. Growth accounting results tend to convey that for the East Asian and the South Asian countries efficiency changes(technological catch up) have contributed the most, while for the European countries it is the technical changes which has contributed more to labour productivity changes between 1966-2000. We also analyze the evolution of cross country distribution for the 29 countries included in our sample using Kernel densities. It seems that there are other factors like trade openness,quality of governments,population rate of growth, savings rate, corruption perception indices, rule of law index, social capital and trust variables, formal and informal rules governing the society, among others, rather than the ones that are included below for the growth accounting exercise, which may be primarily responsible for the existence of bimodal labour productivity distribution for countries included in our sample. However, from this growth accounting exercise, we do find that there is convergence in statistical terms of efficiency changes and human capital accumulation across countries of the EU, South Asian and East Asian regions.

I: Introduction

Very much in the spirit of Quah's (1993, 1996b, 1997) suggested approach (also adopted by Galor [1996] and Jones [1997]), we analyze the evolution of the entire distribution of the four growth factors: technological change, technological catch-up, capital accumulation and human capital accumulation[2]. We analyze the contribution of these four components to the growth of countries labour productivity and to the shift in the countries distribution of labour productivity over time. Data envelopment analysis has been used to estimate the best production frontier for some of the Developed(EU Nations),Developing(South Asians) and Newly Industrialized Countries(East Asian nations) included in our study. The countries production frontier is constructed using deterministic methods requiring no specification of functional form for the technology nor any assumption about market structure or the absence of market imperfections. Technological catch up signifies movement towards the frontier, technical change is movement of the frontier, capital accumulation is movement along the frontier and human capital accumulation implying changes in the efficiency of labor.

Quah has argued compellingly that analyses based on standard regression methods focusing on first moments of the distribution cannot adequately address the convergence issue. These arguments are buttressed by the empirical analyses of Quah and others posing a robust stylized fact about the international growth pattern that begs for explanation. A plot of the distribution of output per worker across 29 countries consisting of 5 South Asian,8 East Asian and 16 EU countries(country names are given in Appendix Table I at the last) in 2000 and 1966 appears in Figure 1 and II respectively, below. (The data and the kernel based method of smoothing the distribution is described below in the section on methodology). Over this 34 year period, the distribution of labour productivity was transformed from a tri-modal distribution in 1966 into a bimodal distribution in 2000 with

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[2] This approach to Growth Accounting is not dependent on particular assumptions about the technology,market structure,technological change and other aspects of the growth process.

a higher mean(data on output per worker is available in Table III below- column II and Column III)[3]. This transformation in turn means that, while in 1966 there were countries in the lower, middle income and upper income groups, in 2000 the world had become divided, as a stylized fact, into two categories: the rich and the poor. It seems that

Figure I: Distribution of Output Per Worker , 2000(Bimodal)

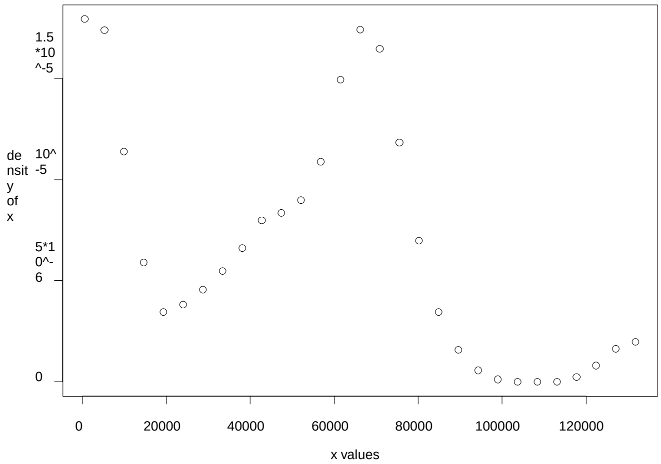
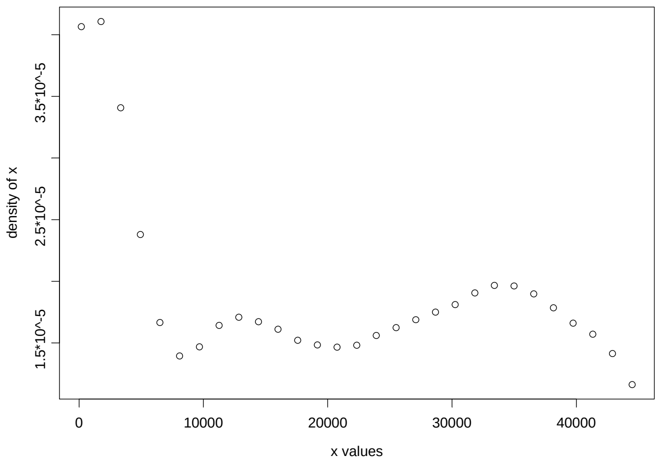


Figure II: Distribution of Output Per Worker , 1966 (Trimodal)



that almost all of the East Asian economies have joined the elite 'rich group'. Quah (1996a, b, 1997) refers to this phenomenon as “two-club”, or “twin-peak”, convergence a phenomenon that renders suspect analyses based on the first moment (or even higher

[3] Two-Sample Kolmogorov-Smirnov Test(non parametric test) is used to test whether two sets of observations could reasonably have come from the same distribution. This test assumes that the samples are random samples, the two samples are mutually independent, and the data are measured on at least an ordinal scale. In addition, the test gives exact results only if the underlying distributions are continuous. data: x: output per worker in 1966 , and y: output per worker in 2000 ks = 0.5172, p-value = 0.0007 alternative hypothesis: cdf of x: output per worker in 1966 does not equal the cdf of y: out put per worker in 2000 for at least one sample point.We conclude from the test that two sample probability distributions of output per worker in 1966 and 2000 are indeed different statistically.

moments) of this distribution. Our analysis is aimed at explaining this bipolarization of the distribution of output per worker, as well as its growth pattern, in terms of the tripartite and quadripartite decomposition described below. As such, it builds upon Quah's insights about the need to examine the "dynamics of the entire cross-section distribution" (Quah, 1997, p. 29). In this study we will further identify policies which may reduce differential levels of per-capita income levels and growth rates of regions and work out the reasons for the existence of bimodal distribution of per capita income across countries. Also, related to the concept of labour productivity is the concept of efficiency, i.e amount by which outputs can be increased without requiring extra inputs. We will also work out the 'efficiency levels' of countries included in our sample by using linear programming method of data envelopment analysis .

The main variables in use in this study will be GDP at Constant 1995 US $,capital(Constant 1995 US $) labour, life expectancy in years(proxy for human capital) and labour productivity(GDP divided by labour force) prevailing in different countries/ regions included in our study.

The paper is organized as follows. Section II reviews literature on data envelopment analysis and on growth accounting without the need for specification of a functional form for the technology, for the assumption that technological change is neutral, or for the assumptions about market structure or the absence of market imperfections. Section III is on objectives of the study, Section IV states the hypotheses. Section V is on Methodology. Section VI describes the variables used in the study and in the efficiency analysis and gives an account of the data sources. Section VII discusses the results for efficiency levels and changes and growth accounting of the countries included in our sample .Section VIII discusses the counterfactual probability distribution and contrasts it with the labour productivity distribution of 1966. Section IX gives conclusions. References and Appendix Tables(available with author on demand) are at the end

II.Review of Literature:Data Envelopment Analysis and Growth Accounting

We have used DEA framework to work out efficiency indexes for countries included in our sample.

