# Indian Economy - TFP or Factor Accumulation: A Comprehensive Growth Accounting Exercise

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**Abstract**

Constructing data series from various sources, I do comprehensive growth accounting for the Indian Economy. Without accounting for human capital, total factor productivity differences over time accounts for 48% to 69% of output variation. TFP growth accounts for 35% to 70% of the total GDP growth between 1960 and 2004 depending on measure of human capital. Even after using the Mincer wage regression coefficients, TFP growth still remains significant in explaining the output growth.

Starting from a modest rate in 60s Productivity growth dipped and became negative in 70s. This productivity growth rate started accelerating in 80s (much before the reform-period of early 90s) and is estimated between 3% and 4.5% in 2000s.

Variance decomposition of *growth rates* show negative relation because input and output growth accelerated in different periods. Capital-Output ratio seems to transition from one-steady state to another. Capital-per-Worker has reached a constant rate of growth.

Accounting estimates, decompositions and period-wise trends point toward Indian growth being triggered by overall efficiency improvement (TFP) rather than input accumulation growth.

# 1 Introduction

In recent years Economics of Growth has been one of the most fascinating research topic. Economic growth of the India after 1990s is impressive and it is often cited as success of good economic policies. India struggled in 60s and 70s due to centralized economy, then slowly started opening its economy for trade. In early 90s it adopted broad based reforms, which culminated in Indian economy growing at 7% to 9% per year. But that is where the consensus ends.

How is this growth happening? A simple question like how much of the growth can be attributed to various factors gets different answers. Even though most of the researchers agree on the similar techniques, the results obtained are not similar.

One of the main reason for varying results is the fact that productivity and technology can not be easily measured. There is no perfect instrument to proxy for these unobservables. What we can do is to identify as much as we can using better measures (of inputs) and then attribute the residual to efficiency and technology changes.

In this paper, I use many of the measures of human capital like average years of schooling, primary/ secondary/ post-secondary enrollment and completion. I also calculate the results after using Mincer regression coefficients of schooling on wage rates. I do not suggest which one of the results is the best. The aim of this paper is to do a comprehensive accounting and analyze the results with respect to various methods and measures used.

Using data from various sources, I decompose the output growth into factor growth and productivity growth. For this, I use the decomposition as in Klenow and Rodriguez (1997) [6]. All of the results point toward productivity growth being responsible for 48% to 69% without taking any human capital into consideration. With human capital the residuals become as low as 17% (when taking sum of primary, secondary and post-secondary completed as the measure). I use two sets of Mincer regression coeffecients for India as calculated by Psacharopoulos and Patrinos (2002) [12] and Duraisamy (2000) [4]. I find that input changes are responsible for only 55% and 62% of changes in the output respectively. The reason for this difference in residuals is the difference variance of respective measures. The human capital per labor ratio used in the second approach grows from 1.1 to 1.6. This result is very close to one obtained by Lahiri and Yi (2006) [7]. While human capital per output ratio moves from 1.5 to 2.6 in the alternative decomposition. Following Caselli (2004) [3], I also check two success criteria for input changes accounting for differences in output.

I calculate these decompositions and success criteria for both levels and growth rates. Surprisingly the growth rate of the input is not positively correlated with growth rate of output for few measures. Using the trend-only series of growth might provide better insight into relationship between growth rates of input and output.

The second objective is to find out what happened to macroeconomic aggregates in Indian economy between 1961 and 2004. There have been many studies on India's economic growth, but few of them provide reliable and reproducible growth accounting estimates. Lack of macroeconomic data has restricted the researchers to concentrate on specific sectors only.

Virmani (2004) [14] calculates the TFP trends for India, but his analysis uses population between age of 15 to 64 as a measure of *potential workers* in his calculation. Accounting for Human capital is absent from almost all of these studies.

I use National Account data from Reserve Bank of India website. It provides link to Handbook of Statistics on Indian Economy which is compilation of National Account series by Central Statistics Organization. It contains most of the series as outlined in United Nations SNA (1993) [9]. For employment data I use Groningen Growth and Development Centre's total economy database [2]. It has estimated labor series for India using ADB publications. For human capital measures I use Barro-Lee (2000) [1] international database on education attainment.

The paper attempts to come up with theoretically-sound estimates and analysis of period-wise macroeconomic growth in India. The results for trends in productivity growth are very remarkable. In 1960s the average annual TFP growth was a modest 0.22%. It dipped to -1.16% in 1970s before reaching to average of 1.63% between 1981-1990. Productivity growth rate increase to 2.57% to 2.95% to 3.08% from the period 1991-1995 to 1996-2000 to 2001-2004. Same trend is observed in the HP filtered series. The results are robust to measure of human capital and decomposition method used. Changing income share of capital and starting capital stock does not change this trend.

India experienced accelerated input and output growth in different periods. First two decades (1961-1980) were period of high growth in factor accumulation, while output growth rate picked up after 80s. Hence the variance decomposition of *growth rates* consistently show negative relation.

These results are striking in the sense that they confirm what economist have long suspected. 60s-70s were a period of controlled economy and what is often called license raj. It decreased the overall efficiency of economy and resulted in productivity decline. Productivity starts growing once the first set of reforms were introduced in 80s and its rate of growth increased as more reforms were adopted.

Another interesting result is the movement of capital output ratio. It has been growing till 2000 and seems to peak now. This trend is robust to starting capital output ratio and to the measures of investment. This growth path is similar to one indicating the transition between steady states.

I start with calculating the period-wise growth rate of macroeconomic aggregates using simple indexes. I do growth accounting and period-wise decomposition first only with physical capital and then with human capital. I calculate productivity growth using another method of human capital accounting with Mincer regression coefficients. Each section shows results' tables & figures and discusses them in regards to insights into growth literature and into Indian economy.

# 2 Macroeconomic Growth Indexes: 1961-2004

Last four decades have been very interesting for Indian Economy. It has seen the metamorphosis of India from a centralized economy with socialist outlook and policies to more decentralized and market-oriented economy. Panagariya (2004) [11] and Rodrik and Subramanian (2004) [13] highlight this transformation and attribute it to success of reforms.

To find out what was happening during these different periods, I collect input-output data needed for growth accounting from various sources [1]. Then for deriving economic information (growth/ trends) from these series, I calculate simple indexes with base period variable equal to 1 so that the growth can be compared easily across periods and between economic variables.

## 2.1 Output - Quantities and (Implicit) Prices

Table 1 summarizes the growth in macroeconomic quantities and prices for each time period. Appendix 6 details how each this index and its growth rate is calculated. The table should be read as follows.

