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A Total Factor Productivity-Capital Accumulation Hypothesis of India's Growth Transitions

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Abstract

This paper re-examines the role of physical capital accumulation in the Indian economy over the period 1953-2010. As an alternative to the orthodox total factor productivity (TFP) view, the paper develops a combined TFP-capital accumulation hypothesis of growth transitions. The results show that the first phase of India's faster-growing regime during 1980-2002 was mainly TFP driven. However, the large increase in uninvested profits accumulated during the first phase together with evidence of a sharp rise in the productivity of capital and an exogenous saving/investment rate implies that India had a significant amount of untapped *long-run* growth potential. Consistent with the prediction of the model, the growth surge experienced during 2003-2007 reflects the capital accumulation-driven part of the growth transition. Despite the turbulent years of the global financial crisis since 2008, the analysis suggests that physical capital accumulation will continue to be a driving force of India's future growth performance.

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Keywords: physical capital accumulation, total factor productivity, Solow model, learning by doing model, growth, India, technical progress function

JEL classification codes: C22, O4, O5, O41, O53,

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1. INTRODUCTION

From the comprehensive surveys in Bond *et al.* (2010), Easterly and Levine (2001) and Helpman (2004), it is apparent that there is an influential body of literature that views physical capital accumulation as a relatively unimportant determinant of a country's growth and development performance. For example, Blomström *et al.* (1996) and Attanasio *et al.* (2000) show that per capita output growth Granger-causes investment, whereas Carroll and Weil (1994) find causality from growth to saving. These studies show that physical capital accumulation is the outcome rather than the underlying cause of growth. In addition to endogeneity issues, the small share of capital in total income of around one-third in national accounts has often been cited as evidence against the physical capital accumulation hypothesis in explaining large differences in per capita income levels across countries (Easterly and Levine, 2001; Hall and Jones, 1999; Romer, 2006). In a more general context, the low elasticity of output with respect to capital ($\alpha = 0.33$) derived from national accounts implies that a given policy shock to the saving/investment rate will be relatively ineffective in raising per capita income. Taken together, this strand of literature attributes most of the cross-country differences in the level and growth rate of per capita income to an 'unexplained' part, which growth economists typically refer to as total factor productivity (TFP), rather than physical capital accumulation.

Consistent with the orthodox TFP view in the growth literature, Madsen, Saxena, and Ang (2010) (hereafter MSA) downplay the importance of physical capital accumulation in India on the basis of three empirical observations/findings over the period 1950-2005. First, movements in India's saving rate have not coincided with increasing productivity growth rates. Second, the factor accumulation hypothesis predicts that the growth rate in the capital-labour ratio precedes labour productivity growth. In contrast, MSA provide evidence of reverse causality from labour productivity growth to capital accumulation. Third, by using capital's share in total income of 0.30 as a proxy for the productivity of capital, MSA's growth accounting exercise shows that TFP growth rather than capital per worker growth accounts for the bulk of per capita income growth in the Indian economy. In an attempt to explain India's large 'unexplained' (TFP) part of growth, MSA provide empirical evidence of a technology-driven model, which is consistent with the predictions of Schumpeterian growth theories developed in Aghion and Howitt (1998).

MSA's finding of a negligible growth effect of physical capital accumulation in the Indian economy is not unambiguous. Felipe et al.'s (2008) growth accounting exercise shows that the differential growth performance between China and India during the 1980s and 1990s can largely be explained by different rates of physical capital accumulation. To match China's extraordinary growth performance since the late 1970s, the authors advise India to address several supply constraints on aggregate investment spending.