II.1Data envelopment analysis (DEA)

DEA is a mathematical programming approach for estimating the relative technical efficiency (TE) of production activities. The term DEA was originally proposed by Charnes et al. (1978). The Charnes et al.(1978) work extended the Farrell (1957) multiple input, single output measures of TE to the multiple-output, multiple input technology.The DEA technique permits an assessment of the performance or TE of an existing technology relative to an ideal, "best-practice", or frontier technology (Coelli et al. 1998). The frontier or best-practice technology is a reference technology or production frontier that depicts the most technically efficient combination of inputs and outputs (i.e., output is as large as possible given the technology and input levels, or input levels are as small as possible given the output levels). The frontier technology is formed as a non-parametric, piece-wise, linear combination of observed "best-practice" activities. Data points are enveloped with linear segments, and TE scores are calculated relative to the frontier technology.

II.2 Growth Accounting

The results of total factor productivity estimation differ due to different assumptions made in respect of production functions and limitations of data availability on productivity of capital and labor and quality of workers.Kumar and Russell(KR,2002) and Henderson and Russell(2003) studies are exceptions.

Kumar and Russel (2002) use frontier methods to analyze international macroeconomic convergence. In particular, they decompose the labor-productivity growth of 57 industrial, newly industralized, and developing countries into components attributable to (1) technological change (shifts in the world production frontier),(2) technological catch-up (movements toward or away from the frontier), and (3) capital accumulation (movement along the frontier). These calculations amount to standard growth accounting with a twist—without the need for specification of a functional form for the technology, for the assumption that technological change is neutral, or for assumptions about market structure or the absence of market imperfections. Indeed, market imperfections, as well as technical inefficiencies, are possible reasons for countries falling below the world-wide production frontier. Taking a cue from the Quah critique spelled out in the introduction of this study, KR(2002) go on to analyze the evolution of the entire distribution of these three growth factors.

Although the analysis of KR is quite simple, it yields somewhat striking results:

(1) While there is substantial evidence of technological catch-up (movements toward the production frontier), with the degree of catch-up directly related to initial distance from the frontier, this factor apparently has not contributed to convergence, since the degree of catch-up appears not to be related to initial productivity.
(2) Technological change is decidedly non-neutral, with no improvement—indeed, possibly some implosion—at very low capital/labor ratios, modest expansion at relatively low capital/labor ratios, and rapid expansion at high capital/labor ratios.
(3) Both growth and bimodal polarization are driven primarily by capital deepening.

Henderson and Russell(2003) introduce human capital into the Kumar and Russell(KR,2002) growth accounting analysis of international macroeconomic convergence.They amend the KR methodology by (1) adopting the Diewert(1980) approach to dynamic frontier analysis,thus precluding implosion of the worldwide production frontier over time and (a) changes in the mean and (b) mean-preserving shifts in the distribution of productivity.Their principal conclusions were

* Over half of the increase in mean productivity attributed to KR to the accumulation of physical capital was,in fact, the result of the accumulation of human capital.

* In contradiction to the KR conclusion that capital accumulation also accounts for the shift in the distribution, primarily from unimodal to bimodal, their analysis indicates that efficiency changes account for the qualitative shift from unimodal to bimodal,whereas the accumulation of physical and human capital account for the increased worldwide dispersion of productivity.

*There is evidence of technological progress in the developed nations only.

In this study we also do growth accounting with a twist-without the need for specification of a functional form for the technology,for the assumption that technological change is neutral,or for the assumptions about market structure or the absence of market imperfections.We use sample of 29 developing, newly industrialized and developed nations.The objective is to reconfirm whether indeed KR(2002) and Henderson and Russel(2003) results holds for the sample of countries included in our study.

III. Objectives of the study

- To work out technical efficiency index for each of the 29 countries in the sample and examine the impact of some of its determinants on the efficiency levels for five year interval period starting from 1966 and ending in year 2000.

- To undertake growth accounting exercise which can decompose labor productivity growth into components attributable to technological changes(shifts in the overall production frontier),technological catch up or efficiency changes(movement towards or away from the frontier),capital accumulation(movement along the frontier) and human capital accumulation.
- Identify reasons for the existence of bimodal labour productivity distribution prevailing across countries by particularly analyzing the evolution of cross country distribution over time for the 29 countries included in our sample consisting of some South Asian,East Asian and EU countries

IV.Hypothesis

1.South Asian and East Asian countries presently are more 'efficient' than the Developed nations included in the sample.
2.To test whether technological change, technological catch up ,capital accumulation and human capital accumulation are primarily responsible for differential growth in labor productivity across countries and regions and are also responsible for the existence of bimodal labour productivity distribution across countries included in our sample.

V.Methodology

The level of efficiency for each country has been worked out using Data Envelopment Analysis(DEA)[4] for five year interval period starting from 1966 and ending in year 2000.

Further, we decompose labor productivity into its components, efficiency change, technological change, capital accumulation and human capital accumulation. Technological change reflects shifts in the world production frontier, determined conceptually by the state-of-the-art, potentially transferable technology; while efficiency change reflects the movements toward (or away from) the frontier as countries adopt "best practice" technologies and reduce (or exacerbate) technical and allocative inefficiencies; and the third capital accumulation reflects movements along the frontier. The world production frontier at each point in time is constructed using deterministic, nonparametric (mathematical programming) methods (essentially, finding the smallest convex cone enveloping the data) and efficiency is measured as the (output-based) distance from the frontier. These data-driven methods do not require specification of any particular functional form for the technology, nor do they require any assumption about market structure or about the absence of market imperfections; market imperfections, as well as technical inefficiencies, are possible reasons for countries falling below the worldwide production frontier. We proxy human capital accumulation by life expectancy changes.Introduction of human capital results in a quadripartite decomposition of productivity growth.

V.1Non Parametric Construction of Technologies and Efficiency Measurement

Our approach to constructing the worldwide production frontier and associated efficiency levels of individual economies (distances from the frontier), motivated in part by the first such effort in this direction by Fare, Grosskopf, Norris, and Zhang (1994b), Charnes et. al(1978),followed by Kumar and Russell(2002) and Henderson and Russell,(2003) which in turn is based on the pioneering work of Farrell (1957) and Afriat (1972).We follow mainly Kumar and Russell(2002). The basic idea is to envelop the data in the "smallest", or "tightest fitting", convex cone, and the (upper) boundary of this set then represents the "best practice" production frontier. Although this data-driven approach, implemented with standard mathematical programming algorithms, requires no specification of functional form, it does require an assumption about returns to scale of the technology (as well as free input and output disposability).Our technology contains four macroeconomics variables: aggregate output and three aggregate inputs – labor, physical capital, and human capital(proxied by life expectancy in years). Let $\left(Y_t^j, L_t^j, K_t^j, H_t^j\right)$ t = 1, …, T, j =- 1, l… J, represent T observations on these four variables for each of the J countries. In particular, we construct the constant-returns-to-scale, period-t technology using (in principle) all data up to that point in time :

$$\tau_t = \left\{ \left(Y, L, K, H\right) \in R_+^4 \mid Y \le \sum_{\tau \le t} \sum_j z_\tau^j Y_\tau^j \right.$$

$$\left. L \ge \sum_{\tau \le j} \sum_j z_\tau^j L_\tau^j \;\; K \ge \sum_{\tau \le j} \sum_j z_\tau^j K_\tau^j, H \ge \sum_j z^j H, z^j \ge 0 \forall j \right\} \qquad \textbf{(1)}$$

This technology is the Farrell cone; other assumptions about returns to scale would incorporate an additional constraint on the activity level, t = 1, …, T, j = 1, …. J (see, e.g., Fare, Grosskopf, and Lovell (1994)].

In this construction,each observation is interpreted as a unit operation of a linear process.z_j represents the level of operation of that process and every point in the technology set is a linear combination of observed output/input vectors or a point dominated by a linear combination of observed points.The constructed technology is a polyhedral cone,and isoquants are piecewise linear.