GDP in 2004 was 7.2 times the GDP in 1961. GDP grew at an annual average rate of 3.4% in 70s and in 1981 it was 1.34 times the GDP in 1971.

Output per worker growth is interesting. Between 1971-1980 output grew at a slower average rate than employment and as a result output per worker went down (negative growth rate). Later period experienced the opposite situation, with output growing at a faster rate than employment and hence a positive output per worker growth. More importantly, this growth rate itself has been increasing implying that productivity has been accelerating in last three decades.

[1] List of Data Sources is included in appendix 6

I also calculate the indexes and growth rates of these indexes for each component of GDP. While private consumption has grown 5.1 times between 1961 and 2004, government consumption increased 13 times and investment became 15.2 times its starting value. Exports and Imports grew 15 times and 16.3 times at even faster rate (just between 1970-2004).

Growth of component prices was at annual average rate of 5% to 7% in 1960s. But next 25 years saw huge increase in growth rate of these prices (between 12% to 16% per year). After 1995, the growth in prices seem to have been comparatively moderate.

I have plotted these growths in figures 1 and 2. In figure 1, we can see that output and labor were growing at the similar rate (the flat portion in Panel A) till 1970s, but then output just takes off. It grows at a considerable higher average annual rate (6%-7%) compared to labor (1%-3%) as shown in Panel B. This results in output per worker growing at a faster rate (3% - 4%) and the output per work curve becoming steeper. My calculations (and trends) of output per worker are similar to Penn-World Table RGDPWOK (real-gdp per worker) series.

Figure 2 shows that all the output quantities (C,G,I) clearly show a **flat** portion representing slow growth period between 1960-1980 and a **steep** portion for the period after 1981 when these grew at a much faster rate. In panel A, consumption seem to have this flat portion till mid-90s, and even after that the growth rate increase is not as prominent as other quantities. For export and import, the pattern is similar. But the flat period is from 1970 to 1990 and after that higher growth rates result in steeper plots.

## 2.2 Input - Physical Capital

Period-wise growth in capital formation is summarized in Table 2. The growth rate in capital formation and domestic savings was impressive between 1981-1990, but it dropped sharply in 90s because of balance-of-payment crisis. In first four years of 21st century, the growth rate in capital formation measures has averaged between 11% to 20%.

Figure 3 shows growth in different measure of physical capital formation. Domestic Capital Formation to GDP ratio has increased around 100% (both Gross and Net) over the period of 44 years (panel A). Gross Domestic savings grew 16 times, at flat rate till mid 80s and more rapidly after that. The savings rate (ratio of GDS to GDP) has increased 2.5 times during the same period (panel C). This explains the growth pattern of the components of GDP with consumption growing a lot less than the investment.

| | Overall | Avg. Annual Growth Rate | | | | | |
|---|---|---|---|---|---|---|---|
| | **1961-2004** | **61-70** | **71-80** | **81-90** | **91-95** | **96-00** | **01-04** |
| **GDP** ($Y$) | 7.2 times | 4.2% | 3.4% | 7.2% | 5.6% | 6.6% | 7.0% |
| **Labor** ($L$) | 2.4 times | 0.8% | 3.5% | 3.0% | 1.2% | 1.9% | 2.0% |
| **Output per Worker** ($\frac{Y}{L}$) | 3 times | 3.2% | -0.1% | 3.2% | 4.2% | 4.3% | 4.7% |
| **Pvt. Consumption** ($Q_C$) | 5.1 times | 3.1% | 3.8% | 5.0% | 4.1% | 5.3% | 5.5% |
| **Govt. Consumption** ($Q_G$) | 13 times | 12.4% | 5.5% | 9.3% | 3.9% | 9.7% | 2.4% |
| **Investment** ($Q_I$) | 15.2 times | 7.4% | 6.7% | 9.5% | 5.8% | 6.0% | 15.2% |
| **Export**[a][b] ($Q_X$) | 15 times | - | 8.1% | 8.0% | 19.5% | 9.7% | 14.3% |
| **Import** ($Q_M$) | 16.3 times | - | 10.2% | 7.3% | 23.3% | 7.1% | 14.9% |
| **Implicit** $P_C$ | 23.9 times | 7.6% | 12.7% | 12.4% | 13.0% | 8.2% | 3.5% |
| **Implicit** $P_G$ | 20 times | 4.5% | 11.9% | 13.8% | 12.7% | 7.6% | 4.4% |
| **Implicit** $P_I$ | 26.8 times | 6.5% | 15.0% | 16.3% | 12.6% | 5.2% | 5.1% |
| **Unit Value** $P_X$ | 16.3 times | - | 14.1% | 17.0% | 13.1% | 5.8% | 4.3% |
| **Unit Value** $P_M$ | 18.8 times | - | 28.0% | 9.9% | 6.2% | 7.7% | 9.0% |

[a]Total Growth between 1970-2004.
[b]Quantity is calculated using $\frac{TotalValue}{Unit-Value}$

