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**SOURCES OF INDIA'S ECONOMIC GROWTH:
Trends in Total Factor Productivity**

Arvind Virmani

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Foreword

One of the important areas of ICRIER's research is that of Macroeconomic and growth. We intend to systemise and deepen this policy research and expand it to include issues of employment and poverty.

The current working paper is the second in a series of papers on Indian Economic growth performance. The first paper in the series tried to clear up the misperception about Indian economic growth history, not only among foreigners, but even among Indians. It was therefore necessary to start with a simple paper that set forth the basic unvarnished facts and sets the record straight. The paper also explored some of the causes of changes in growth trends and variations in performance.

The current paper, the second in the series, explores the productivity performance that underlines the growth performance.

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May 2004

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Abstract

This paper reviews India's productivity performance that underlines the growth performance since independence. The primary focus is on estimation of trends in total factor productivity (TFPG) for the economy. This information is also used to derive average TFPG for the periods and sub-periods identified in an earlier paper as constituting significant growth episodes in India's economic history. It links changes in TFPG growth to the changes in economic growth analysed in the previous paper. Subject to the limitations of data availability, an effort is also made in this paper to estimate TFPG for all (NAS) sectors of the economy. These are used to estimate their relative contribution to overall productivity growth. Some light is also shed on the contribution of inter-sectoral shifts in factors on TFPG. The analysis deepens our understanding of the collapse of growth during 1965-6 to 1979-80 and its revival from 1980-81.

Key Words: Indian Economy, Total Factor Productivity, and Economic Growth.

JEL Number: N1, O1, O4, O5.

1 INTRODUCTION*

In a recent paper Virmani (2004a) analysed the growth performance of the Indian economy since 1950-51. The paper showed that the trend growth rate of the economy declined gradually from 1951-2 to reach a trough around 1972-3. It then rose more rapidly to reach a peak around 1995-96 and has been on a downtrend since then. The present paper attempts an explanation of these trends in terms of the standard sources of growth methodology.

There is an extensive empirical literature on total factor productivity growth (TFPG) in India's registered manufacturing sector.¹ Fewer authors have estimated aggregate productivity. Brahmananda (1982), King and Levine (1993, 1994) and Guha-Khasnobis and Bari (2003) have estimated aggregate Total Factor Productivity Growth in India based on NAS data on GDP and investment. Of these only Brahmananda (1982) estimated TFPG for GDP sectors. The current study differs from earlier ones in the following respects. Firstly it covers the entire period from 1950-1 to 2003-4. Second it derives a time series for TFPG to show the changes in trend over the entire period, by using a Hodrick-Prescott filter. It shows that even the period averages can differ significantly from the period averages derived from the unfiltered series when TFPG is close to zero. Third it is probably the only study that estimates the aggregate production function with rainfall as an exogenous variable. It then uses the estimated elasticity instead of factor shares, which are difficult to estimate in an economy with a large informal sector, characterised by mixed (profits & wages) income of self-employed. Fourth it covers all major National accounts sectors of the economy (but without the innovation applied to aggregate). Fifth it does not account for education.²

* I would like to thank Roberto Zaghera for encouraging me to explore TFPG and to Bishwanath Goldar for his comments. My thanks to Gurnain K Pasricha for research assistance and Manmeet Ahuja for secretarial assistance

¹ Ahluwalia (1985 & 1991), Barik and Pradhan (1999), Goldar (2002), Goldar and Kumari (2003), Unel (2003), Balakrishnan et. al(2000), Krishna & Mitra (1998), Srivastava (1996). Goldar and Mitra (2002) and Das(2003) provide a review of some of these studies.

² Whether this worse than assigning an ad hoc share to schooling is a matter of judgement.

The paper is structured as follows. Section 2 gives an overview of the historical growth experience of the Indian economy and the relevant growth trends. Section 3 outlines the standard sources of growth methodology, the estimating equations to determine the sources of growth and the decomposition methodology for determining the contribution sector TFPG and capital deepening to aggregate TFPG. Section 4 discusses the data used and presents the estimated equations and TFPG estimates. The results are then analysed in section 5. Section 6 analyses the determinants of TFPG. Sector Total factor productivity trends are estimated and discussed in Section 7. Section 8 concludes the paper. The appendix presents average TFPG estimates by different periods.

2 GROWTH TRENDS

Figure 1 shows the annual growth rate of Net Domestic Product at factor cost (NDPfc), the growth rate of the Hodrick- Prescott filtered NDPfc series (NDP_{hp}) and the 3rd & 4th order polynomials fitted to the annual growth rate series.³ The NDP growth rate trend (as measured by the HP-filtered series) started at 4.8% per annum in 1951-2 and decelerated during the fifties and sixties to reach a low of less than 3.2% per annum during 1971-72 to 1972-73. The trend growth rate accelerated from the mid-seventies to reach a peak of almost 6.2% per annum during 1994-95 and 1995-96. Thereafter, the trend growth rate has decelerated to 4.8% in 2003-4, a rate that is still higher than in 1982-3. The 3rd order polynomial starts in a similar way as the HP filtered series, makes an earlier trough and then keeps rising even after the HP series has peaked. In contrast the 4th order polynomial starts much lower and remains flat for some time. Its trough in the seventies and peak in the nineties is closer to that of the HP filtered series. Because of these variations with order of the polynomial we prefer to use the HP filtered series for analysis of growth trends.

³ The NDP series is derived from the published GDP series using the fixed capital series derived by us using a 5% depreciation rate for capital.