The Farrell (output based) efficiency index for country j at time t is defined by

$$E\left(Y_t^j, L_t^j, K_t^j, H\right) = \min\left\{\lambda \mid \left(Y_t^j \mid \lambda, L_t^j, K_t^j, H\right) \in \tau_t\right\} \qquad (2)$$

This index is the inverse of the maximal proportional amount that output Y_t^j can be expanded while remaining technologically feasible, given the technology τ_t and the input quantities L_t^j, K_t^l ,and H ; it is less than or equal to 1 and takes the value of 1 if and only if the jt observation is on the period t production frontier. In this case of a scalar output, the output based efficiency index is simply the ratio of actual to potential output

[4] Our efficiency calculations were carried out using the Onfront software(demo version),available from Economic Measurement and Quality I Lund AB(Box 2134,S-220 Lund,Sweden(www.emq.se).

evaluated at the actual input quantities, but in multiple-output technologies the index is a radial measure of the (proportional) distance of the actual output vector from the production frontier.
In our simple case, we deal with only three macroeconomic variables: aggregate output and two aggregate inputs: labor and capital. Let $\left(Y_t^j, L_t^j, K_t^j\right), t = 1,.., T, j = 1,\ldots J$, represent T observations on these three variables for each of the J countries.

The Farrell efficiency index can be calculated by solving the following linear program for each observation:

$$\min_{\lambda, z^1,\ldots,z^j} \lambda \text{ subject to}$$

$$Y^j/\lambda \le \sum_k z^k Y_t^k$$

$$L^j \ge \sum_k z^k L_t^k$$

$$K^j \ge \sum_k z^k K_t^k$$

$$z^k \ge 0 \forall k.$$

The solution value of λ in this problem is the value of the efficiency index for country j at time t.

V.2 Tripartite Decomposition of the Factors Affecting Labor Productivity

We decompose the ratio of labour productivity in current year to labour productivity in base year into its three components: efficiency change(catching up to the frontier),technical change(movement of frontier) and capital accumulation(movement along the frontier).Please refer to Kumar and Russell Paper(2002) for the derivation.

$$\frac{y_c}{y_b} = \frac{e_c}{e_b}\left(\frac{\bar{y}_c(k_c)}{\bar{y}_b(k_c)} \times \frac{\bar{y}_c(k_b)}{\bar{y}_b(k_b)}\right)^{1/2}$$

$$\times\left(\frac{\bar{y}_b(k_c)}{\bar{y}_b(k_b)} \times \frac{\bar{y}_c(k_c)}{\bar{y}_c(k_b)}\right)^{1/2}$$

= : EFF × TECH × KACCUM.

<u>V.3Quadriparite Decomposition of the Factors Affecting Labor Productivity</u>

<u>Conceptual Decomposition</u>

Further We can decompose the ratio of labour productivity in current year to labour productivity in base year into its four components: efficiency change(catching up to the frontier),technical change(movement of the frontier), capital accumulation(movement along the frontier) and Human Capital Accumulation. Please refer to Henderson and Russell(2003) Paper for the derivation.

$$\frac{y_c}{y_b} = \frac{e_c}{e_b}\left(\frac{\hat{y}_c(k_c)}{\hat{y}_b(k_c)} . \frac{\bar{y}_c(k_b)}{\bar{y}_b(k_b)}\right)^{1/2} \left(\frac{\hat{y}_b(k_c)}{\hat{y}_b(k_b)} . \frac{\bar{y}_c(k_c)}{\bar{y}_c(k_b)}\right)^{1/2} \frac{H_c}{H_b}$$

= : EFF × TECH × KACC × HACC.

V.4Kernel Densities

We employ kernel based density functions for estimating the cross country labor productivity distribution for various years.The density estimates are computed using the Rosenblatt-Parzen kernel density estimator.We use an optimal bandwidth parameter chosen as h=1.0592*σ*N^(-.20) where σ is the standard deviation of the data and N is the number of observations.Splus software has been used to estimate the Kernel smoothers.

VI.Data and Variable Description

For the technical efficiency and growth accounting exercise (labour productivity decomposition into four factors), we consider a sample of 29 countries(5 South Asian+8 East Asian+16 EU Countries) over the period 1966-2000,using data from the World Development indicators on CDROM(various years).The included countries are identified in Appendix Table I. For DEA ,Our measure of aggregate output is GDP calculated at constant 1995 US $.Aggregate inputs used in the DEA model are capital stock, labor force and life expectancy(proxy for human capital) .The capital stock for each country was calculated from gross capital formation(current US $).The measurement method is as described in(Chou,1993) . Appropriate deflator was used to estimate capital stock at constant 1995 US $.

VII. Discussion of the Results:Efficiency Levels and Changes, Technological Changes, Capital Accumulation and Human Capital Accumulation and Contribution of Such Factors to Labour Productivity Changes(1966-2000)

VII.1 Empirical Results:Technological Catch Up(Efficiency Levels and Changes)

Table I and II lists the efficiency levels of each of the 29 countries for the years 1966,1971,1976,1981,1986,1991,1996 and 2000.Efficiency indexes are calculated from the input and output data for the 29 countries included in our study.The output and input data are given below in the Appendix Tables(available with author). For comparison purposes,we calculate these indexes both with and without life expectancy (denoted by LE and WLE in the tables, respectively).Human capital is proxied by life expectancy of countries in year

Table I: Technical Efficiency Indexes(1966-2000)

	WLE	LE	WLE	LE	WLE	LE	WLE	LE
Country	1966	1966	1971	1971	1976	1976	1981	1981

Bangladesh	0.29	0.29	0.37	0.37	0.71	0.75	1	1
India	0.11	0.56	0.19	0.53	0.46	0.58	0.67	0.86
Nepal	0.53	0.53	0.56	0.56	1	1	0.97	0.97
Pakistan	0.12	0.12	0.22	0.22	0.5	0.5	0.84	0.84
Sri lanka	0.1	0.1	0.21	0.21	0.51	0.51	0.59	0.59
Belgium	0.77	0.82	0.8	0.89	0.88	0.95	0.9	0.91
Austria	0.67	0.72	0.74	0.81	0.8	0.87	0.84	0.87
Denmark	0.98	1	0.92	1	0.91	0.98	0.86	0.86
Finland.	0.59	0.62	0.6	0.65	0.65	0.71	0.71	0.75
France	0.72	0.84	0.75	0.94	0.79	0.9	0.83	0.86
Germany	0.91	1	0.75	0.96	0.79	0.9	0.83	0.83
Greece	0.33	0.36	0.4	0.43	0.45	0.49	0.59	0.59
Ireland	0.41	0.42	0.43	0.44	0.48	0.48	0.83	0.83
Italy	0.48	0.77	0.52	0.81	0.57	0.79	0.7	0.86
Luxembourg	1	1	1	1	1	1	1	1
Netherland	1	1	1	1	1	1	1	1
Portugal	0.22	0.24	0.26	0.29	0.26	0.28	0.35	0.35
Spain	0.46	1	0.48	1	0.72	1	0.93	0.95
Sweden	0.82	0.86	0.77	0.86	0.78	0.85	0.76	0.78
UK	0.55	1	0.51	0.96	0.52	0.89	0.96	1
Norway	0.77	0.79	0.73	0.79	0.8	0.87	0.85	0.85
Malaysia	0.16	0.16	0.22	0.22	0.65	0.65	0.96	0.96
China	0.12	0.54	0.17	0.37	0.34	0.42	0.35	0.47
Indonesia	0.08	0.22	0.17	0.23	0.78	0.8	1	1
Japan	0.62	0.98	0.78	1	0.88	1	1	1
Phillipines	0.08	0.18	0.11	0.16	0.38	0.38	0.69	0.69
Singapore	0.25	0.25	0.34	0.34	0.42	0.42	0.7	0.7
Thailand	0.13	0.15	0.17	0.17	0.53	0.53	0.78	0.78
HongKong	0.3	0.3	0.31	0.31	0.75	0.75	1	1
Mean	0.46	0.58	0.50	0.60	0.67	0.73	0.81	0.83
SA (5) Mean	0.23	0.32	0.31	0.67	0.64	0.67	0.81	0.85
EU(16) Mean	0.66	0.78	0.67	0.81	0.71	0.81	0.81	0.83
EA (8)Mean	0.21	0.35	0.28	0.62	0.59	0.62	0.81	0.83