The main purpose of this paper is to re-examine the role of physical capital accumulation in the Indian economy. As its basic starting point, the analysis follows the central theme in Rodrik and Subramanian (2005) and a growing number of recent studies, and highlights the importance of India's growth transition in 1980[1]. In this framework, the 1980s 'policy shift' hypothesis explains what *ignited* India's growth transition, whereas the sweeping reforms during the post-1990 liberalisation period explain what *sustained* the initial growth shift. In effect, as will be shown more formally in Section 2, India's growth experience over the period 1953-2010 can broadly be characterised by three regimes: (1) a slow-growing regime during 1953-1978; (2) a fast-growing regime during 1980-2002; and (3)

[1] In addition to Rodrik and Subramanian's (2005) influential paper, several subsequent studies have also identified the period in or around 1980 as a major turning point in India's growth performance (see Balakrishnan and Parameswaran, 2007; Nell, 2012, 2013; and Virmani, 2006). The exact date of the growth transition, however, is not uncontroversial (see Basu, 2008; Ghate and Wright, 2012; MSA, 2010; Panagariya, 2005, 2008; and Sen, 2007). Section 5 re-examines the relevance of these competing views in light of the empirical results obtained from the growth model developed in section 3 of this paper.

a faster-growing regime during 2003-2007. The turbulent years (2008-2010) of the global financial crisis and outlying growth in 1979 are excluded from the sample.

Within India's three-regime framework, the paper uses Kaldor's (1957, 1961) technical progress function analysis together with some of the theoretical insights of learning by doing endogenous growth models (Romer, 1986, 1987) to re-examine the relative importance of physical capital accumulation and TFP in India's growth transitions. The analysis distinguishes between two competing theoretical paradigms: i) the orthodox TFP view, and ii) the new TFP-capital accumulation view. The orthodox TFP view refers to the large body of literature cited earlier, including MSA's (2010) study of India, which downplays the role of physical capital accumulation in the growth process due to its endogeneity and capital's small share in total income. As an alternative, this paper develops a new TFP-capital accumulation hypothesis of India's growth shifts. The novelty of this approach is that it models the role of TFP and capital accumulation in a multiple-regime framework, as opposed to the single-regime frameworks of MSA (2010) and the growth literature in general, and is therefore consistent with some of the important stylised facts of India's growth performance.

The key features of the new TFP-capital accumulation model developed in section 3 are the following. The model assumes that the economy uses capital goods with disembodied technical progress in the slow-growing regime. In the faster-growing regime, on the other hand, some of the technical progress is embodied in capital goods[2]. Based on these assumptions, the *initial* shift out of the slow-growing regime into a faster-growing regime is due to an unexplained TFP part and an explained physical capital accumulation part. The capital accumulation part of the initial growth shift is triggered by a set of policy measures that changes the composition of investment in favour of equipment investment. Greater trade

[2] Embodied technical progress means that some technical improvements can only be introduced into the productive system through new investment, whereas disembodied technical progress is independent of capital accumulation (see De Long and Summers, 1992).

openness, for example, will raise imported equipment investment relative to other types of investment and also make the domestic capital goods sector more competitive and productive (for example, see Sen, 2007). Consistent with De Long and Summers' (1992, 1993) original growth-equipment investment nexus, the change in the composition of investment raises the degree of embodied technical progress and learning by doing (also see Temple, 1998). The rise in the learning by doing parameter constitutes the capital accumulation part of the first phase of the growth transition. However, because some technical progress is also disembodied, part of the initial growth shift remains unexplained or TFP driven.

In the second phase of the faster-growing regime, physical capital accumulation in an *economy-wide* sense becomes the sole determinant of *long-run* growth. As will be shown more formally in section 3, the positive learning by doing parameter implies that aggregate physical capital accumulation – inclusive of investment in equipment and structures – determines technical progress in the second phase of the growth transition. An increase in the *total* saving/investment rate and economy-wide capital stock is therefore necessary to move the economy into an equilibrium position in the faster-growing regime. Whether firms are willing to reinvest their profits accumulated during the first phase of the growth transition will crucially depend on the domestic investment climate.