Figure 1: NDP Growth Trends - HP filtered series and 3rd & 4th Order Polynomial

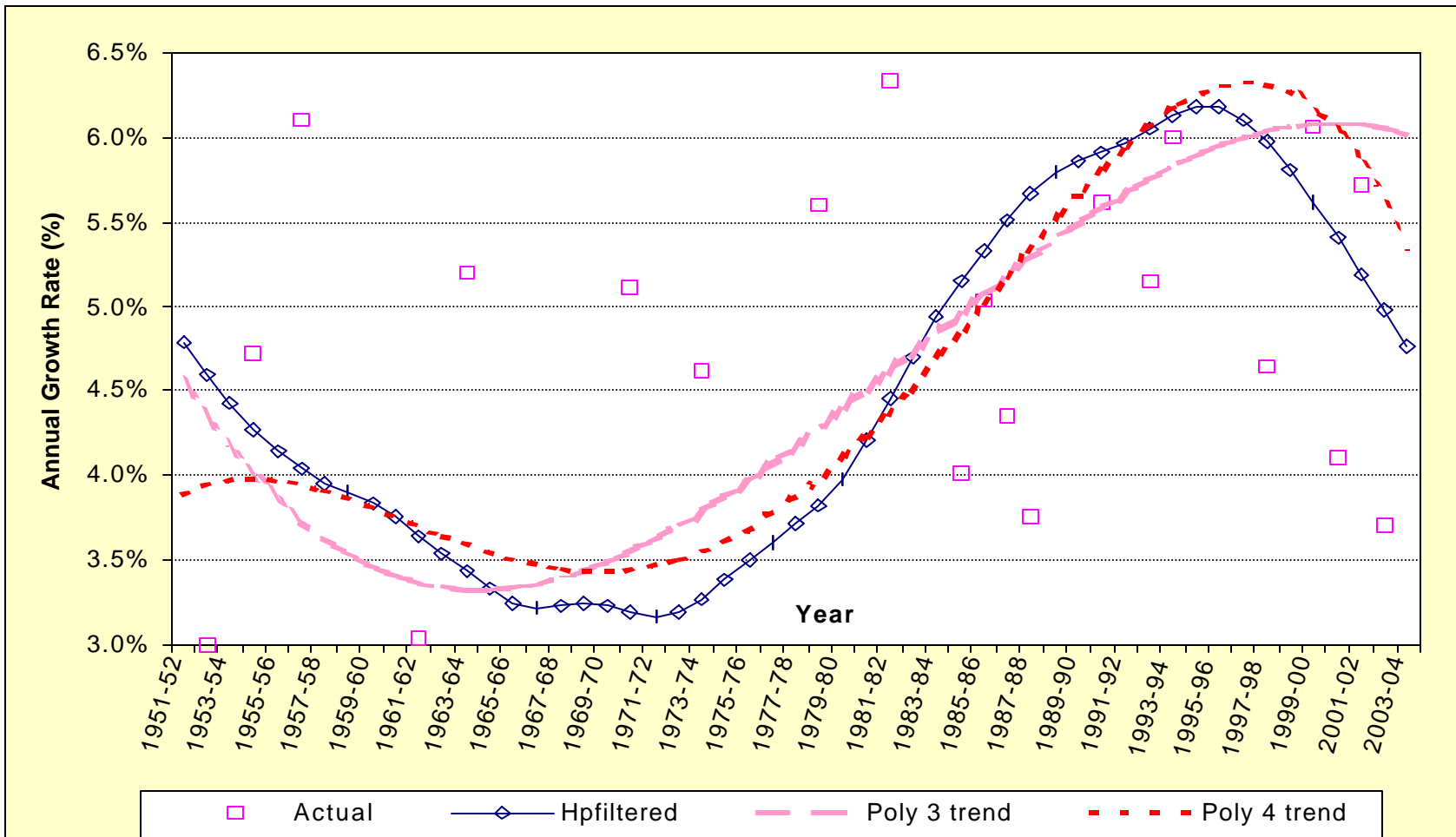


Figure 2: Trends in Hodrick-Prescott Filtered Series- NDP, NDPpc & NDPpwrk

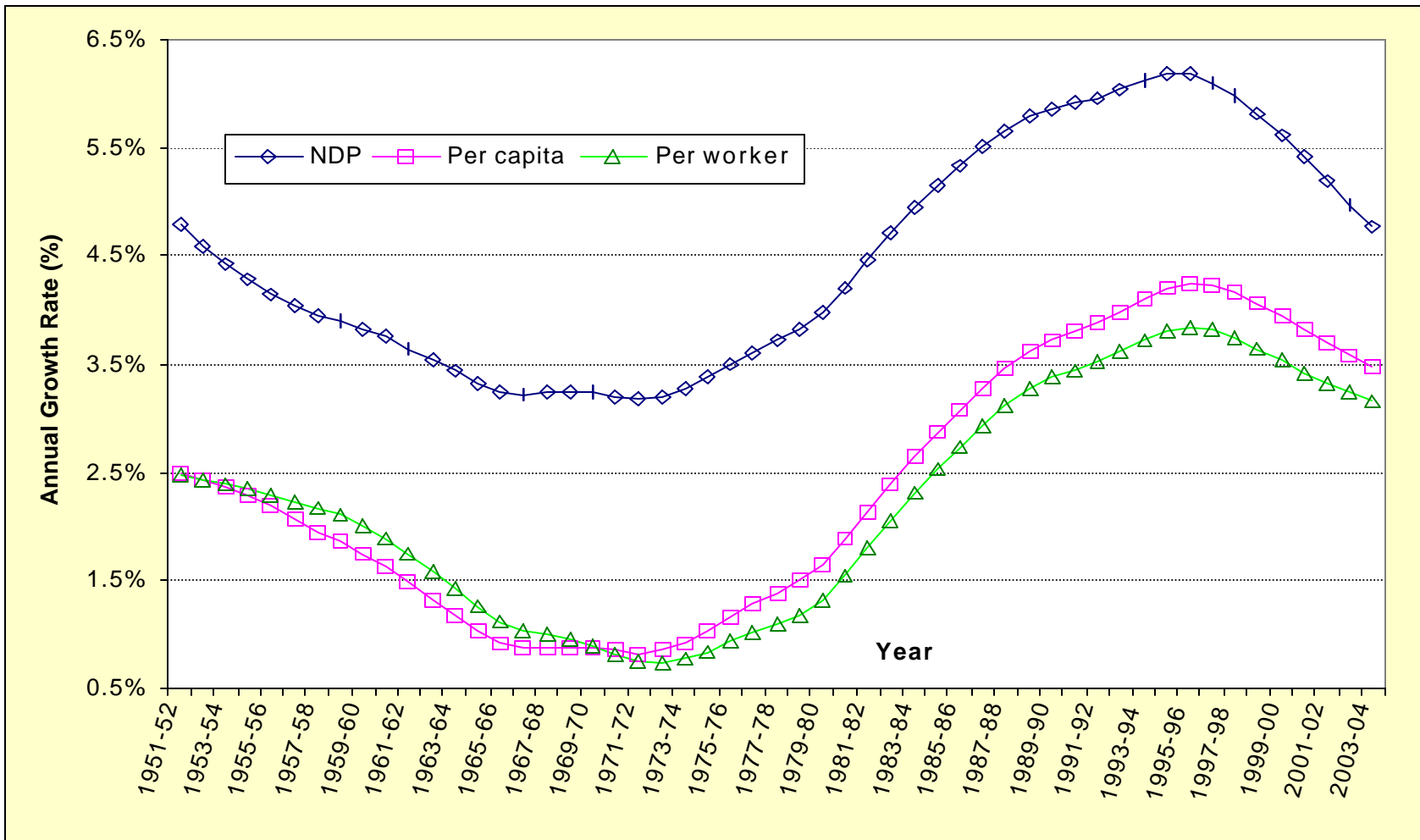
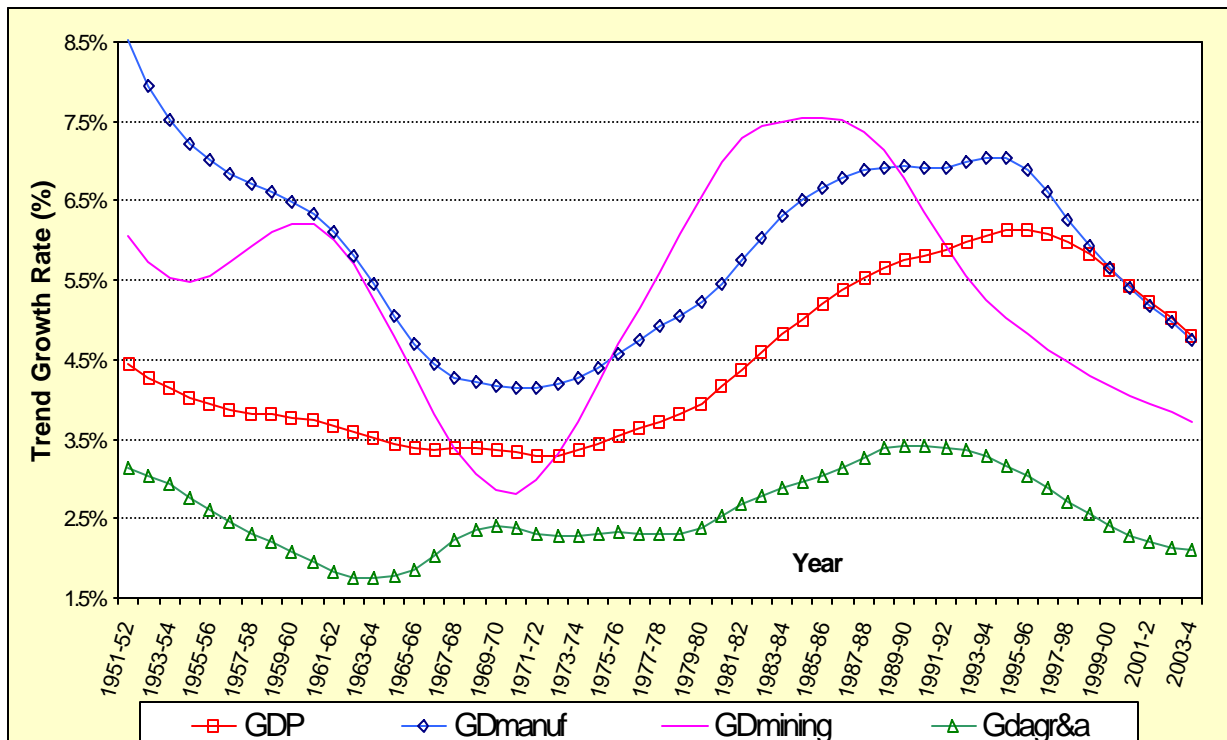


Figure 2 shows the growth trends in Per capita NDPfc (PCndp) and Per worker NDP (PWndp) along with that in NDPfc.⁴ Both the per capita and per worker series start at a trend growth of 2.5% per annum in 1951-2. They reach a trough of 0.7% per annum in 1971-2 and 0.8% in 1972-3 respectively. Thereafter they rise to a peak of 4.25% and 3.84% respectively in 1995-96. Currently (2003-4) the trend rate is 3.5% per annum in per capita NDP and 3.1% per annum in per worker NDP.

Figure 3: Tradable Sector Growth Trends



The above Figure 3 suggests that recent GDP growth trends are driven by the tradable goods sector. The trend growth in manufacturing has been decelerating since 1997-8. The downtrend in agricultural growth started earlier at the beginning of the nineties, while mining growth has been trending down since the mid-eighties with the downtrend continuing in the nineties. Import protection (QRs and Tariffs) for the tradable goods sector has been reduced over the nineties. During a transitional phase this would (ipso facto) lead to an increase in the rate of growth of the non-tradable sector

⁴ As an annual series for work force is not available, the population aged 15 to 64 is used as a proxy.

relative to that of the tradable sector. This has indeed happened. The apparent decline in the trend rate of growth of the tradable goods sectors (manufacturing, mining and agriculture) over the last 5-7 years is however disturbing and points to the need for domestic reforms related to these sectors (Virmani (2004b) and references therein).

3 METHODOLOGY

3.1 Sources of Growth

We can use the standard growth accounting framework to apportion growth between capital accumulation, labour supply and total factor productivity growth. For this purpose we make the conventional assumption of a constant returns to scale production function F . Because of the importance of rainfall to the Indian economy we include rainfall in the production function, assuming that its effect is multiplicative and factor neutral:

Equation 1: $Y_t = A_t G(\text{rainfall}) F(K_t, L_t)$ and $y_t = A_t G(\text{rainfall}) f(k_t)$

where, $Y_t = \text{NDPfc}(t)$, A_t is neutral technical change, $K_t = \text{Capital stock}$, $L_t = \text{Labour}$, $y_t = Y_t/L_t$ (NDPfc per unit of labour), $k_t = K_t/L_t$ (Fixed capital per unit of labour). Rainfall is an area-weighted index of monsoon rainfall all over India. If we assume the fulfilment of the competitive marginal product conditions we would need the share of wages and returns to capital. Because of the large size of the unorganised/self-employed sector as much as 45% of total income is classified as mixed income (labour and capital) in the National accounts statistics. A time series for labour/capital income shares is consequently not available. We therefore assume a Cobb-Douglas production function and on differentiation of Equation 1, obtain the estimating equation,

Equation 2: $Gy_t = C + \alpha * Grk + E * \text{Drainm} + e * \text{Drainm}(-1) + U_t$

Where Gy_t is the rate of growth of y , Grk is the rate of growth of k , Drainm is the percent variation of rainfall from mean with $\text{Drainm}(-1)$ representing the lagged value of the same and U_t is the error term. A_t is commonly set at C when estimating the coefficients of Equation 2. The most direct and immediate effect of rainfall is on crop output and agricultural GDP. The change in the amount of water available in hydel reservoirs also

affects electricity generation. The change in availability of surface water also affects the demand for electricity for drawing sub-surface water. The change of income of farmers would, also affect the aggregate pattern of demand and consequently the sectoral pattern of supply. Earlier studies ignore rainfall and therefore include only the first two terms of Equation 2. This could give biased estimates of elasticity and consequently an under estimate of TFPG.

Once we have obtained the coefficients of this equation, we can calculate the Total factor productivity growth (TFPG) as,

Equation 3: $TFPG = \alpha \cdot Grk - E \cdot Drainm - e \cdot Drainm(-1)$

The analysis of the previous section suggests that Growth rate of A_t could also equal $C_0 + C_1 \cdot Dummy$.

If we have constant returns to scale production function without rainfall, competitive factor markets and a capital share of α , then TFPG would be as follows:

Equation 4: $tfpg = \alpha \cdot Grk$

Thus we can obtain an alternative estimate of $tfpg$ using any value of α . The estimate obtained by inserting the coefficients estimated in Equation 2 into Equation 3 (TFPG0), however, has one weakness. The entire error term in the GDP growth equation is attributed to/contained within this estimate. We therefore need to use some smoothing operation such as the Hodrick-Prescott filter to purge the series of the error term and derive the underlying trend (TFPG0hp). If TFPG does not have the form $C_0 + C_1 \cdot Dummy$ and has varied over time because of changes in the policy environment, the estimate in equation could also be biased. We therefore follow a two-stage procedure. The filtered series (TFPG0hp) is inserted back into Equation 2 to obtain the following equation:

Equation 5: $Gry = TFPG0hp + \alpha \cdot Grk + E \cdot Drainm + e \cdot Drainm(-1) + u_t$

This equation is estimated to obtain revised values for the co-efficient which are then used in equation **Equation 3** to derive another value for TFPG (TFPG1). The HP filtered

version of this (TFPG1hp) then shows the time trend in TFPG. Period averages are, however, obtained by averaging the unfiltered series (TFPG0 or TFPG1).

3.2 Determinants of TFPG

The link between investment, capital and growth is the foundation of the standard sources of growth methodology. If technology is capital augmenting, Equation 1 is modified as follows:

$$y_t = A_t G(\text{rainfall}) f(b_t k_t) = (A_t b_t)^\alpha k_t^\alpha G(\text{rainfall})$$

assuming a Cobb-Douglas form. In this case the estimating equations for TFPG remain unchanged. If technology is embodied in capital stock each vintage of capital has different productivity and the measurement of aggregate capital stock requires either the relative price of each vintage or the relative quality.⁵ Such information is not available in India.

De Long and Summers (1991, 1992) have emphasised the link between equipment investment and growth. They also showed that equipment prices and equipment investment are inversely related. If technology is embodied in equipment (and not in structures K_{st}), augmentation would occur primarily in the machinery & equipment part of the capital stock (K_m). It would therefore be necessary to separate out the two forms of capital in the production function:

$$y_t = A_t G(\text{rainfall}) f(b_t k_{mt}, k_{st}) = (A_t b_t^{\alpha_1}) k_{mt}^{\alpha_1} k_{st}^{\alpha_2} G(\text{rainfall})$$

De Long and Summers also found that equipment imports are the best predictor of equipment investment. In a 1993 paper they showed that the effect of equipment investment is primarily through TFPG. Hulten (1993) showed that for capital goods with embodied technology, improvements in quality could explain 20% of the residual (TFPG). Lee (1995) modelled the effect of capital imports and showed that if trade reduces the price of investment and increases real investment there will be faster investment and technological progress. Thus TFPG may be a function of total or imported equipment investment or their ratio to total capital stock in Equation 1.

$$y_t = A(\text{Imp}_t/I, \text{Ime}_t/I, t)G(\text{rainfall}) f(k_t)$$

$$y_t = A_t (K_{me_t}/K_t)^{\alpha_1} k_t^\alpha G(\text{rainfall}) \text{ or } y_t = A_t (K_{imp_t}/K_t)^{\alpha_1} k_t^\alpha G(\text{rainfall})$$

⁵ Hulten (1992), Good, Nadiri, Sickles(1996), Greenwood, Hercowitz & Krusell(1997), Lutz (2000).

In the developing country context where technical change is largely a consequence of diffusion of technology from the developed countries, most embodied technology would enter through imported capital goods. Technological change could also be affected by the variety of manufactured intermediates available to the producers. Restrictions on the import of capital good and intermediate inputs and the tariffs imposed on them would therefore influence import of these goods and the rate of technological change.⁶ Such import policy restrictions would also lead to an appreciation of the real exchange rate ($XR_{real} = P_t/P_{nt}$, P =price, t =tradables & nt =non-tradables). Changes in the real exchange rate would capture both the price wedges introduced by QRs & tariffs and the quality differential between domestic and imported capital goods & intermediates. Thus technical change could be inversely related to the real exchange rate (i.e. an appreciation of the exchange rate is correlated with lower TFPG).

Because of the difficulty of estimating augmented capital stock we assume for our estimation that technological change is either neutral or labour augmenting. TFPG (A_t in Equation 1) is a function H of investment in machinery & equipment and of changes in import restrictions captured by the growth of the real exchange rate ($GrXR_{real}$), i.e.