Table 1: Growth of Macroeconomic Aggregates

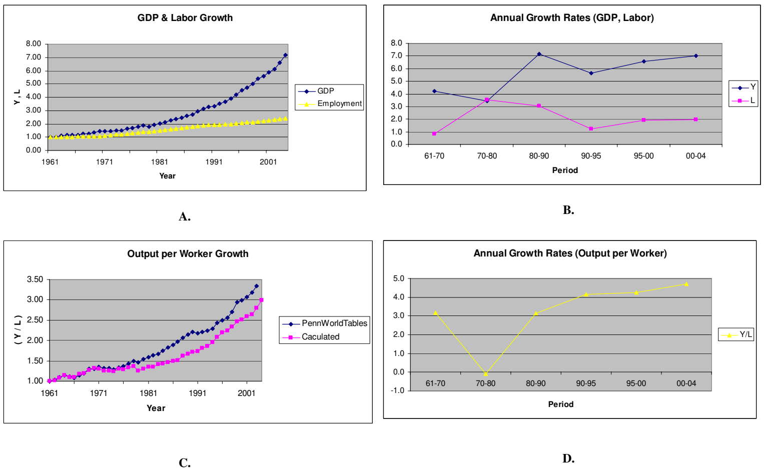



Figure 1: Output per Worker Growth

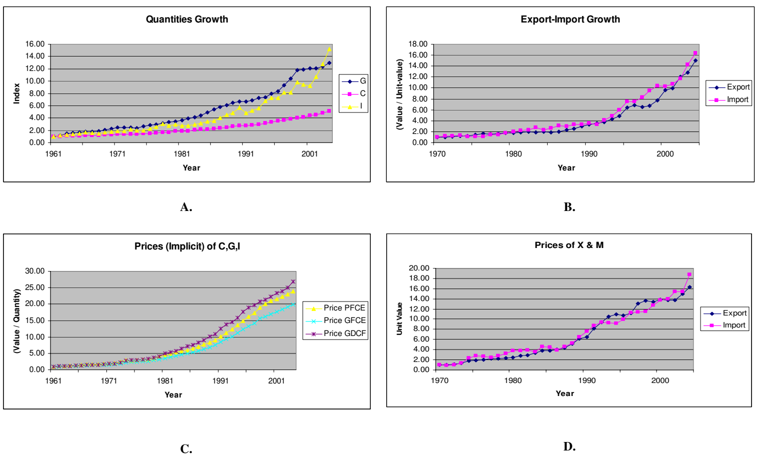



Figure 2: Quantities and Prices Growth

| | Overall | Avg. Annual Growth Rate | | | | | |
|---|---|---|---|---|---|---|---|
| | **1961-2004** | **61-70** | **71-80** | **81-90** | **91-95** | **96-00** | **01-04** |
| **GDCF** | 15.20 times | 7.4% | 6.7% | 9.5% | 5.8% | 6.0% | 15.2% |
| **NDCF** | 14.45 times | 5.9% | 5.9% | 10.6% | 5.1% | 4.7% | 19.8% |
| **GFCF** | 12.10 times | 5.6% | 6.3% | 8.7% | 7.3% | 6.0% | 10.9% |
| **GDS** [a] [b] | 15.92 times | 7.7% | 7.4% | 11.0% | 7.9% | 4.8% | 13.9% |

[a]Converted to constant price series. See appendix 6 for details.
[b]Total Growth between 1961-2003.

Table 2: Growth in Physical Capital Formulation

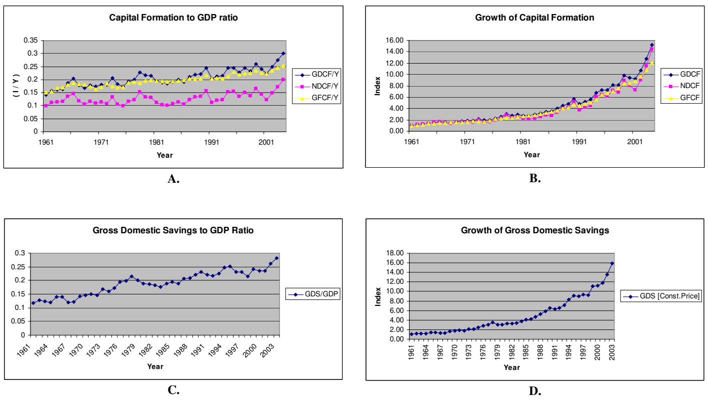



Figure 3: Capital Formation Growth

## 2.3 Input - Human Capital

Till now I have calculated the growth in input and output economic series. As pioneered by Mankiw, Romer and Weil (1992) [8], the actual production function needs to be augmented using *Human Capital*. The idea being that we can further reduce the residual from the growth accounting by taking care of labor force quality. Most important (or at least most used) measures of human capital are workers' education (e.g. enrollment and completion rates, average year of schooling etc.).

Just like earlier, I convert these education measures into indexes by equating year 1961's value to 1. Calculated growth rates in education levels and other human capital measures are summarized in Table 3 . Data for these education measures if taken from Statistical Pocketbook India (various years) [10].

These indexes and growth rates are more interesting as they show different period-wise and overall trend. The percentage of population over 15 that have attained some primary education grew 1.5 times. Even though the increase in percentage who have enrolled at post-secondary level grew 14.73 times, it is still only 4.42% of total population over 15. So the reason for these huge growth rates is that the base level was too low. But at the same time we have to remember that the population of India increased 2.3 times during this period. That is why I use data on *number of scholars* by education-levels published by CSO and calculate the growth rates.

Unlike output and physical capital, growth rates in human capital measures seem higher in 1960s and 1970s. This reflects the fact that early policy makers put more emphasis on education and many schemes for improving education were implemented in earlier five-year plans.

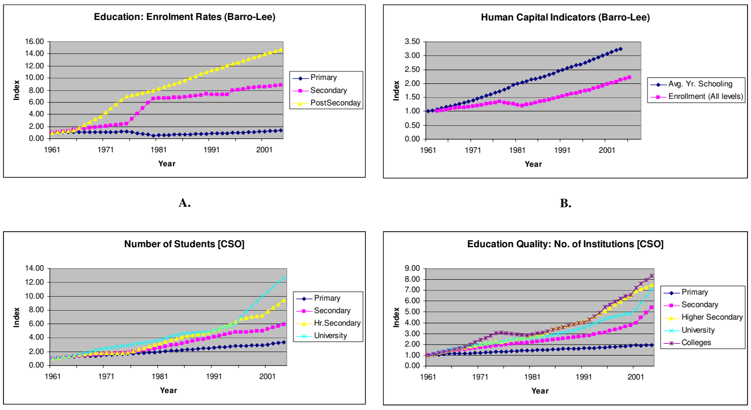
If human capital was growing at a faster rate in 60s and 70s meaning labor-force quality was *improving*, then the output should have grown at a faster rate (everything else equal). But lower output and output per worker growth during this period means that overall TFP that measures technology and efficiency must be going down during the period. This is exactly what I find when I do growth accounting calculations.

Human capital measures' growth is shown in Figure 4. The flat periods and steep periods are not as evident as in output and physical capital series. Panel A shows that for Post-secondary enrollment 1960-1975 was period of high-growth (graph is steep) and the growth slowed after that (graph becomes flatter). Similar trend is observed for educational quality measures i.e. number of institutions by education level as well (panel D). Starting with high slope (growth) the plot becomes flatter as a result of growth slowing. Growth rate increases again in mid 90s.