The key results of the paper can be summarised as follows. First, by excluding the global financial crisis years (2008-2010) and outlying growth in 1979 from the sample, the long-run causality results show that the total saving/investment rate is exogenous with respect to per capita income in India's slow-growing regime (1953-1978) and faster-growing regime (1980-2007). Second, the results show that there has been a large structural shift in the productivity of capital across the two regimes, which mainly resulted from an increase in private corporate equipment investment relative to other types of investment (also see Sen, 2007). More specifically, with a share of capital in total income of 0.33, the results imply that the learning by doing parameter increased from zero in the slow-growing regime to 0.50 in the faster-growing regime. Third, the first phase of India's faster-growing regime during 1980-2002 was primarily driven by TFP growth. However, the large increase in uninvested profits accumulated during the first phase of the growth transition together with the sharp rise in the productivity of capital implies that India had a significant amount of untapped *long-run* growth potential, which could have been unleashed through a faster rate of physical capital accumulation. Fourth, consistent with the prediction of the TFP-capital accumulation model, the growth surge experienced during 2003-2007 reflects the economy-wide, capital accumulation-driven part of the growth transition, following a more favourable domestic investment environment after significant reductions in administered interest rates. Overall, the results strongly support the TFP-capital accumulation view of India's growth transitions. Finally, the model suggests that a crucial precondition for India to sustain per capita income growth rates in excess of 7% in the aftermath of the global financial crisis is to maintain high aggregate saving/fixed investment rates.

The rest of the paper is organised as follows. Section 2 draws on previous research to identify several stylised facts of India's growth performance over the period 1953-2010. These stylised facts, in turn, will serve as essential background information to set up the TFP-capital accumulation growth model in section 3. Section 4 outlines the empirical hypothesis and econometric methodology. Section 5 provides an in-depth empirical test of the TFP-capital accumulation model. Section 6 concludes.

2. SOME STYLISED FACTS OF INDIA'S GROWTH PERFORMANCE: 1953-2010

This section draws on descriptive evidence and previous growth narratives to list several stylised facts of India's growth performance over the period 1953-2010. Following the advice given by Kaldor (1961) many years ago, the theorist should first look at the stylised facts and then construct an economic model that captures these broad facts in the best possible way.

2.1 India's 1980 growth transition

A salient feature of MSA's (2010) growth narrative of the Indian economy is that they indentify a permanent growth shift in the post-1990 liberalisation period:

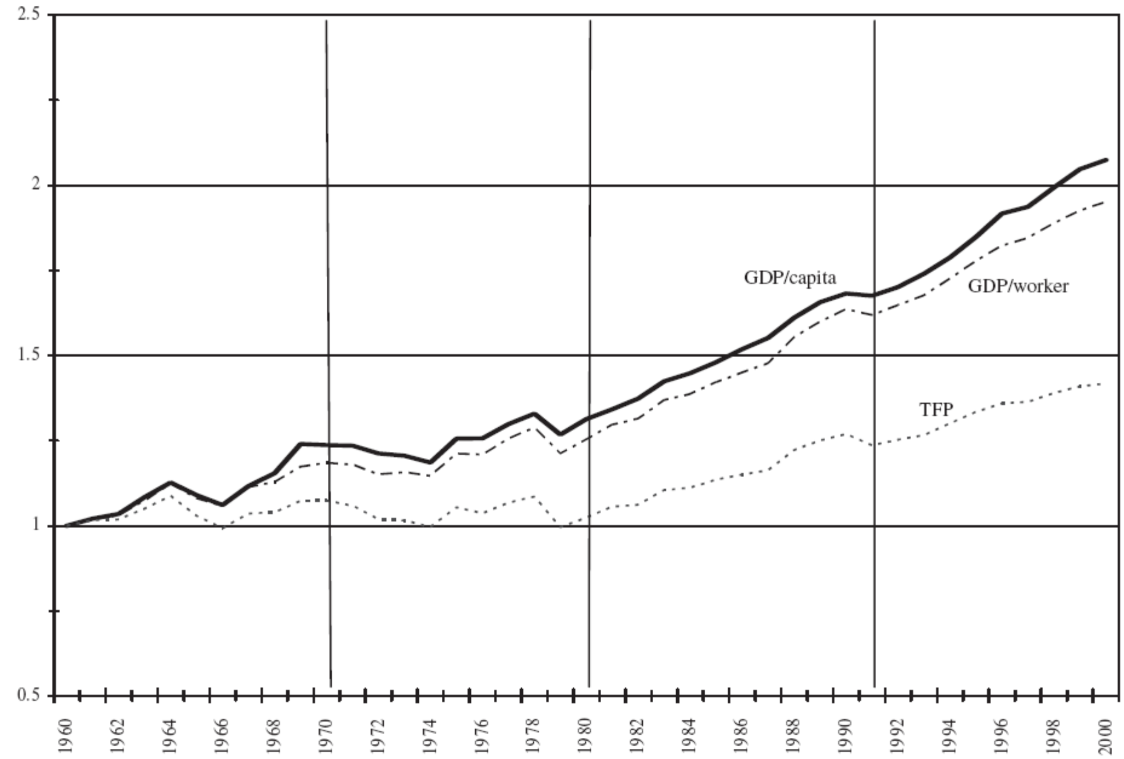
> *"The economy grew at an average annual growth rate exceeding 6% in per capita terms in the period 1990-2005, which is 4 percentage points higher than the Hindu growth rate experienced between 1950 and 1990. The coincidence of increasing growth rates and reforms in the 1990s has led a large body of the literature to argue that the policy reforms have been the main drivers of the increasing growth rates" (MSA, 2010, p. 38).*

MSA's contention of a 1990/1991 growth transition presents a departure from the central theme in Rodrik and Subramanian (2005) (hereafter R-S, 2005). R-S (2005) stress that growth narratives of the Indian economy have tended to understate the growth performance of the 1980s, while over-emphasising the growth effect of the sweeping economic reforms since 1991. The gist of their argument is captured in Figure 1 (adopted from R-S, 2005: p.197). Real GDP per capita, real GDP per worker and TFP all show a significant and upward trend break that begins in 1980.

The average growth surge during the 1980s (1980-1990) relative to the pre-1980 period in output, output per worker and TFP is summarised in Table 1. Moreover, as Table 1 shows, there appears to be no discernible difference between the aggregate growth performance of the 1980s and the post-1990 liberalisation period. In fact, average TFP growth slowed down from 2.49% during the 1980s (1980-1990) to 1.57% in the 1990s (1990-1999) when economic liberalisation measures were at their peak (R-S, 2005: p. 198).

The R-S (2005) contention of a significant growth shift in or around 1980 is strongly supported by several other studies (see Balakrishnan and Parameswaran, 2007; Nell, 2012, 2013; and Virmani, 2006). These studies have typically based their analyses on different break-point detection methods and/or theory-consistent economic models that explicitly incorporate the 1980 growth transition.

Figure 1. Economic Performance in India, 1960-2000



Sources: GDP data from Penn World Table 6.1 and TFP from Bosworth and Collins (2003).

Table 1. India: Growth Indicators (annual average percentages)