Equation 6: $TFPG = H(I_{me_t}/I, GrXR_{real}, t)$

3.3 TFPG by Sector

Equation 4 is also the method used for calculating the TFPG for each sector of the economy based on an estimate of the capital share (α) for that sector. The contribution of TFPG in each sector to aggregate/overall TFPG is estimated as follows (the time subscript t is dropped):

$$Y = A F(K, L) \text{ or } A = Y/F(K, L),$$

$$Y = \sum_{i=1}^n Y_i = \sum_{i=1}^n A_i F_i(K_i, L_i)$$

Substituting the second equation in the first we have,

$$A = \sum_{i=1}^n S_i A_i, \text{ and } S_i = F_i(K_i, L_i) / F(K, L) = K_i^{\alpha_i} L_i^{1-\alpha_i} / K^\alpha L^{1-\alpha}$$

⁶ See also Mazumdar (1996), Connaly (2003).

is the ration of total factor input in sector i to total factor input (TFI) into aggregate GDP. Differentiating this equation with respect to time we have,

$$\text{Equation 7: } dA = \dot{A} \left(\sum_{i=1}^n S_i dA_i + A_i dS_i \right)$$

The term on the left represents the change in total factor productivity of aggregate GDP. The first term on the right represents the contribution of sectors' TFPG and the second term the contribution of the change in allocation of total factor input among different sectors. The TFPG of sector i contributes a proportion $S_i dA_i / dA$ to total TFPG while the factor shift to sector i contributes $A_i dS_i / dA$. If dA is close to zero or negative this fraction can be misleading and it is better to use the absolute numbers $S_i dA_i$ and $A_i dS_i$ to compare the relative contribution of different sectors.⁷

4 Empirical Estimation

4.1 Data

The capital stock series is constructed using fixed investment at constant 1993-4 prices from the National Account Statistics (NAS), using the perpetual inventory method. The depreciation rate is assumed to be 5%. Starting stock (end 1950-1) is also obtained from the National Account Statistics. The same depreciation values are also used to construct Net Domestic Product from Gross Domestic Product at factor cost. As an annual labour or worker series is unavailable we use the population aged 15 to 64 to measure potential workers for L . This data is obtained from the World development indicators (from 1960 onwards) and from the UN for 1950. The data for the rest of the fifties is constructed by interpolation of the ratio of population 15 to 64 over the total population.

The data problems are more severe when we move from the aggregate to the sector level. Time series on number of workers or worker hour are not available even at the aggregate level. We however, have data from national census and National sample surveys on the number of workers for about nine distinct years for most sectors. The important exception is Insurance, Banking, Housing Real estate and Business services,

which is put in the residual category along with Government and Social & personal services. Approximately consistent series can be constructed for eight of these years based on the work of earlier authors.⁸ Capital share values (α) for all sectors can be derived from Brhmananda (1982). Based on GDP data and the fixed capital series constructed by us, we can calculate total factor productivity growth rates by sector for these seven periods using Equation 4 (These are given in the Appendix table A2).⁹

These years do not however coincide with the turning points identified in the aggregate data. Nor do they coincide with the phases and sub-phases of growth identified in Virmani (2004a). To get an idea of the cyclical trends (peaks, troughs and periods of rising or declining productivity) we interpolate the share of workers by sector for the missing years and use the population of 15 to 64 year olds to interpolate the total workers for the missing years. This is then used along with the GDP data and the capital series to derive annual TFPG estimates for each sector (from 1952-53 to 2000-01) using capital share values (α) in Equation 4.¹⁰ This allows us to estimate the average productivity growth during the phases and sub-phases of growth identified earlier.¹¹ We then filter the TFPG series using an HP filter to find the trend in TFPG and then compare these trends as represented by the fitted line.

4.2 Production Function and TFPG

OLS estimates of Equation 2 yields the following result:¹²

$$\text{Equation 8 : } \text{Gry} = 0.0148 + 0.430 * \text{Grk} + 0.202 * \text{Drainm} - 0.118 * \text{Drainm}(-1)$$

$$(2.35)** \quad (1.6)* \quad (5.7)*** \quad (-3.4)***$$

$R^2 = 0.51$, R^2 (adj) = 0.48, DW = 2.29. When the Equation 8 is re-estimated with AR(1), the coefficient on the AR term is not significant. The negative parameter on previous

⁷ This is what happens in sub-phase IB.

⁸ We use Krishnamurthy (1970) for 1951 & 1961, Sundaram (2001) for 1993-4 & 1999-2000 and Sharma (1997) for the rest.

⁹ The same depreciation rate of 5% is used for all sectors. The cobb-douglas capital co-efficient on total gdp is taken as estimated earlier (0.42). Sector estimates are derived from simple regression on nine values and cross-checked against Brahmananda (1982).

¹⁰ The income share for the residual sector is derived by subtracting the sum of wages/NDP from sectors from total wages/NDP.

¹¹ We then average these over the 7 original periods and compare as a cross-check (appendix A2).

¹² The numbers in bracket are t-statistics. The level of significance is represented by * (10%), ** (5%) and *** (1%).

years' (lagged) rainfall deviation indicates that the short run (one year) effect of rainfall deviation on growth (2/10th of rainfall deviation) is higher than the long-term (two-year) effect (less than 1/10th of rainfall deviation). This is probably due to substitution on both supply side (e.g. agricultural imports, thermal electricity generation) and demand side (e.g. income transfers from government or food for work programs) that take time to adopt.

These parameters are substituted into Equation 3 and TFPG0hp estimated. TFPG0hp is then used to estimate Equation 5. The results are as follows;

Equation 9:

$$\text{Gry} = 1.11 \text{ TFPG0hp} + 0.34 * \text{Grk} + 0.22 * \text{Drainm} - 0.12 * \text{Drainm}(-1) - 0.35 * \text{AR}(1)$$

(4.6)*** (1.9)* (6.9)*** (-4.0)*** (-2.5)***

$R^2 = 0.62, R^2(\text{adj}) = 0.59, \text{DW} = 2.1.$

The most important change is the reduction in the capital coefficient (implicit profit/capital share). This estimate is almost identical to the capital share (0.35) used by Collins and Bosworth (1996) and by Guha-Khasnobis and Bari (2003).¹³ It however differs from that of Brahmananda (1982), who estimated the share of wages in total income for the economy as 75% from 1950 to 1970 and 71% for 1980. This suggests a capital share of 25% in the fifties and sixties, rising to 29% between 1970 and 1980 and perhaps even higher in the nineties. Our estimate of 0.34 therefore appears quite reasonable. These new coefficients are reinserted into Equation 3 to get a second estimate of total factor productivity (TFPG1). This is again smoothed using the Hodrick-Prescott filter to obtain the trend value (TFPG1hp).¹⁴

If we estimate the same regressions using GDP growth as the dependent variable instead of NDP growth the estimated total factor productivity and its trend (as per the HP

¹³ The latter was based on Nehru and Dhareshwar (1993)

¹⁴ If a third stage estimate is done using tfpg1hp the co-efficient on capital per worker falls to 0.239 and becomes insignificant i.e. there is no convergence.

filtered series is virtually the same.¹⁵ However the filtered total factor productivity series using GDP is everywhere below the filtered TFPG series derived using NDP.¹⁶

If Equation 4 is used (instead of Equation 3) to estimate TFPG (tfpg0a) and the HP filtered series (tfpg0ahp) used in the estimation of Equation 5, we obtain

Equation 10:

$$\text{Gry} = 1.04 \text{TFPG0ahp} + 0.41 * \text{Grk} + 0.21 * \text{Drainm} - 0.13 * \text{Drainm}(-1) - 0.32 * \text{AR}(1)$$

(4.3)*** (2.4)** (6.4)*** (-4.2)*** (-2.3)***

$$R^2 = 0.61, R^2 (\text{adj}) = 0.58, \text{DW} = 2.1.$$

There are two noticeable differences from the estimates obtained using tfpg0hp. One, the co-efficient on the capital per worker appears to be different from that obtained in Equation 9 (0.411 instead of 0.337) and is significant at a higher level of confidence (2% instead of 6%). Two, there is virtually no difference in the co-efficient on the capital per worker from that obtained in Equation 8 (0.43).¹⁷ The estimates that use the tfpg calculated without subtracting the effect of rain fall on ndp growth (0.41) are close to that of Senhadji (1999) who obtains an estimate of 0.42 for the capital share in case of South Asia (when estimated in difference form). These estimates contrast both with our previous estimate of 0.33 and with the non-labour share (0.25 to 0.29) estimated by Brahmananda (1982).

5 ANALYSIS & IMPLICATIONS

5.1 Productivity Trends

The values of total factor productivity obtained above (TFPG0, TFPG1) are plotted in Figure 4 in filtered form (TFPG0hp, TFPG1hp). The two HP filtered series for TFPG follow a broadly similar pattern, though TFPG1hp is found to be higher than TFPG0hp for all years except the first half of the fifties. Total factor productivity growth started at 2.4% after independence, but was on a declining trend thereafter. TFPG fell below single digit at the beginning of the sixties and bottomed out at 0.39% per annum in

¹⁵ Significance tend to be somewhat higher however. Thus in borderline cases the regressions using GDP growth may be significant at the 10% confidence level but not those using NDP growth.

¹⁶ By about 1/8th.

¹⁷ In other words there is greater convergence.

1972-73 (TFPG1hp). TFPG has accelerated steadily during the seventies and the eighties and peaked at 2.62% in 1988-89. This was followed by a temporary setback due to the BOP crises after which TFPG has essentially plateaued out at around 2.7% per annum since 1996-97(Figure 4).¹⁸

The significant decline in TFPG during mid-sixties to the end-seventies can also be confirmed directly by the introduction of a dummy variable for the period 1965-66 to 1980-81 (D6580) into Equation 8:

Equation 11:

$$\text{Gry} = 0.021 - 0.020 * \text{D6580} + 0.41 * \text{Grk} + 0.21 * \text{Drainm} - 0.15 * \text{Drainm}(-1) - 0.3 \text{ AR}(1)$$

$$(3.9)^{***} \quad (3.5)^{***} \quad (2.0)^* \quad (6.0)^{***} \quad (-4.4)^{***} \quad (2.2)^{**}$$

$$R^2 = 0.61, R^2(\text{adj}) = 0.57, DW = 2.1 .$$

Equation 11 suggests that TFP growth which averaged about 2.1 per cent per annum during the over fifty year period, fell by 2.0 per cent points to almost zero during 1965-66 to 1980-81. Virmani (2004a) showed that other exogenous factors such as oil prices do not have a significant effect on GDP growth and therefore the effect of the dummy variables could be interpreted as the effect of the set of policies undertaken during the sub-period. These policies included a comprehensive control regime for the private sector that can be named Legislative-bureaucratic socialism (popularly known as ‘Licence-Permit-Quota Raj’ and ‘Inspector raj’), which affected not just manufacturing but all areas of business. Even agriculture was not left untouched as the Essential commodity act and other restrictions on trade, transport, sale and processing affected agricultural growth.¹⁹ These along with the after effects of the public monopoly created till the mid-sixties seem to have played a role in the decline in productivity during 1965-6 to 1979-80.

¹⁸ The TFPG0hp series in contrast shows a peak of 2.4% per annum in 1996-97 and a decline to 2.2% per annum at the current time.

¹⁹ See for instance Virmani and Rajeev (2002) or Virmani (2004b).