| | Overall | Avg. Annual Growth Rate | | | | | |
|---|---|---|---|---|---|---|---|
| | **1961-2004** | **61-70** | **71-80** | **81-90** | **91-95** | **96-00** | **01-04** |
| **Avg. Years of Schooling**[a] | 3.25 times | 3.5% | 4.4% | 2.5% | 2.0% | 2.4% | 2.0% |
| **Primary Attained** | 1.37 times | 0.9% | -5.3% | 6.3% | 2.6% | 4.3% | 5.0% |
| **Secondary Attained** | 8.79 times | 9.6% | 23.6% | 1.1% | 1.7% | 1.4% | 0.8% |
| **Post-Secondary Attained** | 14.73 times | 26.7% | 11.8% | 3.8% | 2.4% | 2.2% | 2.0% |
| **Some Schooling** [b] | 2.22 times | 2.0% | 0.0% | 3.2% | 2.2% | 2.9% | 2.5% |
| **Primary Scholars** [c] | 3.37 times | 4.6% | 3.0% | 3.2% | 2.5% | 0.7% | 3.8% |
| **Middle Scholars** | 5.94 times | 6.3% | 4.8% | 6.4% | 4.1% | 0.9% | 4.7% |
| **Higher-Secondary Scholars** | 9.42 times | 7.8% | 6.7% | 6.1% | 6.1% | 3.2% | 7.6% |
| **University Scholars** | 12.67 times | 13.7% | 4.7% | 3.9% | 4.5% | 13.5% | 6.7% |
| **Primary Schools** | 1.96 times | 1.9% | 2.1% | 1.2% | 1.3% | 1.6% | 1.2% |
| **Middle Schools** | 5.4 times | 6.5% | 3.1% | 2.5% | 3.0% | 4.1% | 10.9% |
| **Higher-Secondary Institutions** | 7.49 times | 9.0% | 4.0% | 5.0% | 5.3% | 5.7% | 3.7% |
| **Universities** | 7.08 times | 9.2% | 3.2% | 3.6% | 5.3% | 2.5% | 11.2% |
| **Colleges** | 8.31 times | 11.9% | 2.9% | 4.0% | 7.5% | 4.1% | 6.6% |

[a] Barro-Lee Database. Missing values are generated using linear trends.
[b] This is calculated using (100 - Percentage with No Schooling)
[c] Source: Central Statistical Organization, India.

Table 3: Growth in Education and Human Capital Measures




A. B.

C. D.

Figure 4: Growth in Measures of Education

These macroeconomic indexes and their growth rates show that each of the time-periods were different for Indian economy. Trends in these series confirm the general view among economists that during more-controlled period of 60s and 70s, economy was less efficient (slow and even negative output per worker growth). Stepwise economic reforms of later period resulted in increased efficiency as indicated by higher output per worker growth rates.

# 3 Productivity Estimates

What explains these differences in output per worker and its growth rates across time? Growth in capital intensity might be responsible for these changes or changes in the productivity of Indian economy might be causing output per worker to change over time. Literature on explaining these difference across countries has equally convincing papers in both categories. There is *neo-classical* view claiming that output levels and growth rates are different because of differences in capital. The other claim often grouped as *endogenous progress* is that differences in output levels and growth rates are due to technology differences. In fact both factor accumulation changes and production technology changes are responsible for changes in output levels (and its growth rates). The debate is more about which one of these two is more important.

The other question of interest is the productivity numbers for Indian Economy during this period. Was productivity in 60s lower or higher than 70s? The growth rates of productivity estimates will help us find out whether the productivity has been increasing since 80s and at what rates

I do standard Solow model growth accounting using following production function specifications.

$$Y = A.K^{\alpha}.L^{1-\alpha} \tag{1}$$

$$Y = K^{\alpha}.(AL)^{1-\alpha} \tag{2}$$

About two production function are different in the way they measure productivity (or Solow Residual). Parameter A in equation 1 is a measure of overall effectiveness of the economy, while in equation 2 it measures the effectiveness of labor.

These equations can be rewritten in terms of output per worker.

$$\frac{Y}{L} = A.(\frac{K}{L})^{\alpha} \tag{3}$$

$$\frac{Y}{L} = A.(\frac{K}{Y})^{\frac{\alpha}{1-\alpha}} \tag{4}$$

Equation 3 shows output per worker as a function of capital per worker or *capital intensity* and total factor productivity. Equation 4 specifies output per worker as a function of capital-output ratio and labor productivity. Both of these specifications are commonly used in literature and are supported by reasonable arguments. I calculate the productivity and its period-wise growth rates for both.

I use income share of capital ($\alpha$) equal to 0.3 and initial capital as being 1.5 times the output. In this benchmark case, I use sum of gross fixed capital formation and change in inventory/ stock as measure of investment for generating the capital series . Later I check how the results and trends change with changes in $\alpha$, $K_0$ and $I$.

I derive the HP Filtered and Non-Linear smoothing series for estimated $A$ and calculate the period-wise growth rates. I also try another method of smoothing i.e. calculating productivity after smoothing the output and input series. Results are shown in Table 4.

Notice that Non-Linear smoothing and calculating productivity after HP-filtering series give the averages that are different from actual average. This is not good from accounting point of view. So I limit myself to smoothing

| | Avg. Annual Growth Rate | | | | | | |
|---|---|---|---|---|---|---|---|
| | **1961-2004** | **61-70** | **71-80** | **81-90** | **91-95** | **96-00** | **01-04** |
| $(\frac{Y}{L}) = A(\frac{K}{L})^{\alpha}$ | | | | | | | |
| **No Smoothing** | 1.05% | 0.22% | -1.16% | 1.63% | 2.57% | 2.95% | 3.08% |
| **TFP-Then-HP** | 1.05% | -0.37% | -0.41% | 1.29% | 2.60% | 2.85% | 3.12% |
| **HP-Then-TFP** [a] | 0.98% | -0.52% | -0.40% | 1.32% | 2.70% | 2.81% | 2.52% |
| **TFP-Then-NL** | 1.65% | 1.12% | 0.52% | 1.07% | 3.07% | 3.23% | 3.40% |
| **%age of $\Delta\frac{Y}{L}$** | | | | | | | |
| $(\frac{Y}{L}) = A(\frac{K}{Y})^{\frac{\alpha}{1-\alpha}}$ | | | | | | | |
| **No Smoothing** | 1.50% | 0.32% | -1.65% | 2.32% | 3.67% | 3.83% | 4.40% |
| **TFP-Then-HP** | 1.50% | -0.53% | -0.58% | 1.84% | 3.72% | 4.08% | 4.45% |
| **%age of $\Delta\frac{Y}{L}$** | | | | | | | |

[a] Average is not same as that of actual TFP, so not useful.

Table 4: Periodwise Estimates: TFP and Labor Productivity

using HP-Filtering the productivity series after the calculation (which retains the same average as the actual productivity series).

Between 1960 and 2004, total factor productivity grew at an average annual rate of 1.05% while the rate of labor productivity growth using the alternative specification was 1.5% during the same period. The productivity growth was sluggish in 60s, but in 70s the average growth in productivity was negative. This means that productivity of economy and labor force **decreased** during this decade. The productivity growth rate has been increasing since 1980s. This hold for both the specifications and the trend remains the same even after using different kinds of smoothing.