Note: Technical Efficiency is calculated using Onfront Software. Note higher values means higher technical efficiency while value one means that the country is moving along the best production frontier. Efficiency Indexes are calculated using inputs and output data. While the inputs are Labour force, Capital Stock(constant 1995 US$) and Life Expectancy(in years);output is GDP at constant 1995 US$; LE denotes Life Expectancy is included in efficiency measurement; WLE Denotes efficiency measurement without Life Expectancy

Table II (Continued): Technical Efficiency Indexes(1966-2000)

	WLE	LE	WLE	LE	WLE	LE	WLE	LE	Mean Efficiency	Mean Efficiency

									WLE 1966-2000	LE 1966-2000
Country	1986	1986	1991	1991	1996	1996	2000	2000		
Bangladesh	1	1	1	1	0.96	0.96	0.91	0.91	0.78	0.78
India	0.74	0.89	0.54	0.58	0.62	0.76	0.66	0.76	0.49	0.69
Nepal	0.92	0.92	0.8	0.8	0.69	0.69	0.73	0.73	0.77	0.77
Pakistan	0.84	0.86	0.77	0.79	0.8	0.85	0.73	0.74	0.60	0.61
Sri lanka	0.68	0.68	0.63	0.63	0.69	0.69	0.69	0.69	0.51	0.51
Belgium	0.81	0.86	0.73	0.96	0.75	1	0.68	0.93	0.79	0.91
Austria	0.77	0.86	0.75	0.96	0.74	0.97	0.63	0.87	0.74	0.86
Denmark	0.81	0.87	0.73	0.92	0.79	0.99	0.71	0.91	0.83	0.94
Finland.	0.69	0.77	0.64	0.8	0.59	0.77	0.61	0.8	0.63	0.73
France	0.76	0.82	0.68	0.92	0.7	0.98	0.63	0.9	0.73	0.89
Germany	0.76	0.81	0.7	0.94	0.7	1	0.59	0.86	0.75	0.91
Greece	0.53	0.56	0.64	0.68	0.68	0.78	0.57	0.63	0.52	0.56
Ireland	0.89	0.93	0.91	0.95	1	1	1	1	0.74	0.75
Italy	0.81	0.93	0.86	1	0.71	0.93	0.61	0.83	0.65	0.86
Luxembourg	1	1	1	1	1	1	1	1	1	1
Netherland	0.95	1	0.83	1	0.81	1	0.72	0.97	0.91	0.99
Portugal	0.4	0.43	0.58	0.6	0.61	0.7	0.51	0.56	0.39	0.43
Spain	0.9	0.98	0.97	1	0.75	0.92	0.61	0.78	0.72	0.95
Sweden	0.69	0.74	0.7	0.86	0.65	0.82	0.62	0.81	0.72	0.82
UK	0.87	0.99	0.9	1	0.8	1	0.86	1	0.74	0.98
Norway	0.82	0.87	0.67	0.77	0.65	0.89	0.67	0.89	0.74	0.84
Malaysia	0.67	0.7	0.65	0.66	0.7	0.78	0.55	0.59	0.57	0.59
China	0.47	0.59	0.4	0.46	0.58	0.73	0.61	0.77	0.38	0.54
Indonesia	0.67	0.73	0.6	0.63	0.7	0.84	0.47	0.53	0.55	0.62
Japan	0.93	1	0.89	1	0.78	1	0.68	1	0.82	0.99
Phillipines	0.5	0.53	0.53	0.54	0.72	0.79	0.61	0.64	0.45	0.48
Singapore	0.52	0.54	0.65	0.73	0.77	0.87	0.68	0.79	0.54	0.58
Thailand	0.7	0.74	0.73	0.74	0.68	0.81	0.44	0.49	0.52	0.55
HongKong	0.89	0.93	0.9	0.95	0.84	0.96	0.7	0.81	0.71	0.75
Mean	0.75	0.81	0.74	0.82	0.74	0.88	0.67	0.80	0.6651	0.7544
SA Mean	0.84	0.87	0.75	0.76	0.75	0.79	0.74	0.77		
EU Mean	0.78	0.84	0.77	0.90	0.75	0.92	0.69	0.86		
EA Mean	0.67	0.72	0.67	0.71	0.72	0.85	0.59	0.70		

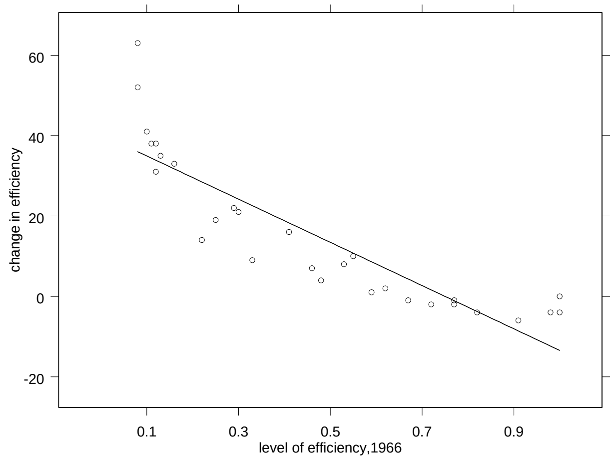
Note: Technical Efficiency is calculated using Onfront Software. Note higher values means higher technical efficiency while value one means that the country is moving along the best production frontier. Efficiency Indexes are calculated using inputs and output data. While the inputs are Labour force, Capital Stock(constant 1995 US$) and Life Expectancy(in years); output is GDP at constant 1995 US;$;LE denotes Life Expectancy is included in efficiency measurement; WLE Denotes efficiency measurement without Life Expectancy

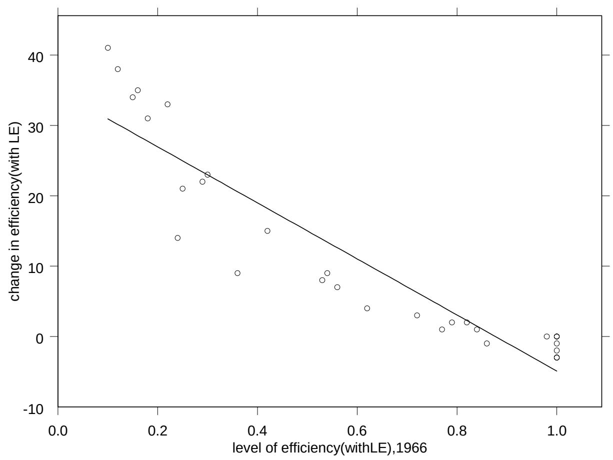
Luxembourg has an efficiency score of one in all the years with or without life expectancy(human capital).Netherlands also has an efficiency score of one in 1966,1971,1976 and 1981.Japan,UK,Belgium,Ireland,Indonesia,Spain and Germany has an efficiency score of one in at least one of the years from 1966 to 2000.In the year 2000 though mean efficiency levels(without including life expectancy as input) of South Asian countries is higher than the European Union Countries and East Asian countries. Japan has the highest average efficiency followed by Hong Kong in the East Asian region in the period 1966-2000.