Figure 4: Total Factor Productivity Growth (TFPG)

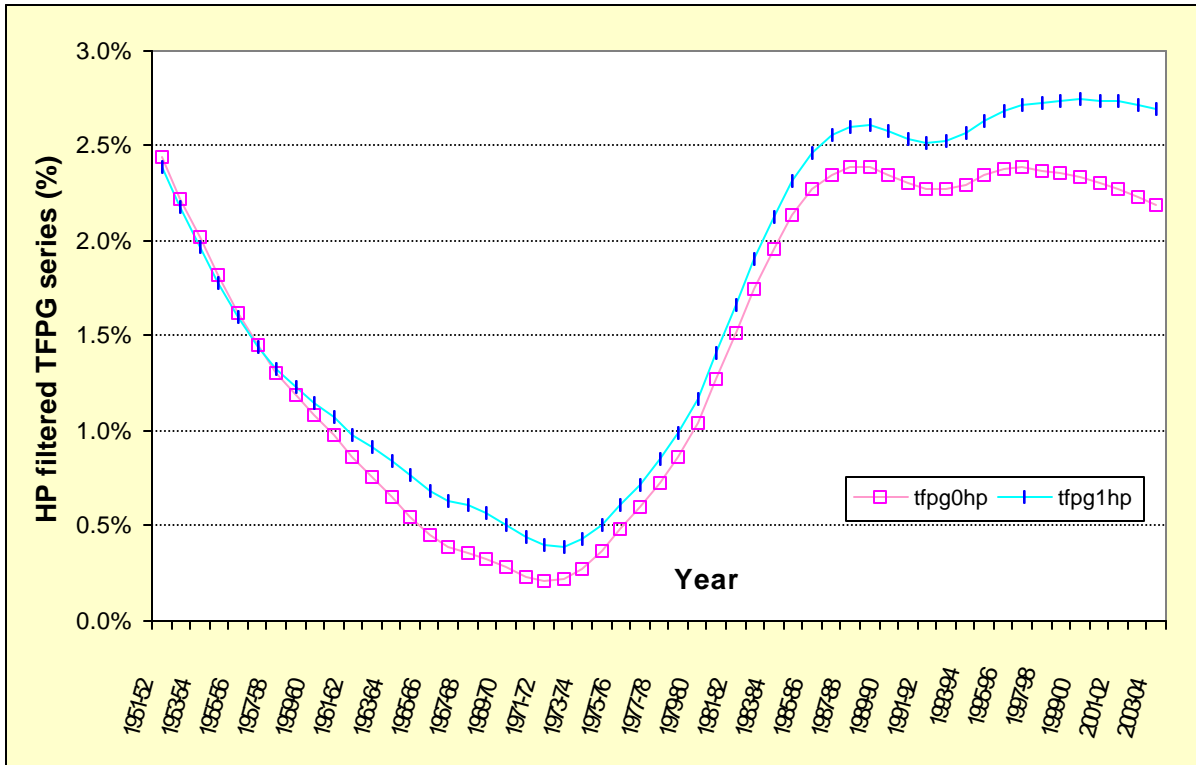
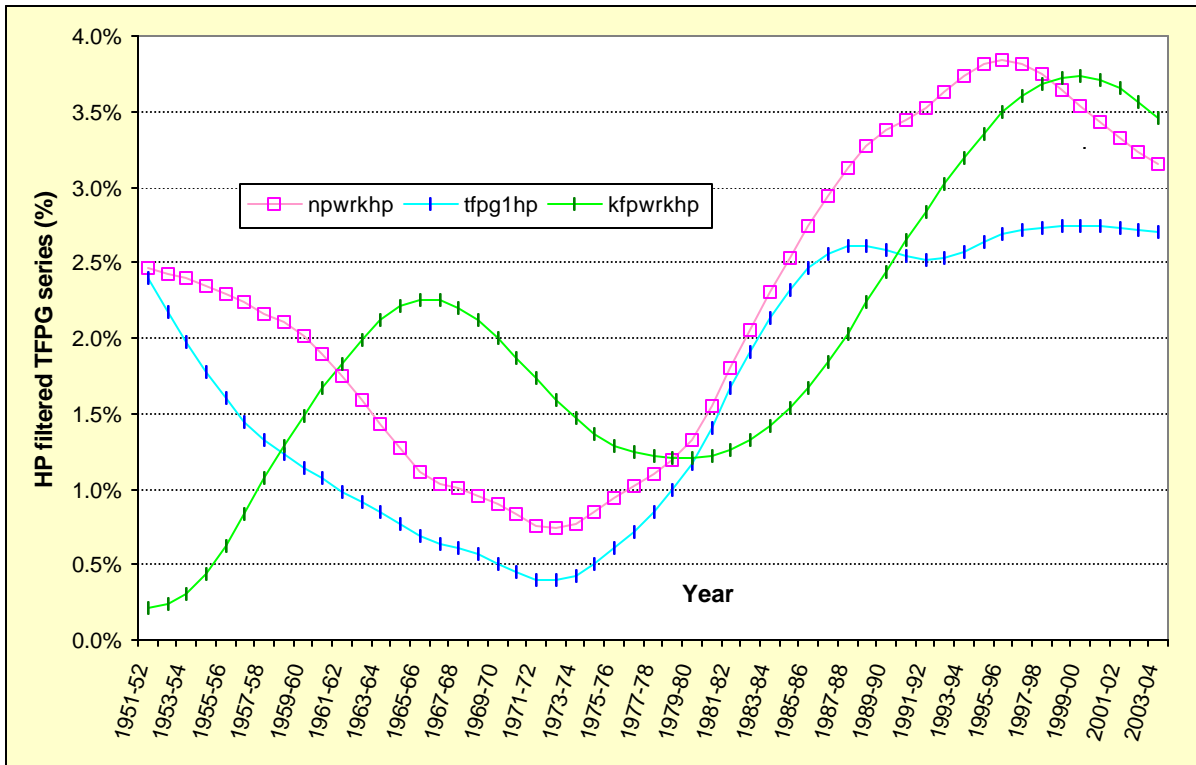


Figure 5: Sources of Growth (HP filtered series) Per worker NDP/Capital & TFPG



5.2 *Relative Contribution to Growth*

As the annual growth of income and fixed capital are quite volatile, we use the HP filtered series to see the trend in growth of GDP per worker and in the growth of fixed capital per worker. The same series are used to show the trend in the contribution of TFPG and growth of Capital per worker to growth of GDP per worker. The growth trend of NDPfc per worker (npwrkhp) has gone through a long cycle stretching over 50 years or so (Figure 5). The trend rate of growth of NDP per worker was decelerating during the fifties and sixties, reached a trough in the early seventies followed by sustained acceleration till the mid-nineties when it peaked. It has decelerated since then. The trend growth rates of NDP per worker and TFPG were broadly in consonance from the beginning of the period till the mid-nineties, so that the latter appears to be the main driving force for the latter. Thereafter capital deepening appears to be the main driver of per worker NDP even though the capital per worker cycle seems to lag that of NDP per worker (Figure 5).

Over the same period, the trend rate of growth of fixed capital per worker (kfpwrkhp) seems to have gone through one and a half cycle (almost two) with one and a half troughs and two peaks (Figure 5). The cycle starts mid-way (?) through the first trough at the time of independence and peaks in the mid-sixties. The second trough was at the end of the seventies and the second peak in the mid-nineties, both at a much higher level than the first.

To evaluate the change in the contribution of productivity and capital productivity over time we need to adjust for the volatility in the series. This is done in two ways. First we multiply the capital per worker series and the rainfall deviation series by the estimated impact coefficients (from Equation 9 for evaluating the contribution of tfpg1). The resultant growth rates for tfpg1 and kfpwrk1 and rain1 are plotted and a 3rd order polynomial fitted to each to show the trend (Figure 6). The second method is to subtract the impact of rainfall variations from the growth of NDP per worker and then use this as divisor for TFPG and Capital per worker growth, to obtain their relative contribution (share). A third order polynomial is then fitted to find out the trend in relative contribution (Figure 7).

Figure 6: Sources of Growth in Per Worker NDP

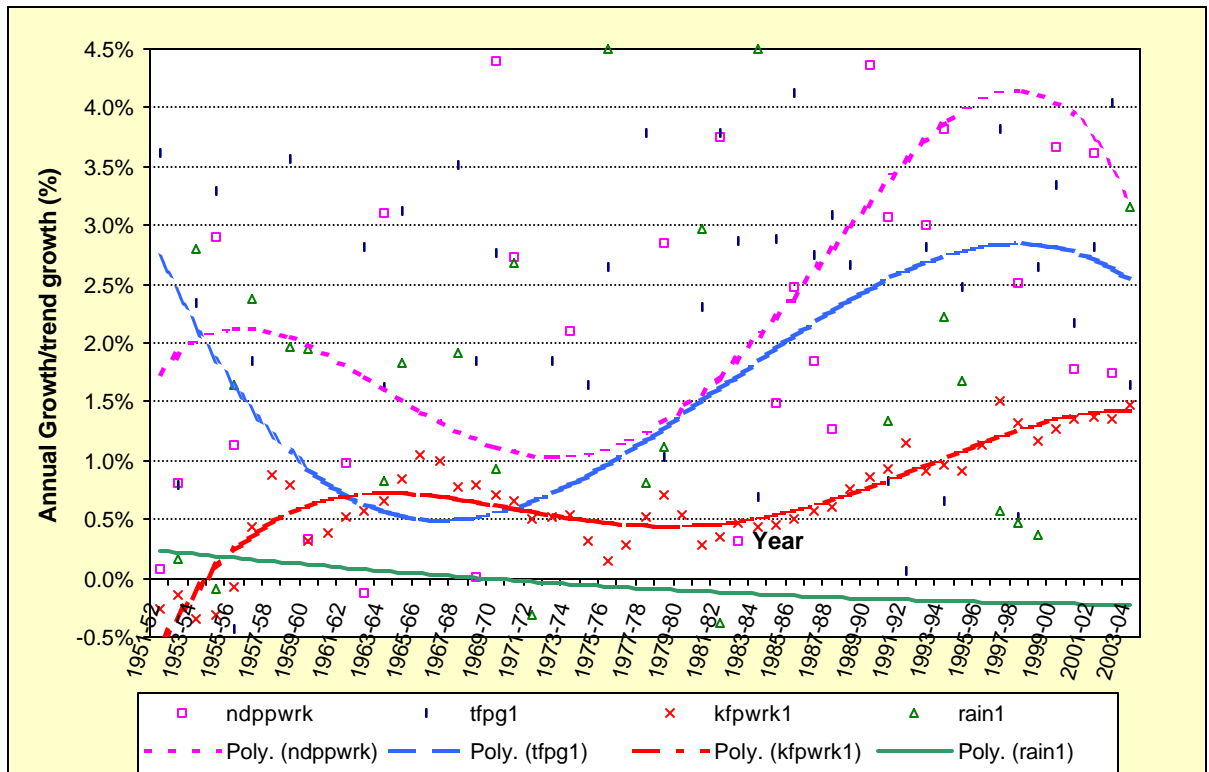
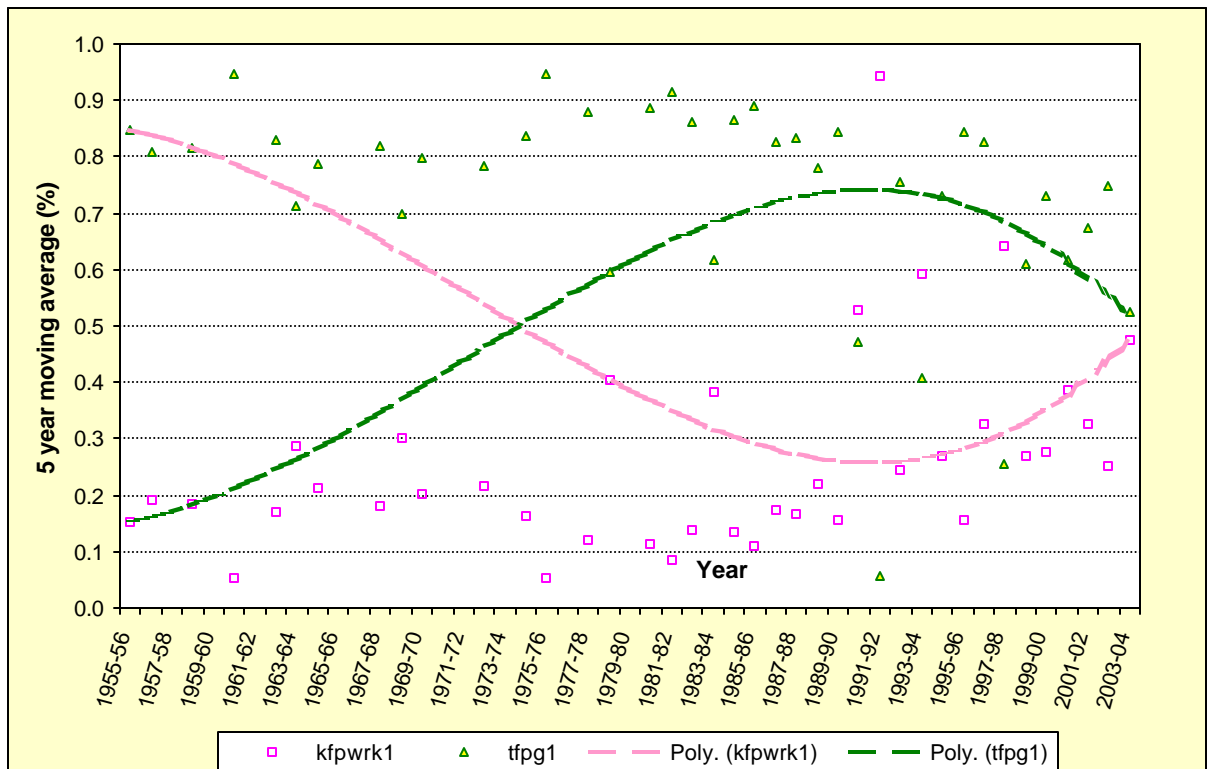


Figure 7: Contribution to Growth of Per worker NDP (adjstd for rainfall deviation)



The dotted line at the top of Figure 6 shows the trend in the growth of NDP per worker, while the dashed line just below it is TFPG. The third dashed line shows the impact of growth of capital per worker. The contribution of TFPG to growth was initially high and even offset the negative consequence of capital shallowing. As the contribution of rainfall to growth was positive (though falling) the growth of NDP per worker accelerated for about five years till the mid-fifties. The contribution of TFPG declined over time while that of capital deepening increased. As the deceleration of TFPG was sharper than the acceleration in capital deepening the growth of NDP per worker decelerated after the mid-fifties. The acceleration in growth of capital per worker was driven by a sharp rise in public investment, which more than tripled the public share of fixed capital from about one tenth ($1/10^{\text{th}}$) in 1950-51 to more than one third ($1/3^{\text{rd}}$) of total by 1964-65. Public investment was clearly not driven by the profit motive, but the increase in poverty during this period suggests that the social benefit-cost ratio for this investment (whether borrowed or raised through distorting taxes) was also low. The low productivity of this public capital formation appears to have pulled down total factor productivity growth.