Figure 5 shows the movement in productivity for the benchmark case ($\alpha = 0.3$ ; $K_0 = 1.5 * GDP[0]$ ; $I = GFCF + \Delta Stk.$). Panel C explains the growth phenomena of Indian economy between 1960 to 2004 and offers interesting insights about the growth rates.

- During 1960s and 1970s, the growth in factor accumulation exceeds the output growth rate.
- 60s and 70s were periods of negative productivity growth.
- The growth rate of output started increasing after 1980s.

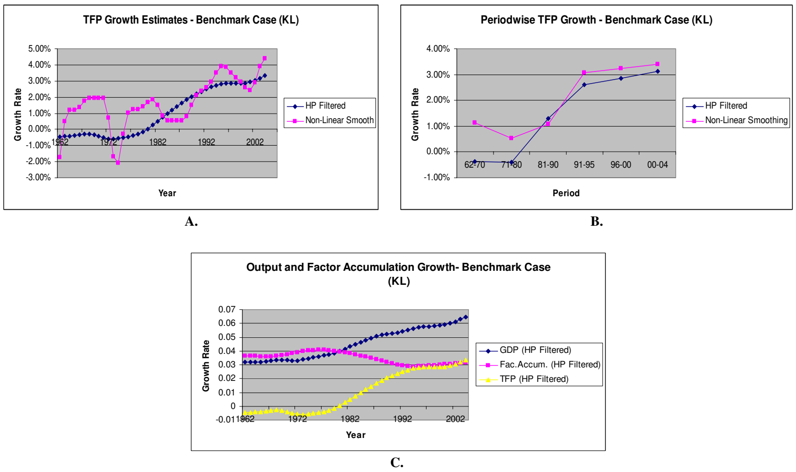



Figure 5: TFP Estimates: $Y = AK^{\alpha}L^{1-\alpha}$; $\alpha$=0.3; $K_0 = 1.5Y_0$;

- Productivity growth also accelerated at the same time (80s).
- Between early 80s and mid 90s, factor accumulation growth rate went down and has been stable since.

These simple calculations imply that the impressive performance of Indian economy (i.e. high output growth rate) are result of increased productivity growth and not so much of factor accumulation growth. This validates the common notion that efficiency improvements due to economic reforms, sectoral reallocation etc. are responsible for recent increase in the growth rate of Indian economy.

## 3.1 Sensitivity Analysis

The calculated values of A and therefore its growth rates are sensitive to values of $\alpha$ and $K_0$ and the measure used in generating the capital stock series. I check how the estimates and trends compare for $\alpha = 0.3$; $\alpha = 0.25$; $\alpha = 0.4$ and $K_0 = 1.5{*}GDP[0]$; $K_0 = 1.5{*}GDP[0]$; $K_0 = GDP[0]$; $K_0 = 2{*}GDP[0]$ and if capital is calculated using $GDCF$ or $NDCF$ or $GFCF + \Delta Stk$.. I

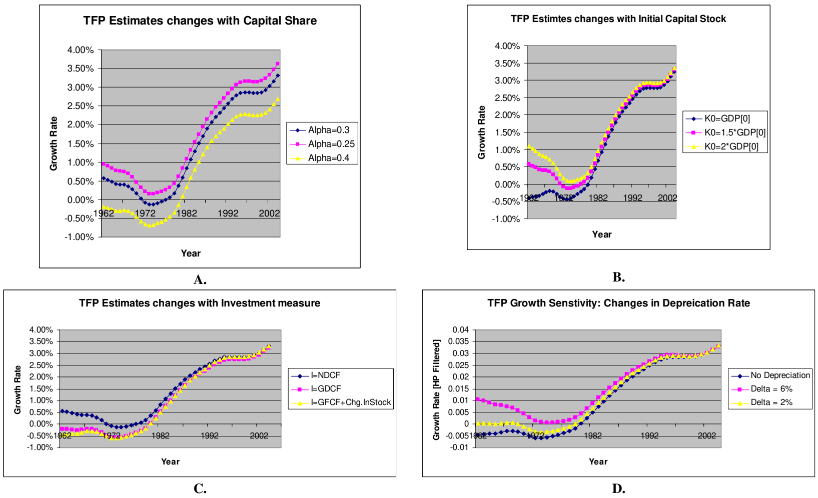



Figure 6: TFP Estimates: Robustness w.r.t. $\alpha$, $K_0$, $I$ values

also calculate the TFP growth rate for capital depreciation rate $\delta = 0$; $\delta = 2\%$; $\delta = 6\%$ .

Figure 6 shows the TFP estimates for each of this set of variations. For income share changes (panel A) the estimated values of total factor productivity growth rate decrease with an increase in $\alpha$. The difference in calculated growth rate is around 1% between $\alpha = 0.25$ and $\alpha = 0.4$. Period-wise trends remain the same for all kinds of variations in the paramters and measures.

For different initial capital stocks, different depreciation rates and different investment measures; the calculated TFP growth estimates differ only for first few periods and then they converge. Again the trends in growth rates are same as the benchmark case.

## 3.2 Capital-Output Ratio

In neo-classical growth models, one important indicator is capital-output ratio. Figure 7 shows the growth rates of $(\frac{K}{Y})$ & $(\frac{K}{L})$ ratios and their period-wise average. Both growth rates show similar trend of starting with high annual average growth rate of 6% and 9% and slowly stabilizing in later

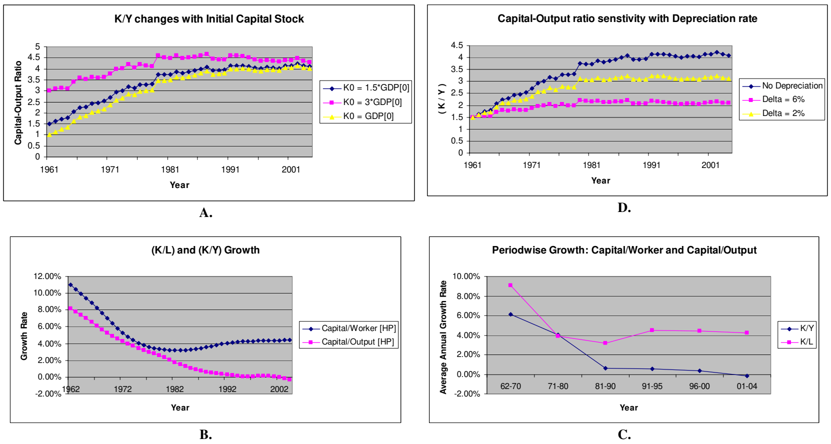



Figure 7: Capital-Output and Capital-Labor Ratio Growth

periods to 0% and 4% respectively.[2]

The capital-output ratio (panel A) is calculated for different initial capital stock. The movement is similar and the final ratios quite close even for very different $K_0$ (3 times more). These calculation show very interesting results.