Bangladesh and India too have scores of one in atleast one of the years from 1966 to 2000.It seems peculiar that these countries are on the frontier. The interpretation of this finding is that Bangladesh and India have low per capita incomes because it seems that they are relatively undercapitalized and not because they make inefficient use of the relatively meager capital inputs that it has. Another(perhaps more plausible) interpretation is that the DEA method of constructing the best -practice frontier-a lower bound on the frontier under the assumption of constant returns-fails to identify the 'true' but unknown frontier, especially at low capital labour ratios[5].

The mean efficiency scores with life expectancy included as an input, in all the years included in our study, is always found to be greater than the efficiency scores which does not take into account life expectancy as an input. This seems to suggest that some of the measured inefficiency in the simpler model, in fact, have been attributed to a relative paucity of the quantity of human capital.

Figure III and IV:Linear Fit Plot between Change in Efficiency and Efficiency Index,1966





FigureIII **Figure IV**

Ordinary least squares regression of the change in efficiency on the level of efficiency(without life expectancy) in 1966(Regressing Column V of Table III on Regressing Column 2 in Table I) yields a coefficient of -53.760 with a t statistic of -9.74 while Ordinary least squares regression of the change in efficiency on the level of efficiency(with life expectancy) in 1966(Regressing Column V of Table IV on Regressing Column 3 in Table II) yields a coefficient of -39.807 with a t statistic of -12.641,indicating that the less efficient countries in 1966 have, on balance,benefited from efficiency improvements than the more efficient countries.Figures III and IV confirm the negative relationship between the two.These two results seems to imply that there is a tendency for technology transfer to reduce the gap between the rich and poor countries in the sample.

VI1.2 Empirical Results for Tripartite and Quadripartite Decomposition of the Factors Affecting Labour Productivity

We have carried out the above calculations for the years 1966 ,1971 ,1976 ,1981 ,1986,1991,1996 and 2000 both with and without including life expectancy as an input besides the other inputs of capital stock and labour force. The conceptual decomposition is discussed in the section on Methodology. Appendix Tables (available with author) give the results for finding out the average efficiency changes, technological changes, capital accumulation and human capital accumulation from 1966 to 2000.The results of tripartite decomposition of labour productivity are summarized in Table III while the results of quadripartite decomposition are summarized in Table IV

Table III lists the percentage changes from 1966 to 2000 in labour productivity and each of the three components: (I) change in efficiency,(ii)technological change, and (iii) capital deepening,for all 29 countries,along with the sample mean percentage changes.The overall averages provide striking evidence that none of the three factors are primarily responsible for most of the productivity improvements over this period.The efficiency factor accounted for less than 16 %,technological change accounted for less than 15 % while the contribution of capital deepening is strikingly negative.One finds the same trend for the the South Asian and East Asian regions;the efficiency factor accounts for 29.40 % of their labour productivity growth,only

[5] We should note that these mathematical programming methods take no account of measurement error, sampling error and other stochastic phenomena. Recent research(Leopold Simar,1996;Alois Kneip et.al,1998;Irene Gijbels,1999;Simar and Paul W.Wilson,2000) has made substantial progress on the use of bootstrapping method to construct confidence intervals around efficiency index .In this study, however ,we are more concerned about the statistical significance of changes in the distributions of efficiency indexes and the components of tripartite and quadripartite decomposition of productivity changes.

10.60% is accounted by technological changes while capital accumulation shows negative value for the South Asian region.For the East Asian region the efficiency factor accounts for 32 % of their labour productivity growth, 20.88% is accounted by technological changes while capital accumulation shows negative value.For the EU region the efficiency factor accounts for mere 2.31 % of their labour productivity growth,only 11.94% is accounted by technological changes while capital accumulation shows negative value.Such results seems to convey that there are some other factors besides the ones decomposed in the growth accounting exercise which may have profound affects on labour productivity growth rates across the countries included in our sample.We have found earlier in the conditional convergence analysis that trade openness,population rate of growth and savings rate may be key in explaining differential levels of growth per capita across nations included in our sample .It seems that there are more important factors particularly for South Asian Region, besides the ones taken here in the growth accounting exercise, which can have greater impact on labour productivity and GDP per capita growth rates. These may be policies directed towards higher infrastructure spending, making bureaucracy efficient, reducing corruption, less restrictive labor regulations, achieving political stability, implementing rule of law, understanding institutions, among others

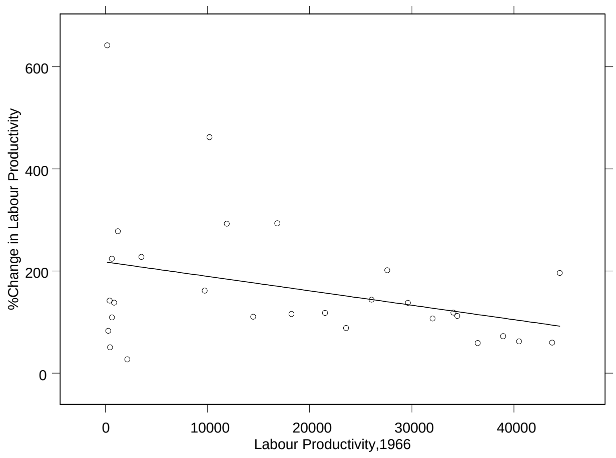
Table III:Percentage Change of Tripartite Decomposition Indexes

Country	Output Per Worker, 1966	Output Per Worker 2000	Productivity Change (2000-1966)	(EFF-1) *100	(TECH-1) *100	(KACC-1)*100
Bangladesh	468	706	50.65	22	6	-13
India	428	1036	141.84	38	14	-18
Nepal	285	521	82.6	8	9	-2.
Pakistan	657	1376	109.23	38	11	-18
Sri lanka	864	2055	137.86	41	13	-20
Belgium	34083	74499	118.58	-1	12	2
Austria	29628	70335	137.39	-1	13	1
Denmark	43752	69814	59.57	-4	7	5
Finland.	26063	63509	143.67	1	14	0
France	32043	66330	107	-2	11	2
Germany	40514	65671	62.09	-6	7	7
Greece	14479	30449	110.29	9	12	-6
Ireland	16835	66177	293.1	16	22	-11
Italy	21508	46789	117.54	4	12	-2
Luxembourg	44493	131722	196.05	0	17	0
Netherland	38955	67133	72.34	-4	8	5
Portugal	9721	25425	161.53	14	16	-10
Spain	18238	39339	115.69	7	12	-2
Sweden	36477	57916	58.77	-4	7	4
UK	23580	44412	88.35	10	10	-4
Norway	34465	72988	111.77	-2	11	2
Malaysia	3541	11602	227.59	33	19	-8
China	185	1375	641.68	31	34	-18
Indonesia	647	2095	223.83	63	19	-8
Japan	27609	83224	201.44	2	18	0
Phillipines	2152	2731	26.91	52	4	-17
Singapore	10194	57290	461.96	19	29	-10
Thailand	1232	4656	277.69	35	22	-8
HongKong	11891	46671	292.49	21	22	-7
Grand Mean	18103	41649.86	166.53	15.17	14.17	-5.31
SA Mean	540.40	1138.8	104.44	29.40	10.60	-14.2
EU Mean	29052	62031	122.11	2.31	11.94	-.44
EA Mean	7181	26205	294.20	32	20.88	-9.5

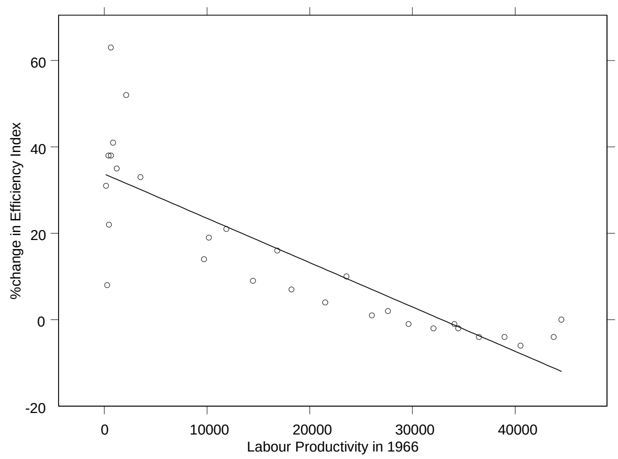
Figure V summarizes these calculations by plotting the four growth rates(labour productivity and its three components against labour productivity in 1966.