The position was therefore reversed between 1960-1 and 1970-71 when TFPG was at a trough. During this period capital deepening contributed marginally more than TFPG to the growth of NDP per worker. The economic situation worsened from the mid-sixties with the growth of capital stock declining, slowly at first and then in an accelerating downtrend till the late seventies where it reached a trough. Since 1971-2, the contribution of TFPG has progressively increased relative to that of capital deepening till the mid-nineties after which it has declined marginally/stabilised. The contribution of rain also became negative from 1971-2. Growth of NDP per worker therefore decelerated till the mid-seventies, picking up only after the decline rate of growth of capital per worker slowed and the TFPG accelerated.

The relative contribution of TFPG and Capital deepening to the growth of NDP per worker adjusted for rainfall deviations is depicted in Figure 7. The contribution of TFPG fell from about 85% at the beginning of the period to 50% in the mid-seventies while that of capital deepening rose from 15% to 50%. The relative contribution of

capital deepening continued to rise till the end of the eighties when it peaked at around 75% and that of TFPG reached a trough of 25%. Since then the contribution of capital deepening has declined to a little over 52% while that of TFPG has declined to a little less than 48%. From the trends it seems likely that the contribution of TFPG will move above 50% over the next few years, while that of capital deepening will fall.

5.3 TFPG During Growth Phases

Virmani (2004a) showed that there were two statistically distinguishable phases of growth: I) Indian version of socialism (1950-51 to 1979-80) and II) Market Reforms (1980-1 to present). It also highlighted four sub-phases: IA Quest for commanding heights, IB Legislative –Bureaucratic Socialism,²⁰ or socialist rate of growth, IIA modest reforms and IIB broader reforms. Table 1 shows the average growth rates and TFPG estimates in terms of these phases and sub-phases. The average rates of growth of GDP and NDP were quite similar over the periods and sub periods, so that the conclusions regarding the sources of growth of NDP per worker and NDP per capita would also apply to GDP per worker.

One striking contrast that emerges is as follows. While the rate of growth of NDP per capita and per worker tripled between the socialist and market phases (from 1.3% to 3.9% and 1.3% to 3.5% respectively), the average rate of growth of capital stock per worker only doubled (from 1.4% to 2.7%). The growth of NDP per worker accelerated despite a fall in the average deviation of rainfall from a positive 0.5% in phase I to a negative 1.8% in phase II. Clearly changes in total factor productivity growth are an important reason for these paradoxes. Equally striking is the fact growth of NDP per worker fell from 2.7% in sub phase IA to 0.3% in sub phase IB despite a doubling of the rate of growth of capital per worker from 0.9% per annum to 1.8% annum. Here rainfall variation provide part of the explanation, with a positive deviations of 4.0% from mean during sub-phase IA turning into a negative deviation 2.7% during sub-phase IB.

Turning to the estimates of TFPG, we find that the average TFPG over the periods and sub-periods as estimated in stage one (TFPG0) and stage two (TFPG1) are very similar. The largest difference of 0.3% between the two measures occurs in sub-phase IB. The results are also very similar if we ignore the rainfall effects completely and assume

that capital share is equal to 0.26 and use this to calculate TFPG using Equation 4 (TFPGs). The largest difference in this case is 0.5% in sub-phase IA. However, if we take the averages of the HP filtered series for TFPG1 (TFPG1hp) the result is different for sub-phase IB (0.5%) and sub-phase IIA (-0.3%). We will therefore use our preferred measure TFPG1 in the discussion, supplemented by TFPG1hp.

A tripling of the growth of total factor productivity from 0.9% per annum in the socialist phase I to 2.7% per annum during the market phase II was clearly the driver in tripling the rate of growth of NDP per capita over these two phases. Of the 2.2% (3.5%-1.3%) points increase in growth rate of NDP per worker, 1.8% points were due to the increase in TFPG1 and 0.4% points due to capital deepening. Consequently the contribution of TFPG to per worker growth increased from 67% during phase I to 76% during phase II. As the contribution of rainfall remained virtually unchanged, the contribution of capital deepening correspondingly declined from 36% to 26% (Table 1).

The reason for the sharp decline in the growth of per worker NDP during the Socialist rate of growth (IB) also becomes clear. More than half the decline of 2.4% points between sub-phase IA and IB is the result of a 1.4% point per annum decline in TFPG1. The rest was contributed by the change from above average to below average rainfall. Thus almost 6/10th (0.57) of the pathetic growth rate of 0.3% during this sub-phase was due to TFPG1 with the rest coming from capital deepening, which also compensated for the negative effect of weather ($0.44 = 2.14 - 1.7$).

The rate of growth of per worker NDP has increased from 3.1% per annum during sub-phase IIA (moderate reforms) to 3.9% per annum in sub-phase IIB (broader reforms). TFPG has remained almost unchanged over these two sub-phases increasing marginally from 2.6% per annum to 2.8% per annum (i.e. by 0.2% point). The growth of capital per worker has however doubled from 1.8% per annum to 3.6% per annum, contributing 0.6% points to the increase in the increase in growth rate of per worker NDP. As a consequence the contribution of TFPG to the overall growth declined from 83% during sub-phase IIA to 71% during sub-phase IIB, while that of capital deepening increased from 20% to 32%. Thus the broadening and deepening of reforms during the latter phase seem to have lifted 'animal spirits' leading to greater investment and growth. The effect

²⁰ Popularly known as the Licence-Permit-Quota Raj

on productivity has been modest if we go by TFPG1, but reasonable if we use TFPG1hp. In the latter case 0.4% of the 0.9% point increase in NDP per worker between sub-phase IIA and IIB (44%) is accounted for by TFPG.

We can compare our estimates of total TFPG with those given in Guha-Khasnobis and Bari (2003). For this purpose we have to create decade averages. Our estimates of TFPG1 are 1.3% per annum during the 1960s, -0.1% per annum during the seventies and 3.0% per annum (appendix table A1). The estimates based on TFPG0 are marginally lower.²¹ Our estimates are therefore close to one of their three estimates in which the growth rates are 1.2%, -0.4% and 2.5% for the same three decades. The estimates of King and Levine (1993, 1994) are 0.66, -1.77 and 3.0 and differ most sharply for the seventies. Our analysis suggests that the TFPG for the seventies is underestimated because of the missing variable rainfall (which was unfavourable). To some extent the same caveat applies to the under estimation of TFPG in the sixties, where the other two estimates of Guha-Khasnobis and Bari (2003) are even lower (0.72 and 0.15).

²¹ The corresponding estimated based on TFPG0 are 1.1% (1960s), -0.2% (1970s) and 2.8% (1980s)

Table 1: Sources of Growth in Net Domestic Product

Variable	Phase Sub-phase	I: 1950-1 to 1979-80			II: 1980-1 to 2003-4		
		Total	IA:1950-1 to 1964-5	IB: 1965-6 to 1979-80	Total	IIA:980-1 to 1991-2	IIB:992-3 to 2003-4
Gross Domestic Product		3.5%	4.1%	2.9%	5.8%	5.5%	6.1%
Net Domestic Product		3.5%	4.5%	2.7%	5.9%	5.6%	6.1%
Per capita NDP		1.3%	2.5%	0.4%	3.9%	3.4%	4.3%
Per Worker NDP		1.3%	2.7%	0.3%	3.5%	3.1%	3.9%
Capital Stock		3.6%	2.8%	4.3%	5.1%	4.3%	5.9%
Capital per worker		1.4%	0.9%	1.8%	2.7%	1.8%	3.6%
Population		2.1%	1.9%	2.3%	1.9%	2.1%	1.7%
Pop 15 to 64		2.2%	1.9%	2.4%	2.3%	2.5%	2.1%
Rainfall deviation from mean		0.5%	4.0%	-2.7%	-1.8%	-1.7%	-1.9%
<u>Total Factor Productivity Growth</u>							
TFPG0		0.7%	1.6%	-0.1%	2.4%	2.4%	2.4%
TFPG1		0.9%	1.6%	0.2%	2.7%	2.6%	2.8%
TFPG1hp (HP filtered tfpg)		1.0%	1.4%	0.6%	2.5%	2.3%	2.7%
TFPGs (share=0.26)		0.9%	2.1%	-0.2%	2.8%	2.6%	3.0%
<u>Contribution to gr of NDPpwrk</u>							
TFPG0		0.58	0.68	-0.21	0.68	0.77	0.61
Capital per worker		0.45	0.16	2.72	0.34	0.25	0.00
Rainfall deviation from mean		-0.03	0.16	-1.51	-0.02	-0.02	-0.02
TFPG1		0.67	0.68	0.57	0.76	0.83	0.71
Capital per worker		0.36	0.13	2.14	0.26	0.20	0.32
Rainfall deviation from mean		-0.03	0.19	-1.70	-0.02	-0.03	-0.02
Impact of CG import on		1.3%	1.3%	1.3%	2.2%	2.0%	2.5%
TFPG1		1.4	0.62	-7.2	0.80	0.76	0.83

Source: NAS and authors estimates

6 DETERMINANTS OF TFPG

A simple regression of the ratio of fixed investment in machinery & equipment to total fixed investment (Ifme/IF) on TFPG yields a highly significant co-efficient:

$$\text{Equation 12: } \text{TFPG1} = 0.044 \text{ Ifme/IF} - 0.17 * \text{GrXRreal} - 0.271 \text{ AR}(1)$$

$$\begin{matrix} (7.8)*** & (-2.77)*** & (-2.3)** \end{matrix}$$

$$R^2 = 0.27, R^2 (\text{adj}) = 0.24, \text{DW} = 2.1$$

GrXRreal is the rate of change of the real exchange rate (measured by ratio of Implicit GDP deflator for tradable goods/non-tradable services). Thus investment in machinery & equipment seems to have a productivity enhancing effect in India.²² Drainm and drainm(-1) are not significant when introduced into this equation for TFPG as expected, as we have taken account of these in calculating TFPG1 (& tfpg0).²³ Similar results are obtained if the dependent variable is Kfme/kf or if the independent variable is TFPG0.

Using the co-efficient of 0.044 we can estimate the impact of machinery and equipment investment on TFPG1. Thus machinery and investment was responsible for an average 0.18% point, 0.15% point 0.32% point and 0.35% point of TFPG in the sub-phases IA, IIA and IIB respectively.²⁴ Thus the contribution of machinery and equipment investment to TFPG growth increased from phase I to phase II. The contribution of the real exchange rate was a fraction of this except in sub-phase IB when an appreciation reduced TFPG by 0.13% point thus nullifying the contribution of machinery investment. Appreciation reduced the TFPG by 0.05% point and 0.06% point in IIA & IIB respectively.

From Equation 11 we know that the dummy for 1965-6 to 1980-1 has a significant effect on TFPG.²⁵ Introducing this into the above equation we have,

²² The inverse equation shows that tfpg1 has an insignificant effect on the ratio of equipment to investment.

²³ Though Ifme_if and Kfme_kf are also significant when introduced into the production equation Equation 8 the co-efficient of capital stock becomes insignificant.

²⁴ As capacity utilisation data is unavailable, the capital series represents installed (and not utilised) capacity.