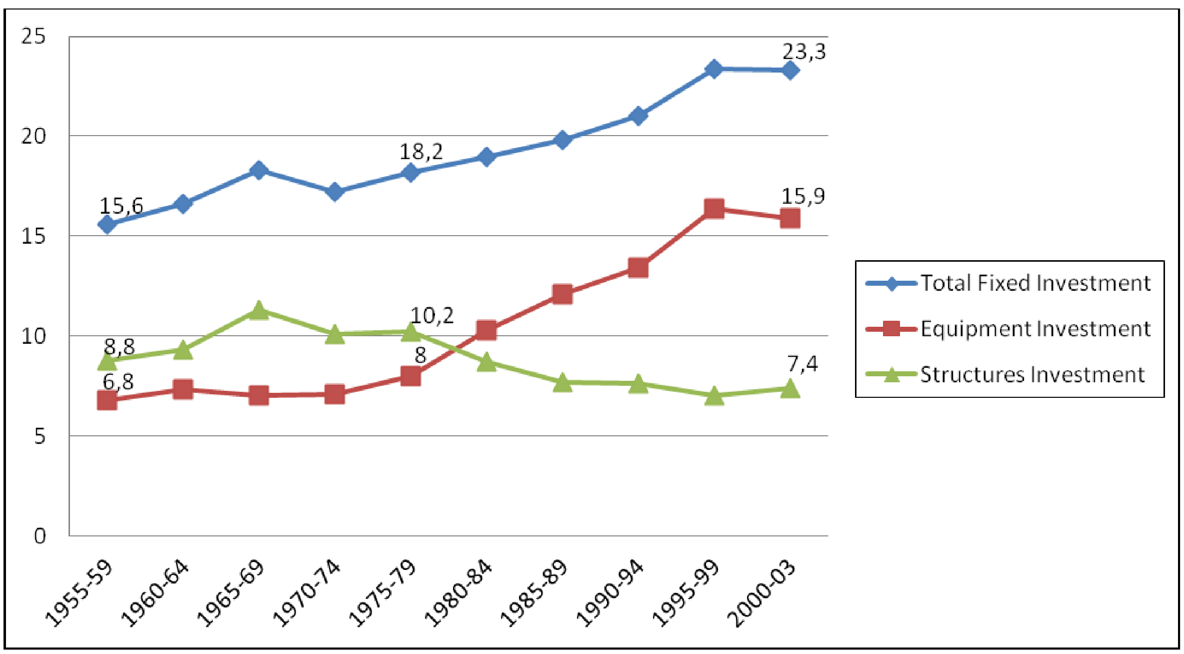
Growth indicator	1960-70	1970-80	1980-90	1990-99
Output	3.84	2.98	5.85	5.59
Output per worker	1.87	0.69	3.90	3.27
Capital per worker	0.83	0.61	1.06	1.32
Total factor productivity (TFP)	0.74	–0.50	2.49	1.57

Source: R-S (2005, p. 198). Data from Bosworth and Collins (2003).

2.2 The TFP-Driven Nature of India's 1980 Growth Transition

From the foregoing analysis, it is apparent that TFP growth accounts for the bulk of India's 1980 growth transition rather than physical capital accumulation. The small rise in capital per worker growth since the 1980s does not match the surge in output per worker growth in Table 1, which, in turn, is reflected in rapid TFP growth. The TFP-driven nature of India's 1980 growth transition can also be gauged by looking at the evolution of the total gross fixed investment rate and its different components over the period 1955-2003. (The discussion that follows draws extensively on Sen's (2007) excellent decomposition of India's aggregate gross domestic investment rate).

Figure 2. India's Total Gross Fixed Investment Rate and Its Components: 1955-2003