Figure V:Percentage Changes Between 1966 and 2000 in Labour Productivity and Three Decomposition Indexes Plotted Against 1966 Labour Productivity

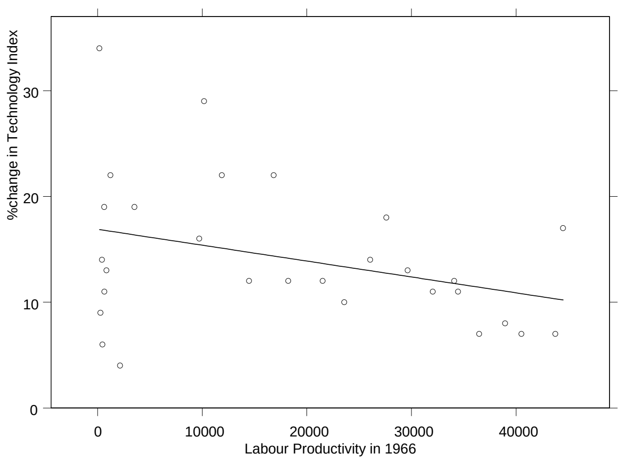
(a)



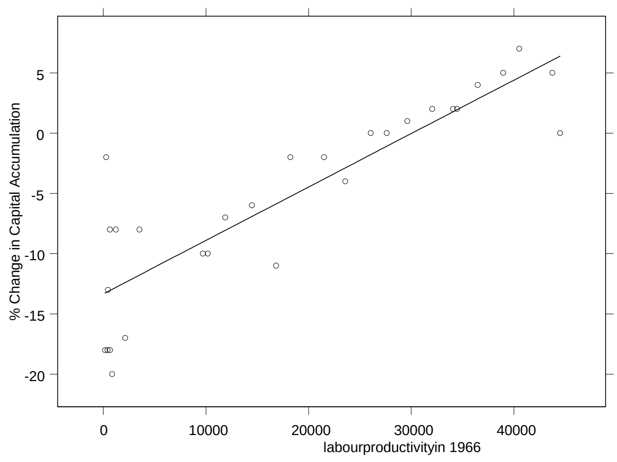
(b)



(c)



(d)



OLS regression lines are also plotted.Figure V(a) indicates that the increases in average productivity reflects positive growth over this period for the countries included in our sample. The prominent spikes at the lower relative incomes reflect the economic emergence of the Asian "miracle" countries and is consistent with the observation about the movement of probability mass from lower and middle income group to higher income group in the cross country distribution(see section I on introduction).The negative slope coefficient of -.0282 with t value as 1.855,while not statistically significant at 5% level of significance without inclusion of critical conditioning variables, is essentially the empirical result that led many to argue that productivity growth patterns support absolute convergence [6] among South Asian, European Union and East Asian countries together(Mathur,2004).

Figure V(b),shows the negative relationship between the percentage change in efficiency index and the initial level of productivity .The beta coefficient has negative value of -.00103 with t value of -8.255 and R^2 of .716.The results suggest that technological catch up is partly responsible for closing some of the gap between rich and poor nations, which is atleast true for the East Asian economies since the developed nations were partly responsible for technology transfers to their region(then underdeveloped) since the 1960s.Technological transfers, however, in the South Asian region is relatively low but can play an important role in increasing their growth rates.

Figure V(C) shows that the relationship between technological changes and initial level of labour productivity is negative(-.00015) though not significant(t value -1.875).While for the East Asian region technological change is responsible for larger than average contributions to growth,it has been quite moderate for the South Asian and EU regions.

Figure V(d) shows that the relationship between capital accumulation and growth is positive and significant.(coefficient value is .000443 with t value of 9.120).The positive regression slope coefficient suggests that relatively wealthy countries have benefited more from capital accumulation than have less developed economies.

Table IV lists the percentage changes from 1966 to 2000 in labour productivity and each of the four components: (I) change in efficiency,(ii)technological change, and (iii) capital deepening and (iv)Human Capital Accumulation,for all 29 countries,along with the sample mean percentage changes.The overall averages provide striking evidence that none of the four factors are primarily responsible for most of the productivity improvements over this period.The efficiency factor accounted for less than 12 %,technological change account for less than 11 %,Human Capital accumulation accounted for less than 4% while the contribution of capital deepening is strikingly negative.One finds the same trend for the the South Asian and East Asian regions;the efficiency factor accounts for 23.20 % of their labour productivity growth,only 4.6% is accounted by technological changes,human capital accumulation accounts for 5.8% while capital accumulation shows negative value for the South Asian region.For the East Asian region the efficiency factor accounts for 23.25 % of their labour productivity growth, 15.50% is accounted by technological changes,human capital accumulation accounts for 5.38% while capital accumulation shows negative value.For the EU region the efficiency factor accounts for mere 2.56 % of their labour productivity growth,10% is accounted by technological changes,1.75 % is accounted by human capital accumulation while capital accumulation shows negative value.Such results convey that there are some other factors besides the ones decomposed in the growth accounting exercise which have important bearing on the labour productivity growth rates the countries of the EU,South Asian and East Asian region.

Figure VI summarizes these calculations by plotting the four growth rates (four labour productivity components) against labour productivity of 1966.This exercise includes life expectancy(human capital) as an additional input besides capital stock and labour force. OLS regression lines are also plotted.

Figure VI(a),shows the negative relationship between the percentage change in efficiency index and the initial level of productivity. The beta coefficient has negative value of -.000711 with t value of -6.369.The results suggest (as before)that technological catch up is partly responsible for closing some of the gap between rich and poor nations(then East Asian countries).

Figure VI(b) shows that the relationship between technological changes and initial level of labour productivity which is found to be negative(-.00002) though not significant(t value -.383).

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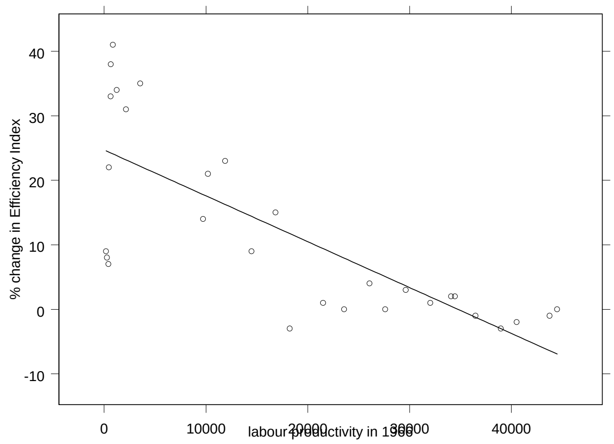
[6] If the poor country's initial income per head is below the rich country's income per head ,then the poor country must grow more rapidly(higher marginal productivity and inviting capital from abroad) than the rich country, for both to ultimately achieve the common level of income per head (assuming same technology, production, population, preferences across countries). This is called absolute beta convergence (also called unconditional convergence because it implies that all countries/regions are converging to common steady state level of income).In its strongest form an implication of this hypothesis is that in the long run countries or regions should not only achieve same steady state level of income per capita but also same per capita growth rates. However, these structural parameters differ across countries and regions and countries may not converge to a common level of income per -capita but to their own steady state level(long run potential level of income).Therefore, economies with lower levels of per capita income(expressed relative to their steady state levels of per capita income) tend to grow faster. Such convergence is called conditional convergence.