²⁵ When crude oil price growth is introduced into this equation its co-efficient of -0.0147 is significant at the 5% level ($R^2(\text{adj})=0.29$). However it becomes non-significant when D6580 is added. Further the same variable is not significant in the production function. This suggests that the oil price increases of 1971 & 1979 interacted with other policies to produce the negative effect of oil price increase on TFPG.

$$\text{Equation 13: } \text{TFPG1} = -0.01 \text{ D6580} + 0.05 \text{ Ifme/IF} - 0.17 * \text{GrXRreal} - 0.35 \text{ AR}(1)$$

$$\begin{matrix} (-2.5)** & (8.9)*** & (-2.7)*** & (-2.8)*** \end{matrix}$$

$$R^2 = 0.35, R^2 (\text{adj}) = 0.31, \text{DW} = 2.1 .$$

The co-efficient on Ifme/Ifixed is marginally higher than in **Equation 12** but similar.²⁶ Thus in addition to import controls and import substitution policies that affected machinery investment and the real exchange rate, TFPG was reduced by 1% point during 1965-6 to 1980-81 due to other policies. In other words approximately 1.1% point of the 1.45% (0.77%) point decline in TFPG1 (TFPG1hp) during sub-phase IB is explained by **Equation 13** (last 2 lines of **Table 1**).

One possibility is that the other policies captured by the dummy worked to reduce capacity utilisation. This is suggested by the rise in the co-efficient on machinery investment on introduction of the dummy and the doubling of the rate of growth of capital per worker during sub-phase IB. The policies introduced during this phase could for instance have reduced the rate of capacity utilisation through the following channels: (a) Rise in import duties leading to higher prices paid by consumers for domestic consumer goods and consequent reduction in consumer demand. (b) Higher (income/excise) taxation and consequent reduction in personal disposable income. (c) Over-investment by government in the production of goods and services for which there was no demand from the private sector.²⁷ This is the sub-period of “Legislative-Bureaucratic socialism” that Virmani (2004a) called the “Socialist Rate of Growth (SRG) period in which GDP growth plummeted.

²⁶ If Ifme_if is replaced by kfme_kf , R² and R² (adj) are marginally greater. Similar results are obtained if TFPG0 is used instead of TFPG1.

²⁷ Purchase and price preference tried to generate demand for such goods and services from other public sector units, but this was perhaps not sufficient

7 SECTOR PRODUCTIVITY TRENDS

7.1 Phase I

The TFPG estimates for the sectors are summarised in period averages (shown in tables below) and also presented in the figures below in the form of filtered (using Hodrick-Prescott filter) series.²⁸ The pattern of TFPG decline in the aggregate series is most clearly mirrored in the TFPG for Other services ('Finance, Real estate, housing & business services' and 'Community services & Government administration') sector and Trade & Hotels (Figure 8). Except for an initial rise and peak in the TFPG in Trade et al, the three series decline till the early seventies, with Trade reaching a trough in 1971-72, aggregate in 1972-3 and Other-services in 1975-76. The TFPG for trade & hotels however falls much more sharply and becomes negative and then recovers equally sharply. This suggests problems relating to capacity utilisation perhaps arising from the negative effect of government appropriating resources from the private individuals and thus having a negative effect on demand for services. The pattern of growth in private consumption is found to mirror that in the aggregate TFPG series with the former reaches a trough in 1970-71(Figure 8), providing support to this hypothesis.

TFPG in Agriculture follows a somewhat similar pattern to aggregate TFPG except that the trough occurs early around 1961-2 and there is an additional peak in 1969-70. TFPG in all other sectors is initially negative and becomes positive in the sixties or seventies (Figure 9 & Figure 10). The negative TFPG in the early fifties could be due to a sudden discontinuous spurt in government investment, which because of a combination of gestation lags and excessive capacity build-up (not being motivated by profitability/efficiency considerations) initially resulted in very low capacity utilisation. Longer lifetime assets (with lower depreciation rate), would also tend to show lower measured productivity in initial years and higher measured productivity in later years.²⁹

²⁸ The TFPG for NDP differs from the earlier estimate TFPGs because the labour series is different.

²⁹ It could also be due to an underestimate of net capital stock in 1951 by the CSO, NAS, DOS, GOI that we use as the initial capital stock for constructing our series.

Figure 8: Total Factor Productivity By Sector-HP filtered Series 1

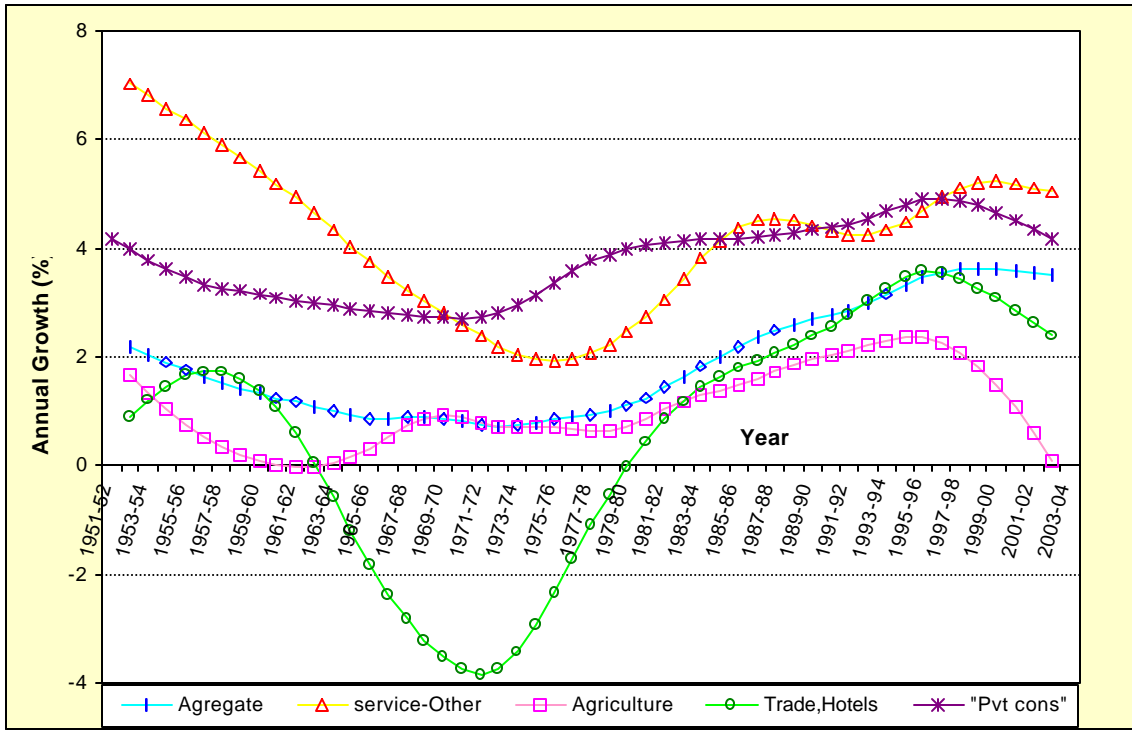


Figure 9: TFGP By Sector -HP filtered series 2

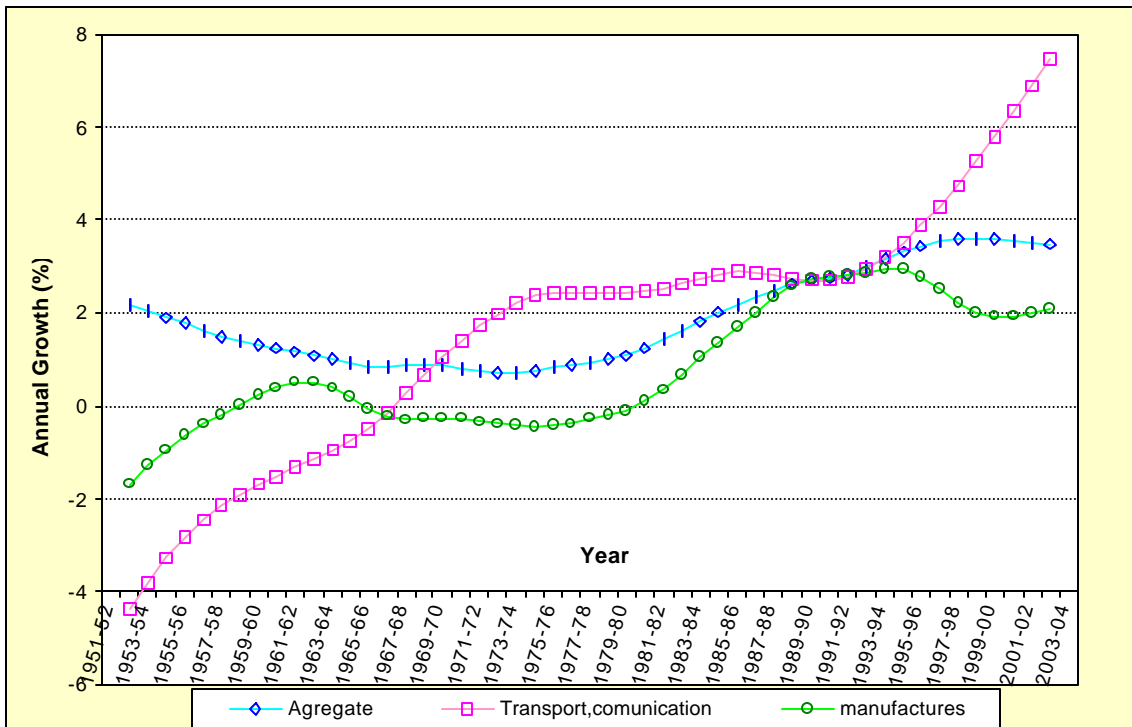
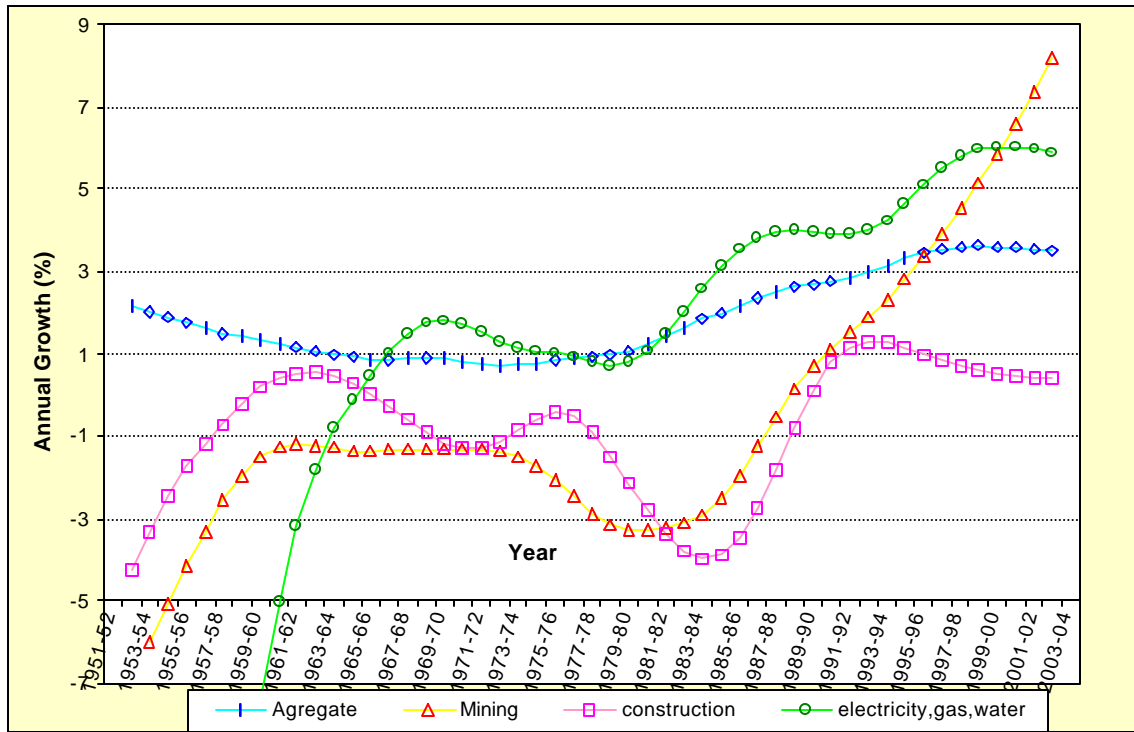


Figure 10: Total Factor Productivity By Sector-HP filtered Series 3



These factors seem to be responsible for the negative TFPG in electricity, mining and transport (road, rail) & communications and construction during the first decade of independence as there was a rapid increase in investment during this period. But this also means that actual TFPG was even lower during sub-phase IB (1965-6 to 1979-80) than our estimates because of the effect of gestation lags and longer lifetime arising from investment in sub-phase IA. Put another way, given the sharp slowing of investment in sub phase IB neglect of these two factors would mean that TFPG is overestimated.