- The capital-output ratio seem to have stabilized.
- It grows for the period between 1961 to 1980 and then reaches its new value.
- The average growth rate is almost 0 in 1980s, 1990s and 2001-2004.
- The final $\frac{K}{Y}$ ratio is around 4.2 regardless of its starting value.[3]

This seems like a typical neo-classical movement between two steady-state capital-output ratios. As shown in panel B, the transition is similar for different depreciation rates (however the final ratio goes down if higher value of $\delta$ is used).

[2]These growth rates are calculated using $K_0 = 1.5 * y_0$

[3]For no depreciation case.

Growth rates of capital per worker ratio are also interesting. The growth rate has been stable at 4% since 1990s. $\frac{K}{L}$ ratio seems to have reached the steady state in growth rather than level (i.e. constant growth rate).

### 3.3 Variance Decomposition

I use my calculated series to address the question of which one between the factor accumulation and the productivity is more responsible for the differences in output per worker. Variance decomposition analysis is used in most of the studies accounting for cross-country output per worker differences. Representing production function in the form of equation 5, we calculate how much of the variance in output Y is due to the variance in input X.

$$Y = AX \equiv logY = logA + logX \tag{5}$$

Klenow and Rodriguez (1997)[6] suggest that equation 5 implies following decomposition -
$var[lnY] = cov[lnY, lnY] = cov[lnY, lnX] + cov[lnY, lnA]$

Since equation 5 also holds in first differences, i.e.

$$\Delta logY = \Delta logA + \Delta logX \tag{6}$$

I calculate following variance decomposition for output level and output growth rate.

$$KR_{level} = \frac{cov.[log(Y), log(X)]}{var(log(Y))} \tag{7}$$

$$KR_{growth} = \frac{cov.[\Delta log(Y), \Delta log(X)]}{var(\Delta log(Y))} \tag{8}$$

Caselli (2004) [3] defines two success (of input changes explaining output changes) criteria -

$$Success^1_{level} = \frac{var(log(X))}{var(log(Y))} \tag{9}$$

$$Success^2_{level} = \frac{[X^{90}/X^{10}]}{[Y^{90}/Y^{10}]} \tag{10}$$

Equation 9 is another measure of the explanatory power of input variance, while equation 10 takes care of the fact that variance gets affected by presence of outliers.

| | Levels | | | Growth Rates | | |
|---|---|---|---|---|---|---|
| | **KR** | **S1** | **S2** | **KR** | **S1** | **S2** |
| $(\frac{Y}{L}) = A(\frac{K}{L})^{\alpha}$ | 0.52 | 0.31 | 0.70 | 0 | 0.039 | 0.58 |
| $(\frac{Y}{L}) = A(\frac{K}{Y})^{\frac{\alpha}{1-\alpha}}$ | 0.31 | 0.18 | 0.59 | -0.43 | 0.26 | 0.36 |

Table 5: Variance Decomposition: TFP and Labor Productivity

I define analogous Success criteria for growth rates as

$$Success^{1}_{growth} = \frac{var(\Delta log(X))}{var(\Delta log(Y))} \tag{11}$$

$$Success^{2}_{growth} = \frac{[(log(X))^{90} - (log(X))^{10}]}{[(log(Y))^{90} - (log(Y))^{10}]} \tag{12}$$

The results are shown in Table 5. Total factor productivity changes explain 48% and using alternative specification, labor productivity is responsible for 69% of output per worker changes between 1961 and 2004 in Indian economy. Both the success criteria seem to imply that considerable percantage of changes can not be unexplanied by changes in input (between 30% to 69% depending on specification and criteria).

KR decomposition does not give intuitive results for growth rates decomposition. One explanation is the business cycle movements. I plan to calculate it for HP filtered series. Success criteria *S2* shows reasonable values for growth rates.

# 4 Accounting with Human Capital

In this section I use various measures of human capital and re-estimate the productivity and its period-wise growth rates. I augment the production function by adding human capital as one of the inputs.

$$Y = K^{\alpha} H^{\beta} (AL)^{1-\alpha-\beta} \equiv \frac{Y}{L} = A.(\frac{K}{Y})^{\frac{\alpha}{1-\alpha-\beta}}.(\frac{H}{Y})^{\frac{\beta}{1-\alpha-\beta}} \tag{13}$$

For generating human capital series, I use education enrollment as a mea-

| | Avg. Annual Growth Rate | | | | | | |
|---|---|---|---|---|---|---|---|
| | **1961-2004** | **61-70** | **71-80** | **81-90** | **91-95** | **96-00** | **01-04** |
| **Primary Completed** | | | | | | | |
| No Smoothing | 0.7% | -2.45% | -3.78% | 3.50% | 3.81% | 3.77% | 4.29% |
| TFP-Then-HP | 0.7% | -3.73% | -2.06% | 2.50% | 4.26% | 4.17% | 4.30% |
| **%age of** $\Delta\frac{Y}{L}$ | | | | | | | |
| **Secondary Completed** | | | | | | | |
| No Smoothing | 1.43% | 0.92% | -2.01% | 2.13% | 3.24% | 3.57% | 4.47% |
| TFP-Then-HP | 1.43% | -0.28% | -0.54% | 1.35% | 3.57% | 3.97% | 4.50% |
| **%age of** $\Delta\frac{Y}{L}$ | | | | | | | |
| **Post-Secondary Completed** | | | | | | | |
| No Smoothing | 2.68% | 1.09% | -1.06% | 4.54% | 4.83% | 4.89% | 5.52% |
| TFP-Then-HP | 2.68% | -0.15% | 0.56% | 3.62% | 5.27% | 5.28% | 5.54% |
| **%age of** $\Delta\frac{Y}{L}$ | | | | | | | |
| **Any level Completed (Pr.+Sc.+PostSc.)** | | | | | | | |
| No Smoothing | -0.07% | -2.57% | -4.40% | 2.07% | 2.72% | 2.95% | 3.79% |
| TFP-Then-HP | -0.07% | -3.84% | -2.74% | 1.13% | 3.14% | 3.36% | 3.80% |
| **%age of** $\Delta\frac{Y}{L}$ | | | | | | | |

Table 6: Period-wise Labor Productivity: Using Human Capital (MRW)

sure of $\frac{I_H}{Y}$ as in Mankiw, Romer and Weil (1992) [8]. [4] I use the same values $\alpha = 0.3$; $\beta = 0.28$ as in MRW. I calculate the results for primary completed, secondary completed, post-secondary completed and their sum for generating the human capital.