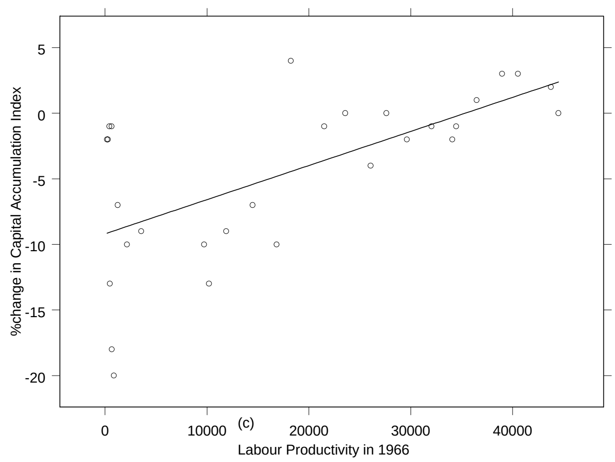
Figure VI(c) shows that the relationship between capital accumulation and growth is positive and significant.(coefficient value is .00026 with t value of 4.343).The positive regression slope coefficient suggests that relatively wealthy countries have benefited more from the capital accumulation than have less developed economies.
Figure VI(d) shows that the relationship between human capital accumulation and growth is negative and significant.(the beta slope coefficient is -.000123 and t value is -5.677).Countries which had lower labour productivity in the sixties accumulated human capital at faster rates than economies which were relatively developed in the sixties;apparently human capital accumulation has contributed to convergence of productivity levels.

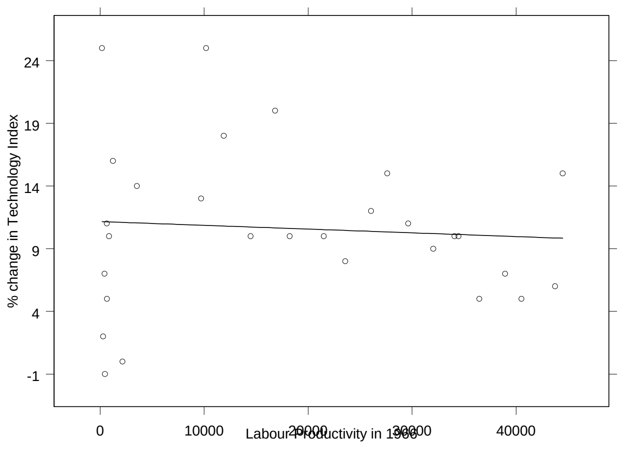
Table IV:Percentage Change of Quadripartite Decomposition Indexes

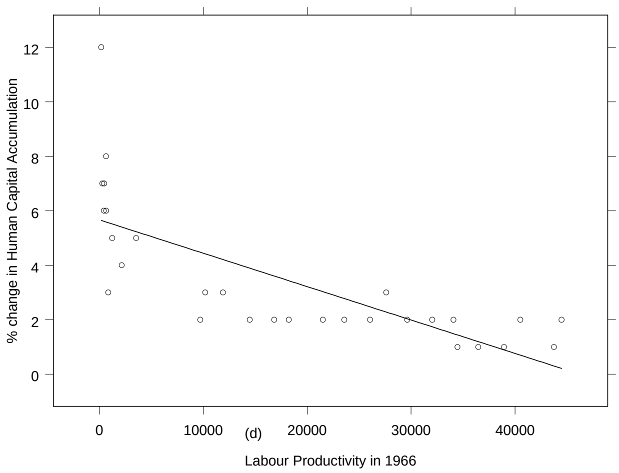
Country	Output Per Worker, 1966	Output Per Worker 2000	Productivity Change (2000-1966)	(EFF-1) *100	(TECH-1) *100	(KACC-1)*100	(HACC-1)*100
Bangladesh	468	706	50.65	22	-1	-13	7
India	428	1036	141.84	7	7	-1	6
Nepal	285	521	82.6	8	2	-2	7
Pakistan	657	1376	109.23	38	5	-18	6
Sri lanka	864	2055	137.86	41	10	-20	3
Belgium	34083	74499	118.58	2	10	-2	2
Austria	29628	70335	137.39	3	11	-2	2
Denmark	43752	69814	59.57	-1	6	2	1
Finland.	26063	63509	143.67	4	12	-4	2
France	32043	66330	107	1	9	-1	2
Germany	40514	65671	62.09	-2	5	3	2
Greece	14479	30449	110.29	9	10	-7	2
Ireland	16835	66177	293.1	15	20	-10	2
Italy	21508	46789	117.54	1	10	-1	2
Luxembourg	44493	13172	196.05	0	15	0	2
Netherland	38955	67133	72.34	-3	7	3	1
Portugal	9721	25425	161.53	14	13	-10	2
Spain	18238	39339	115.69	-3	10	4	2
Sweden	36477	57916	58.77	-1	5	1	1
UK	23580	44412	88.35	0	8	0	2
Norway	34465	72988	111.77	2	10	-1	1
Malaysia	3541	11602	227.59	35	14	-9	5
China	185	1375	641.68	9	25	-2	12
Indonesia	647	2095	223.83	33	11	-1	8
Japan	27609	83224	201.44	0	15	0	3
Phillipines	2152	2731	26.91	31	0	-10	4
Singapore	10194	57290	461.96	21	25	-13	3
Thailand	1232	4656	277.69	34	16	-7	5
HongKong	11891	46671	292.49	23	18	-9	3
Grand Mean	18103	41649	166.53	11.83	10.62	-4.48	3.44
SA Mean	540.40	1138.8	104.44	23.20	4.6	-10.8	5.8
EU Mean	29052	62031	122.11	2.5625	10.06	-1.56	1.75
EA Mean	7181	26205	294.20	23.25	15.50	-6.38	5.38

Figure VI:Percentage Changes Between 1966 and 2000 in Labour Productivity and Four Decomposition Indexes Plotted Against 1966 Labour Productivity









VII.3 Analysis of Productivity Distributions:

Our objective is to assess whether the three components and then the four components of labour productivity can together change account for the deformation of the distribution of labour productivity from tri-modal distribution in 1966 to bimodal distribution in 2000 with higher mean. The distributions are reproduced again here for convenience(Figure VIIa:1966 distribution and VIIb 2000 distribution)

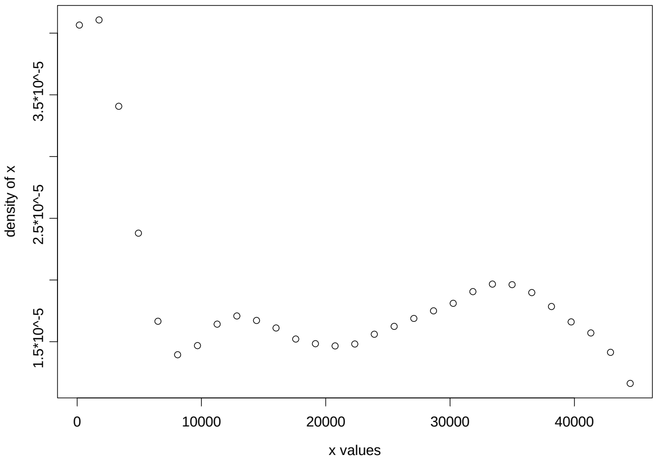


Figure VII(a)