As long as sector TFPG is negative it clearly pulls down aggregate TFPG. TFPG in Transport-communications and electricity generally follow a rising trend with intervening plateau. The trend TFPG in Manufacturing, Mining and Construction made a trough at a negative value in 1974-75, 1979-80s and 1983-84 respectively, after which TFPG rose. The electricity sector has also been on a rising trend since 1978-79.

The TFPG trend (HP filtered series) for manufacturing was positive for only 8 out of the 30 years from 1950-1 to 1979-80 (phase I) mostly during sub-phase IA. According to the unfiltered series TFPG averaged 0.4% in sub-phase IA and -0.3% in phase I as a whole. It was therefore effectively zero during this period of “Socialism with an Indian face,” characterised by the Mahalanobis model of state led heavy industry (machines for making machines) complemented by small-scale industry reservation.³⁰

Given this pattern of TFPG trends in Phase I (1950-1 to 1979-80), TFPG was negative in all sectors except agriculture and the residual sector ‘Other services’ (Table 2). While agriculture TFPG was positive in sub-phase IA alone, TFPG in ‘Other services’ grew strongly in both phases. As a result TFPG was the sole cause of growth of other-service during sub-phase IB, overcoming even some capital shallowing. In sub-phase IB TFPG was responsible for 85% of the growth with the result that during phase I as a whole TFPG contribution was more than 100%. Given the size of these two sectors, this was sufficient to ensure that aggregate TFPG was positive, with a little help from a positive TFPG in ‘Manufacturing’ and ‘Trade, Hotels & Restaurants’ in sub-phase IA and a positive TFPG in ‘Electricity, Gas & Water’ and ‘Transport and communications’ in sub-phase IB.

³⁰ I.e. data limitations do not allow us to distinguish TFPG from zero..

Table 2: Total Factor Productivity by Sector

Sector	Phase	I: 1950-1 to 1979-80			II: 1980-1 to 2003-4		
	Sub-phase K share	Total	IA:1950-1 to 1964-5	IB:1965-6 to1979-80	Total	IIA:1980-1 to 1991-2	IIB:1992-3 to 2003-4
		<u>Total factor productivity growth</u>					
GDPfc: Total	0.26	0.9%	1.9%	0.1%	3.0%	2.5%	3.6%
Agriculture	0.23	0.2%	1.0%	-0.5%	2.1%	2.2%	2.1%
Mining	0.36	-3.1%	-4.3%	-2.1%	2.0%	-0.2%	4.3%
Manufacture	0.32	-0.3%	0.4%	-0.8%	2.0%	1.3%	2.8%
Electricity	0.58	-7.6%	-17.0%	0.6%	4.4%	4.1%	4.7%
Construction	0.16	-0.9%	-0.7%	-1.1%	-0.7%	-1.7%	0.3%
Trade, hotels	0.38	-1.0%	1.3%	-3.0%	2.6%	1.6%	3.6%
Transprt, comn	0.33	-0.2%	-2.1%	1.5%	3.8%	2.8%	4.9%
Service Other	0.23	4.0%	5.8%	2.4%	4.4%	4.1%	4.7%
		<u>Growth rate of NDP per worker</u>					
GDPfc: Total		1.1%	1.9%	0.5%	4.1%	3.3%	5.0%
Agriculture		0.0%	0.4%	-0.4%	2.5%	2.5%	2.6%
Mining		0.9%	1.2%	1.0%	3.8%	2.0%	5.7%
Manufacture		1.6%	3.6%	0.2%	3.9%	3.1%	4.8%
Electricity		5.2%	7.0%	4.3%	7.6%	6.4%	8.9%
Construction		0.4%	2.7%	-0.7%	-0.7%	-1.8%	0.6%
Trade, hotels		1.6%	4.6%	-0.8%	2.5%	1.8%	3.3%
Transprt, comn		1.2%	1.1%	1.6%	3.7%	2.6%	4.8%
Service Other		3.5%	5.1%	2.0%	4.7%	4.1%	5.4%
		<u>Contribution of sector TFPG to Sector growth</u>					
GDPfc: Total		0.26	0.41	0.04	0.52	0.46	0.59
Agriculture		0.05	0.21	-0.18	0.36	0.39	0.34
Mining		-0.88	-0.93	-0.75	0.34	-0.03	0.69
Manufacture		-0.07	0.09	-0.30	0.35	0.24	0.46
Electricity		-2.13	-3.69	0.22	0.76	0.76	0.76
Construction		-0.25	-0.15	-0.38	-0.12	-0.30	0.05
Trade, hotels		-0.29	0.28	-1.08	0.44	0.29	0.58
Transprt, comn		-0.05	-0.45	0.52	0.65	0.50	0.80
Service Other		1.11	1.25	0.85	0.76	0.75	0.77

Note: TFPG for GDPfc differs from that in table 1 because of difference in methodology.
Capital income shares are average values of shares given in Brahmananda.

There was massive decline in factor productivity in the electricity sector in sub-phase IA and a substantial decline in productivity in the mining sector in both sub-phases. Both these sectors were reserved for the government and the share of public sector in total GDP from these sectors went up to 100% in electricity and about 97% in mining by the end of phase I. Gestation lags in investment may have been partly responsible for the mismatch between investment and output, especially in electricity. The government may also have built capacity too far ahead of potential demand on the assumption that supply would create demand through general development (Mahalanobis model!).³¹ The net result, as in the former USSR, was that nationalisation of these sectors had a negative effect on TFPG even though GDP from these sectors continued to grow due to capital deepening and expansion of manpower.

The negative TFPG growth in Manufacturing and in Trade, Hotels & Restaurants in sub-phase IB could have been due to the following: (a) Declining capacity utilisation. (b) Use of inferior domestic (import-substituting) capital goods consequent to imposition of QRs. (c) Use of inferior imported capital goods from the rupee payment areas (Soviet Union, E Europe) which were exempt from QRs/bans applicable to import of capital goods from convertible currency areas. The negative TFPG growth in 'Transport and Communications' in sub-phase IA was due partly to the government monopoly of the railways and communications and partly to the above reasons.

In phase I as a whole TFPG growth in sectors (Table 3 based on Equation 7) was responsible for about 17% of overall TFPG growth with other services being the main contributor (56%). The remaining TFPG growth was the result of a shift of factors from agriculture (33%) and Other-services to all other sectors [Trade & hotels (43%), Manufactures (34%) and construction (20%)]. In sub-phase IA TFPG growth in sectors was responsible for almost 60% of total TFPG with agriculture (27%) and other services contributing almost equally (33%). The remaining contribution came from a shift of factors out of agriculture and other services to the remaining sectors.

³¹ A modified/dynamic version of Says law.

Table 3: Contribution of Sector TFPG and TFI to Overall TFPG

Sector	IA: 1950-1		IB:1965-6	IIA:1980-1		IIB:1992-3
	I: Total	to 1964-5	to 1979-80	II: Total	To 1991-2	to 2003-4
Contribution of sector (tfpg+tfi) to total tfpg						
Agriculture	-36%	15%	-11%	6%	13%	2%
Mining	2%	2%	0%	2%	4%	1%
Manufacture	30%	22%	2%	16%	15%	17%
Electricity, gas,water	2%	0%	0%	2%	3%	1%
Construction	11%	11%	0%	5%	4%	5%
Trade,hotels,restaunt	25%	18%	2%	20%	14%	23%
Transprt, comnication	11%	3%	2%	13%	8%	15%
Rest: Other services	48%	25%	5%	37%	39%	36%
Total	94%	96%	0%	100%	99%	100%
Contribution of sector TFPG to Total TFPG						
Agriculture	0%	27%	-5%	21%	31%	16%
Mining	-7%	-4%	-1%	2%	0%	3%
Manufacture	-4%	4%	-2%	10%	8%	11%
Electricity, gas,water	-3%	-3%	0%	2%	2%	2%
Construction	-8%	-2%	-1%	-1%	-5%	0%
Trade,hotels,restaunt	-18%	7%	-5%	13%	9%	15%
Transprt, comnication	1%	-3%	1%	9%	6%	10%
Rest: Other services	56%	33%	5%	33%	33%	32%
Total	17%	59%	-9%	87%	84%	88%
Contribution of inter-sector TFI allocation						
Agriculture	-36%	-11%	-5%	-16%	-18%	-14%
Mining	9%	6%	1%	1%	4%	-1%
Manufacture	34%	18%	3%	6%	7%	6%
Electricity, gas,water	4%	3%	0%	0%	1%	0%
Construction	20%	12%	2%	6%	9%	4%
Trade,hotels,restaunt	43%	11%	7%	7%	5%	8%
Transprt, comnication	11%	6%	1%	4%	2%	5%
Rest: Other services	-8%	-8%	0%	4%	6%	4%
Total	77%	37%	8%	13%	15%	12%

Note: * TFPG for sub-phase IB is close to zero, so numbers have not been divided by it.

If we look at the full (TFPG + TFI share) contribution of each sector to total TFPG, Other service is the largest contributor (I: 48%, IA: 25%) but is followed by manufacturing (30%, 20%) and Trade, Hotels & Restaurants (25%, 18%). In phase IB the total TFPG is so small that it is difficult to be sure about the relative contributions (Table 3, column 3).

7.2 Phase II

Since 1980-81 TFPG was negative only in mining and construction till 1987-8 and 1988-89 respectively (Figure 8, Figure 9 & Figure 10). TFPG trend in every sector except construction (which bottomed out in 1984-5) was rising, with the trend in most sectors peaking between 1992-3 and 1999-2000. The aggregate TFPG also peaked then. The first sector TFPG to peak was construction at 1.3% in 1992-3, followed by manufacturing TFPG at 3% in 1993-4, agriculture TFPG at 2.35% in 1994-5, Trade-hotels at 3.6% in 1995-6, and electricity (6%) and other-services (5.2%) in 1999-2000. TFPG in mining (8.2%) and transport-communication (7.5%) is however still on an accelerating trend as of 2002-3 with the latter driven primarily by the communication sub-sector. In the case of mining the share of the public sector in GDP and in GCF has been on a downtrend since the late 1980, so that entry of the private sector could have contributed to rising TFPG. In the case of the communication sector, policy and regulatory reform starting with the opening of the sector to private entry and competition arising from the introduction of divisible mobile technologies has clearly fuelled TFPG and Value added growth.³²

Construction is the only sector in which average TFPG was negative during phase II (1980-1 to 2002-3). Its performance has been abysmal. Much of construction is either carried out by government or procured by government. The procurement standards and procedures adopted by the government therefore play a vital role in the evolution of the construction industry. These standard and procedures have not been changed since independence so that the industry has been stuck in a time warp. As noted in Virmani

³² Virmani (2004c) describes Telecom reform as the second most successful reform (after external sector reform) during the nineties.

(2004b), there is an urgent need to modernise procurement and other policies related to the construction sector.

Between Phase IB (1965-6 to 1979-80) and IIA (1980-1 to 1991-2) TFPG accelerated most sharply in Trade & hotels and electricity sectors and least in construction. Transport & communications and Other services, however continued to have above average growth of TFPG during phase IIA and IIB with the former accelerating sharply in IIB and the latter also improving from its high levels.

During phase II, the contribution of sector TFPG to the same sector's GDP per worker ranged from a low of around 35% in mining, manufacturing and agriculture to 76% in 'electricity, Gas & water' and 'Other services.' The rest was contributed by capital deepening.³³ For both electricity and other services the contribution of sector TFPG to sector's GDP per worker remained at around 75% in both sub-phases (IIA & IIB). While in agriculture it varied around 36%, it increased from phase IIA to IIB), in manufacturing (24%, 46%), Trade, Hotels & Restaurants (29%, 58%) and Transport, Storage & communications (50%, 80%).

The contribution of sector TFPG to aggregate TFPG increased sharply during phase II to 87% from the 17% average during phase I and 59% during sub-phase IA. The greatest increase in contribution was in Trade-hotels, followed by Agriculture and Manufacturing. The average contribution of TFPG in Other-services declined sharply, but it remained the largest contributor to aggregate TFPG. The contribution of all other sectors increased by small amounts. Inter-sectoral shifts in factors contributed only 13% to aggregate TFPG during phase II (table 3).