Labor productivity growth rate estimates for different human capital investment measures are shown in Table 6 (along with HP filtered series growth rates).

The average annual productivity growth rates vary between -0.07% and 2.68% depending on the measure of human capital investment used. The estimates using secondary education as the measure are close to earlier estimates (with only physical capital). Main results of previous section about the period-wise trends in productivity growth are reinforced by these calcu-

[4] MRW do not need to construct the human capital series, since they explain output per worker variations across countries.

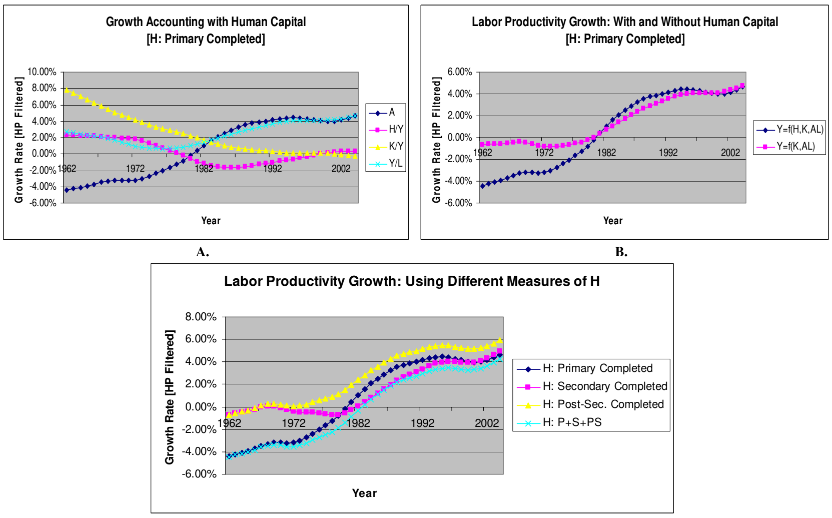



Figure 8: HumanCapital-Output Ratio & Labor Productivity Growth

lations. Productivity growth was negative in 60s and 70s. It turned around in 80s and the growth rates have been increasing ever since.

### Human Capital - Output ratio

The growth of $\frac{H}{Y}$ is plotted in Figure 8 along with productivity movements.

Human capital stock (using primary education) grows at around 2% from 60s to early 70s, and then starts falling resulting in negative growth rate between late 70s and mid 90s (panel A). As a result $\frac{H}{Y}$ ratio falls back to its starting value 1.5 (panel B).

The reason for productivity being higher when using only post-secondary education is that $\frac{H}{Y}$ estimates are too low. Because growth in Y is faster than growth in post-secondary completed. Hence all the increase in the output is coming from productivity increase.Similar and reverse logic goes for productivity estimates being too low when using sum of all levels of education.

Panel A in the figure highlights the period wise trends in input, output and productivity growth rates. The distinction between **Pre-Reform** and

**Post-Reform** period is more stark.

1. Physical and Human capital growth was good in 60s and 70s, but due to negative productivity growth those input growth did not result into high output growth rate.

2. On the contrary, period after 80s saw input growth rate go down, but productivity started growing at very fast rates. This lead to increased output growth rates.

I perform variance decomposition using different human capital measures. The results are reported in Table 7. Interesting result is that with sum of all level of education is used as the measure, input variations can explain up to 83% of the variation in output. It means that productivity changes were responsible for only 17%. Compared to only physical capital case, this result fits the usual neo-classical vs. technological progress debate in the sense that accounting for unmeasurables (using education as proxy for human capital) reduces the unexplained share attributed to residuals.

As earlier in calculating decomposition of growth variance success criteria S1 and S2 give more sensible results than KR. A consistent negative value of KR in growth is because of the fact that India experienced accelerated input and output growth in different periods. While 1961-1980 were the periods of high growth in factor accumulation, output was growing at slower rates during that time because of falling productivity. After 1980s when productivity started to pick up, the earlier high rate of growth of input could not be maintained. But this upward trend in productivity was large enough to keep increasing the output growth rates.

# 5 Using Mincer Regression Coefficients

As we saw in previous section that different measures of schooling give somewhat different estimates. In this section, I use another way of accounting for human capital by using labor market results to construct measure of labor quality.

Using Hall and Jones (1999) [5], I use following production function -

$$Y = K^{\alpha}(AH)^{1-\alpha} \tag{14}$$

H is augmented labor $H = e^{\phi(E)}L$. $\phi(E)$ represents the quality of labor and is function of number of years of schooling $E$. $\phi(E)$ is a piecewise linear function with $\phi'(E)$ being the Mincerian return to schooling.

| | Levels | | | Growth Rates | | |
|---|---|---|---|---|---|---|
| | **KR** | **S1** | **S2** | **KR** | **S1** | **S2** |
| $X = (\frac{K}{Y})^{\frac{\alpha}{1-\alpha-\beta}}$ | 0.51 | 0.49 | 0.71 | -0.52 | 0.73 | 0.60 |
| $X = (\frac{H}{Y})^{\frac{\beta}{1-\alpha-\beta}}$ | | | | | | |
| H: Primary Completed | -0.07 | 0.04 | 0.50 | -0.62 | 0.53 | 0.17 |
| H: Secondary | -0.14 | 0.07 | 0.53 | -0.52 | 0.53 | 0.25 |
| H: Post-Sec. | -0.77 | 0.69 | 0.86 | -0.53 | 0.43 | 0.81 |
| H: Pr.Cmpl.+Sc.+PostSc. | 0.32 | 0.14 | 0.58 | -0.62 | 0.46 | 0.34 |

Table 7: Variance Decomposition: With Human Capital(MRW)

For returns to education parameters, I use two sets of coefficients following Psacharopoulos and Patrinos (2002) [12] and Duraisamy (2000) [4]. I use Barro-Lee database for calculating the number of years of education matrix. Appendix 6 describes the construction of $\phi(E)$ in details.

Calculated human capital productivity estimates and period-wise growth rates are shown in Table 8. Average annual growth rate is 0.7% to 0.9% which is very close to earlier average growth rate using MRW method for primary completed. Period-wise average productivity growth rates calculated using this method behave in exactly the same way. Starting from slightly negative values in 60s growth rates decreased in 70s before turning around to positive rates in 80s and growing since then.

Duraisamy has lower return to education and hence lower $\frac{H}{L}$ value. This results in a slightly higher human capital productivity growth estimates.