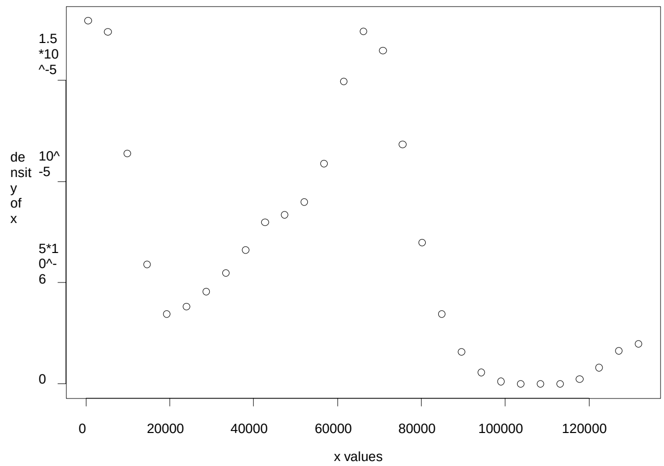
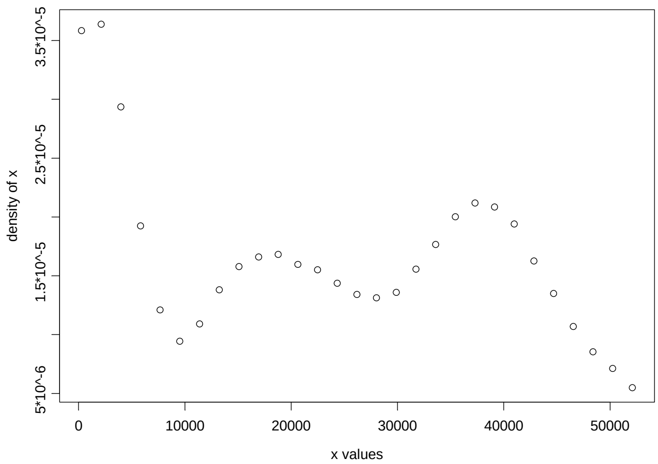


Figure VII(b)

Figure VIII:Counterfactual Distribution of Labour Productivity,2000(including LE)



The distribution we employ are nonparametric kernel based density estimates, essentially Rosenblatt Parzen kernel density estimator (details are given in the section on Objectives and Methodology).

Rewrite the quadripartite decomposition of labour productivity changes as follows:

y_c= (EFF × TECH × KACC × HACC)*y_b

Thus, the labour productivity distribution in 2000 can be constructed by successively multiplying labour productivity in 1966 by each of the four factors. The counterfactual distribution of 2000 is constructed(Figure VIII) by multiplying the average decomposition figures successively with the labour productivity in 1966.It seems from the figure that the distribution remains tri -modal and therefore the four decomposition factors of labour productivity: efficiency change, technological change, capital accumulation and human capital accumulation together have not been able to transform the 1966 distribution and bring it at par with the actual 2000 bimodal distribution of labour productivity[7].This means that some other factors like savings rate,trade

[7] Two-Sample Kolmogorov-Smirnov Test confirms the acceptance of the null hypothesis- two sample kernel probability distributions are same; data: x: Counterfactual labour productivity distribution in 2000(V1) , and y: Labour productivity

openness and rate of growth of population may be are responsible for the transformation of tri modal distribution of 1966 into the bimodal distribution of 2000.It is found that by constructing counterfactual distribution of 2000 by decomposing labour productivity into three factors also do not change the results. This reconfirms our earlier findings in the previous section.

Conclusions

We work out efficiency levels of 29 countries included in our sample using data envelopment analysis. Luxembourg has an efficiency score of one in all the years with or without life expectancy(human capital).Netherlands also has an efficiency score of one in 1966,1971,1976 and 1981.Japan,UK,Belgium,Ireland,Indonesia,Spain and Germany has an efficiency score of one in at least one of the years from 1966 to 2000.In the year 2000 though mean efficiency levels(without including life expectancy as input) of South Asian countries is higher than the European Union Countries and East Asian countries. Japan has the highest average efficiency followed by Hong Kong in the East Asian region in the period 1966-2000.Also, initial level of labour productivity and efficiency index in 1966 had significant impact on efficiency changes from 1966 to 2000 signifying that there is evidence of technological upturn among countries which were relatively backward in 1960s.This seems to hold for sure in respect of the East Asian economies which got the boost due to technological transfers from the developed nations during the same period and also because they started opening their economies at the same time. South Asian economies on the other hand remained closed in 1960s and could not grow at faster rates subsequently.

We decompose labor productivity growth into components attributable to technological changes(shifts in the overall production frontier),technological catch up(movement towards or away from the frontier),capital accumulation(movement along the frontier) and human capital accumulation(proxied by life expectancy).The overall production frontier is constructed using deterministic methods requiring no specification of functional form for the technology nor any assumption about market structure or the absence of market imperfections. Growth accounting results tend to convey that for the East Asian and the South Asian countries efficiency changes have contributed the most while for the European countries it is the technical changes which has contributed to labour productivity changes between 1966-2000. We also analyze the evolution of cross country distribution for the 29 countries included in our sample consisting of some South Asian, East Asian and EU countries using Kernel densities. It seems that there are factors like savings rate , trade openness, quality of institutions ,geography, among others rather than the ones that are included above for the growth accounting exercise which are primarily responsible for the existence of bimodal labour productivity distribution for countries included in our sample(Mathur2005). This particular research problem may be taken up by researchers in future. Our results contradicts the Kumar and Russel(2002) and Henderson and Russell(2003) results which found that different rate of capital accumulation and human capital across nations are primarily responsible for the existence of differential levels of per capita income levels and growth rates across nations respectively and further such factors were also responsible for the evolution of bimodal distribution of labour productivity today across nations. In a way their results(KR) confirmed the use of simple and extended Solow model(Solow,1956,Jones,2002) along with their factor accumulation assumptions in analyzing the convergence process of per capita incomes across nations.Our growth accounting exercise and regression exercise suggest that there is some evidence of absolute convergence(supports the use of Solovian model(1956) in this context) and convergence in statistical terms of efficiency changes and human capital accumulation across countries of the EU, South Asian and East Asian regions.

Generally, speaking policies that will increase labour productivity and particularly in the services sector, open up trade with all countries, increase share of savings in GDP, reduce adverse administrative regulations, increase infrastructure spending, policies that support private capital flows along with technology and human capital skills transfers from rich to poor nations can increase efficiency levels of countries, help more in reducing per capita income differences and growth rates across countries and regions, and also help in achieving the basic goal of planning- i.e., improve the living standards of the people .

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distribution in 1966(V2) ks = 0.1034, p-value = 0.9985 alternative hypothesis: cdf of x: V1 in SP66 does not equal the cdf of y: V2 in SP66 for at least one sample point. Statistical software SPLUS has been used. The data set is in appendix Table (AVAILABLE WITH AUTHOR).

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Appendix Table I:Countries and Regions Included in the Study

Countries(44)/Regions(4)

South Asia(5)

Bangladesh
India
Nepal
Pakistan
Sri-Lanka

European Union(16includingUK)

Belgium
Austria
Denmark
Finland
France
Germany
Greece
Ireland
Italy
Luxembourg
Netherlands

Portugal
Spain
Sweden
United Kingdom
Norway
EAST ASIA(8)
Malaysia
China
Indonesia
Japan
Phillipines
Singapore
Thailand
Hong Kong