The contribution of sector TFPG was marginally lower in sub-phase IIA (84%) and marginally higher in sub-phase IIB (89%). Compared to Sub-phase IIA, IIB also saw a smaller contribution from TFPG in agriculture, and a larger contribution from TFPG in Trade-hotels, construction, transport-communications, manufacturing and mining. In other words the sector TFPG contributions were more evenly distributed in sub-phase IIB even though other-services continued to contribute a little less than 33% (Table 3).

³³ We are unable to make adjustment for the effect of rainfall on production because of data limitations.

TFPG in agriculture has declined sharply during the second half of the nineties (Figure 8). Among the potential reasons for this sharp decline are: (a) The deterioration in the fertiliser (NPK) mix because of price distortions arising from subsidies for urea. (b) Lowering of water table due to inadequate public attention to developing and maintaining water systems for regenerating underground water and optimal utilisation of surface water. (c) Over-exploitation of under-ground water because of provision of free electricity by the State. (d) Deteriorating R&D and extension systems. This highlights the urgency of reforming policies relating to the entire food chain starting from production to retailing (Virmani and Rajeev (2002), Virmani (2004b)).

The trend growth of TFPG has, after rising to 2.5% per annum in the mid-nineties, regressed to 2% per annum. This is less than the aggregate TFPG estimated in the first part of the paper and is significantly lower than TFPG estimated by applying exogenous capital shares and ignoring rainfall effects. Thus manufacturing, instead of acting as a driver of overall TFPG currently appears to be acting as a drag. Economic reforms related to labour intensive manufacturing should be accelerated to raise TFPG and global competitiveness of this tradable sector.³⁴

³⁴ See for instance Virmani (1999), Virmani (2000), Virmani (2004b) for a discussion of required reforms.

8 CONCLUSION

Since independence trend growth of Gross domestic product (GDP) and Net domestic product (NDP) has gone through one complete cycle (growth cycle) with a trough in 1971-72 and a peak in 1994-95. The trend started at around 4.8% per annum in 1951-2 and is currently around the same level. The trends in growth of NDP per capita and NDP per worker were almost identical. This paper uses the source of growth methodology to explain this growth cycle. It shows that Total factor productivity growth followed a V shaped pattern between 1951-2 and 1985-86 with the tip of the V in the year 1971-2. Since the mid-nineties TFPG has flattened out with a gently rising trend. Growth of Net domestic product per worker also follows a V shaped pattern but peaks much later in the mid-nineties and turns down thereafter instead of plateauing out. The pattern of capital deepening (growth of capital per worker) in contrast is quite different, with two almost complete cycles. The first peak occurs in 1965-6 and the second one in 1998-9 to 1999-2000, three years after the peak in growth of per worker NDP.

The contribution of total factor productivity growth to growth of Net Domestic Product per worker (net of effects of variations in rainfall) consequently fell progressively from 85% in 1951-2 to a little over 25% in 1991-92. The contribution has risen sharply since then to almost 50% (a level it last had around 1975-6). The contribution of capital deepening (growth of capital per worker has followed the inverse pattern.³⁵

The paper then goes on to link the TFPG estimates to the analysis of growth and policy structures given in Virmani (2004a). It shows that the collapse of GDP/NDP growth during the sub-period 1965-6 to 1979-80 (sub-phases IB) was due substantially to a sharp fall in total factor productivity growth. Half the decline in growth between sub-phase IA and sub-phase IB was because of the decline in TFPG and the rest because of poor rainfall. The paper also shows that the recovery of growth during 1980-1 to 1991-2 (sub-phase IIA) was due to an increase in TFPG to 1.6 times the level prevailing in 1951-

³⁵ With the effect of rainfall purged, the two contribution must add up to one even though the smooting process may not produce the precise result (i.e. adding up to 100 %)

2 to 1964-5 (sub-phase IA) coupled with a doubling of per worker NDP growth relative to IA. A change of policy direction from an immersion in the Indian version of socialism towards market economics has been responsible for the acceleration in both these sources of growth.

Formal econometric analysis shows that investment in machinery (relative to investment in structures) and changes in protection (through QRs and tariffs) played an important role in the rate of growth of total factor productivity. It is shown that the ratio of machinery to total investment and the rate of change in the real exchange rate (ratio of tradable/goods prices to non-tradable/service prices) have significant effect on TFPG and explain about 25% of the variation in it. Other policies prevailing during 1965-6 to 1979-80, captured by a dummy variable, explain another 5-10% of the variation in TFPG during the entire period from 1951-2 to 2003-4.

The paper goes on to estimate total factor productivity for all major sectors of the economy for which data on workers is available. This allows us to examine the relative contribution of TFPG and capital deepening to per worker growth in each sector. The TFPG estimates are also used to estimate the contribution of each sector's total factor productivity growth and capital deepening to growth of aggregate TFPG. It is shown that the contribution of sector TFPG to aggregate TFPG increased from 17% during 1951-2 to 1979-80 (phase I) to 87% in 1980-1 to 2003-4 (phase II). The greatest increase in contribution was in 'Trade, hotels & restaurants' followed by agriculture and manufacturing. TFPG in 'Other services (financial, real estate, housing, business, personal and govt services) remained the largest contributor to aggregate TFPG (though the change in it was small). Further, more detailed, work needs to be done to identify the productivity drivers in the service sectors.

9 APPENDIX

As most previous studies and global comparisons are in terms of decades we summarise below our estimates of TFPG by decade. The most different result is the positive TFPG for the 1970s using the HP filtered series. This is perhaps because the filtering procedure eliminates temporary fluctuations in capacity utilisation that are not accounted for in the estimation procedures used so far.

Table A1: Sources of Growth in Net Domestic Product

Variable	Decade* =>	1950s	1960s	1970s	1980s	1990s	2000s
Net Domestic Product		3.9%	4.0%	2.8%	5.9%	5.8%	5.7%
Per Worker NDP		2.0%	1.7%	0.2%	3.5%	3.5%	3.4%
Capital per worker		0.4%	2.2%	1.4%	1.6%	3.3%	4.1%
Workers (pop 15 to 64)		1.8%	2.1%	2.5%	2.5%	2.2%	2.0%
Rainfall deviation From mean		3.4%	-1.4%	-0.1%	-2.1%	1.2%	-8.6%
Total Factor Productivity Growth							
TFPG0		1.4%	1.1%	-0.2%	2.8%	2.0%	2.2%
TFPG1		1.4%	1.3%	-0.1%	3.0%	2.3%	2.7%
TFPG1hp		1.7%	0.8%	0.7%	2.2%	2.6%	2.7%
Contribution to gr of NDPpwrk							
TFPG1		0.70	0.76	-0.33	0.84	0.66	0.79
Capital per worker		0.07	0.42	2.21	0.15	0.32	0.41
Rainfall deviation from mean		0.23	-0.18	-0.88	0.01	0.02	-0.21

Notes: * Data for 2000s is only for 4 years.

Workers=Pop15 to64

Source: NAS and authors estimates

The share of workers in different sectors and the number of workers (usual status) in each sector are available only for specific years (of which we have chosen eight). We then used our NDP and fixed capital estimates for all sectors to calculate the total factor productivity. The growth rates used in the estimation of TFPG are compound annual rates for each period. These are shown in the first panel of table A2.

Table A2: Total Factor Productivity Growth

Sector	K share	1951 to	1961 to	72-3 to	77-8 to	1983 to	87-8 to	93-4 to
		1961	1972-3	1977-8	1983	1987-8	1993-4	1999-00
<u>Compound average annual (original worker data)</u>								
All: GDPfc	0.26	1.6%	0.6%	1.8%	0.9%	1.4%	2.7%	4.3%
Agriculture & allied	0.23	0.6%	-0.2%	2.4%	0.3%	-1.0%	2.5%	2.6%
Mining & Quarrying	0.36	-4.2%	-1.7%	-1.1%	-4.2%	-4.0%	2.1%	5.1%
Manufacturing	0.32	-0.5%	0.2%	-1.0%	0.3%	0.6%	2.6%	2.2%
Electricity,gas,water	0.58	-18.1%	-0.2%	0.1%	-1.1%	6.8%	1.0%	8.6%
Construction	0.16	-1.4%	-1.2%	3.6%	-5.1%	-9.0%	4.9%	-0.3%
Trade, hotels etc	0.38	1.8%	-3.3%	-1.7%	1.2%	1.0%	2.1%	4.3%
Trnsprt, Strg, Comn	0.33	-2.5%	0.3%	2.0%	1.8%	5.2%	1.8%	4.7%
Services-other	0.23	6.0%	3.6%	1.5%	2.4%	6.0%	3.4%	6.1%
<u>Average of calculated annual Rates</u>								
All: GDPfc	0.26	1.6%	0.7%	1.9%	1.0%	1.4%	2.8%	4.3%
Agriculture & allied	0.23	0.7%	0.0%	2.7%	0.7%	-1.0%	2.7%	2.7%
Mining & Quarrying	0.36	-4.4%	-1.7%	-1.0%	-4.1%	-3.8%	2.2%	5.1%
Manufacturing	0.32	-0.5%	0.3%	-1.0%	0.5%	0.6%	2.7%	2.4%
Electricity,gas,water	0.58	-20.7%	-0.1%	0.6%	-0.9%	6.9%	1.3%	8.6%
Construction	0.16	-1.2%	-1.1%	3.9%	-4.9%	-9.0%	4.9%	-0.3%
Trade, hotels etc	0.38	1.8%	-3.3%	-1.7%	1.2%	1.0%	2.1%	4.4%
Trnsprt, Strg, Comn	0.33	-2.5%	0.4%	2.1%	1.8%	5.2%	1.8%	4.8%
Services-other	0.23	6.0%	3.6%	1.5%	2.4%	6.0%	3.5%	6.2%

Source: NAS, Krishnamurthy(1970), Sundaram(2001), Visaria(2002) and authors estimate.

Note: Based on estimates of Worker (UPSS)

We have constructed the time series for the sector distribution of workers by linear interpolation of the sector shares between these eight years (and also extrapolated it into the future). The time series for the aggregate work force is constructed as follows: For the chosen eight years the ratio of workers to working age population (age 15 to 64) is constructed. The ratio is constructed for all relevant years through linear interpolation and extrapolation. The constructed ratio is then used along with the time series for working age population (World development Indicators) to obtain total number of workers (us) in every year. These are then used along with interpolated sector distribution of workers to calculate the number of workers (us) in each sector in every time period. This along with the series for NDP and fixed capital for each sector allows us to estimate TFPG for each sector for each year.

As a crosscheck we average these for the time period for which TFPG has been estimated using compound annual growth rates between the eight data points. These values are shown in the second panel of table A2. For instance the TFPG for aggregate

GDP during the period 1951 to 1961 was 1.6% per annum both by the compound annual average method and by averaging the annual TFPG obtained through interpolation of worker series. In contrast, the TFPG for the electricity sector between 1972-3 and 1977-78 is 0.1% per annum by the compound method and 0.6% per annum (or almost six times) by interpolation method. Overall, except for a few sectors and periods the two sets of TFPG estimates are quite close.

The decade averages for the annual estimates by sector are summarised in the appendix table A3.

Table A3: Total Factor Productivity Growth

Variable	Period =>	1950s	1960s	1970s	1980s	1990s	2000s
All: GDPfc		1.5%	1.4%	0.0%	3.0%	3.1%	3.1%
Agriculture & allied		0.6%	0.8%	-0.8%	2.8%	2.0%	0.2%
Mining & Quarrying		-5.7%	-0.9%	-3.3%	-0.6%	3.0%	6.9%
Manufacturing		-1.1%	0.7%	-0.6%	2.2%	1.4%	3.6%
Electricity, Gas & Water		-27%	0.7%	-0.1%	4.1%	4.6%	4.6%
Construction		-2.0%	0.5%	-1.4%	-3.2%	1.5%	0.4%
Trade, Hotels, etc		1.3%	-0.8%	-3.1%	2.1%	3.1%	2.1%
Transport, Strg, Comn		-2.8%	-0.4%	2.1%	3.0%	3.5%	7.2%
Services-other		6.2%	4.0%	2.1%	4.5%	4.6%	3.3%

Note: Based on estimates of Workers (UPSS)

According to this break up, aggregate and sector TFPG growth was the worst during the seventies, consistent with the available studies. The negative TFPG results for so many sectors in the 1950s however contradicts the results of Brahmananda. The results for the 1990s and 2000s are also new, though the latter are very tentative.

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