Figure 9 plots human capital productivity growth. The value of human capital $\frac{H}{L}$ grows from around 1.1 in 1961 to 1.4 - 1.6 in 2004. The estimated productivity growth rate trends using MRW method (with combined completion rate as measure of H) are very similar to the ones calculated using HJ method except for initial periods (panel A).

Results of different variance decompositions are shown in table 9. In levels, input changes account for 55% to 63% of the output changes and thus reducing the role of productivity changes when compared to only physical capital case. As earlier, the result of KR decomposition in growth rates are not informative.

| | Avg. Annual Growth Rate | | | | | | |
|---|---|---|---|---|---|---|---|
| | **1961-2004** | **61-70** | **71-80** | **81-90** | **91-95** | **96-00** | **01-04** |
| **$\phi(E)$: Psacharopoulos** | | | | | | | |
| No Smoothing | 0.71% | -0.22% | -2.62% | 1.57% | 2.92% | 2.91% | 3.51% |
| TFP-Then-HP | 0.71% | -1.10% | -1.46% | 1.06% | 2.92% | 3.17% | 3.53% |
| **%age of $\Delta\frac{Y}{L}$** | | | | | | | |
| **$\phi(E)$: Duraisamy** | | | | | | | |
| No Smoothing | 0.93% | -0.06% | -2.40% | 1.78% | 3.13% | 3.20% | 3.80% |
| TFP-Then-HP | 0.93% | -0.93% | -1.26% | 1.27% | 3.16% | 3.46% | 3.83% |
| **%age of $\Delta\frac{Y}{L}$** | | | | | | | |

Table 8: Human Capital Productivity: With Mincer Regression (HJ)

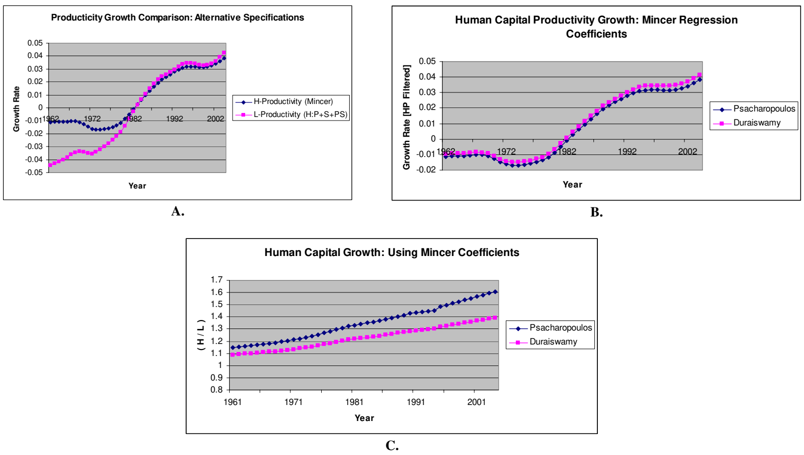



Figure 9: $\frac{H}{L}$ Ratio & H Productivity Growth: Mincer Coefficients

| | Levels | | | Growth Rates | | |
|---|---|---|---|---|---|---|
| | **KR** | **S1** | **S2** | **KR** | **S1** | **S2** |
| $X = (\frac{K}{Y})^{\frac{\alpha}{1-\alpha}}$ | 0.31 | 0.18 | 0.59 | -0.31 | 0.26 | 0.35 |
| $X = (\frac{H}{L})$ | | | | | | |
| $\phi(E)$: Psacharopoulos | 0.32 | 0.12 | 0.58 | 0 | 0 | 0.34 |
| $\phi(E)$: Duraisamy | 0.24 | 0.07 | 0.54 | 0 | 0 | 0.25 |

Table 9: Variance Decomposition: With Mincer Regression (HJ)

# 6 Conclusion

I study Indian macroeconomic series between 1961 and 2004 to identify period-wise growth trends and to find out how much of the changes can be explained by capital accumulation. There seems to be a clear distinction between 1960-1980 and post 1980s periods in terms of input, output and (calculated) productivity growths. In first period impressive input growth could not result into output per worker growth due to negative productivity growth. While in later period, even with slow input growth economy experienced growth in output because of high growth in productivity. Capital-output ratio seems to have stabilized indicating a possible new steady state level.

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# A List of Data Sources

1. Reserve Bank of India website (http://www.rbi.org.in/scripts/Statistics.aspx) and then select "Handbook of Statistics on Indian Economy".

2. Groningen Growth and Development Centre website (http://www.ggdc.net/index-dseries.html) and then select "Total Economy Database" .

3. Center for International Development, Harvard University website (http://www.cid.harvard. and then select "Barro-Lee Data Set".

4. Central Statistics Organization, Govt. of India - Pocketbook of Indian Statistics.

# B Macroeconomic Indexes and Growth

For each time-series I do the following -

1. Divide value for each period by base period value.
   $Y_t^{index} = \frac{Y_t}{Y_{1961}}$

2. To calculate the average annual growth rate between period $t_1$ and $t_2$, I use -
   $g^{t_2,t_1} \;=\; Y_{GrowthRate}^{t_2,t_1} \;=\; \frac{[\frac{Y_t2}{Y_t1}-1]}{(t_2-t_1)}$

3. This index follows the simple property of aggregation -
   $Y_{t2}^{index} \;=\; Y_{t1}^{index} * (t_2 - t_1) * g^{t_2,t_1}$

# C $\phi(E)$ Construction

For constructing the $\phi(E)$ for Mincer return set of calculations, I use:

- $$\phi(E) = \begin{vmatrix} e_1 \\ e_2 \\ \\ e_N \end{vmatrix} . \begin{vmatrix} w_1 \\ w_2 \\ .. \\ w_N \end{vmatrix} \quad (15)$$

- | Barro-Lee Variable | e |
  |---|---|
  | Primary Enrollment | 2 yrs. |
  | Primary Completion | 4 yrs. |
  | Secondary Enrollment | 6 yrs. |
  | Secondary Completion | 8 yrs. |
  | Post-Secondary Enrollment | 10 yrs. |
  | Post-Secondary Completion | 12 yrs. |

- Psacharopoulos returns to each year of education - first 4 yrs. 13.4%, next 4 yrs. 10.1% and after that 6.8%

- Duraisamy returns to each year of education - first 4 yrs. 8.2%, next 4 yrs. 8.4% and after that 13.7%

# D Other Notes

- Gross Domestic Savings series is available only in current prices. To calculate the growth rate of GDS, the growth rate of $(\frac{GDS}{GDP})^{Current}$ is multiplied by growth rate of $GDP^{Constant}$.

- For Education attainment data, I Extrapolated the Barro-Lee data for 2001-2004 by filling in the missing value (assuming a linear trend between the observations).