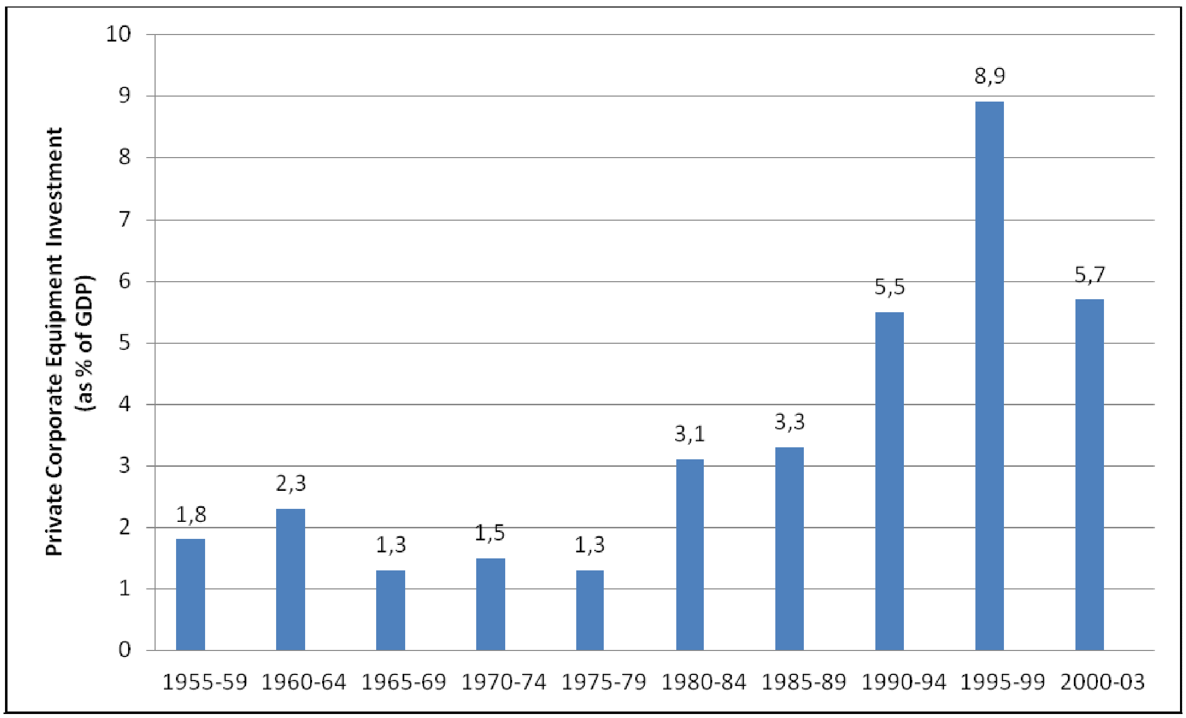


Source: Data from Sen (2007)

Figure 2 plots 5-year averages of the total gross fixed investment rate and its different sub-components over the period 1955-2003. The total gross fixed investment rate displays a steady, but relatively slow, increasing trend since the mid-1970s. There is no 'visible' break in the total fixed investment rate that matches the large shift in output per worker growth in Table 1, which again seems to reflect a TFP-driven growth transition. Figure 2 further reveals that the increasing trend of the total was largely due to a steady rise in equipment investment, which more than offset the decreasing trend in structures investment.

Sen's (2007) decomposition of the total equipment investment rate, on the other hand, shows that the increase in the total was largely driven by movements in private corporate equipment investment relative to private household and public equipment investment. Figure 3 shows a large structural shift in the private corporate equipment investment rate since 1980.

Figure 3. India's Private Corporate Equipment Investment Rate: 1955-2003



Source: Data from Sen (2007)

During the first half of the 1980s (1980-1984) the private corporate equipment investment rate averaged 3.1% and during the second half (1985-1989) it averaged 3.3% This represents a more than 100% increase relative to the average rates that prevailed during the sub-periods 1965-1969 (1.3%), 1970-1974 (1.5%) and 1975-1979 (1.3%). The post-1990 liberalisation period witnessed another structural shift in the private corporate equipment investment rate, with an average rate that settled at 5.7% over the period 2000-2003, following the sharp increase in the mid- to late-1990s.

To summarise this sub-section, it appears as if the bulk of India's 1980 growth transition can be attributed to TFP growth rather than physical capital accumulation: trend movements in the total gross fixed investment rate and the corresponding growth rate of capital per worker do not match the large upward shift in output per worker growth. At the same time, the analysis also shows a clear structural shift in the composition of total investment since 1980: private corporate equipment investment rose sharply relative to structures investment.

2.3 *Another Growth Transition in 2003*

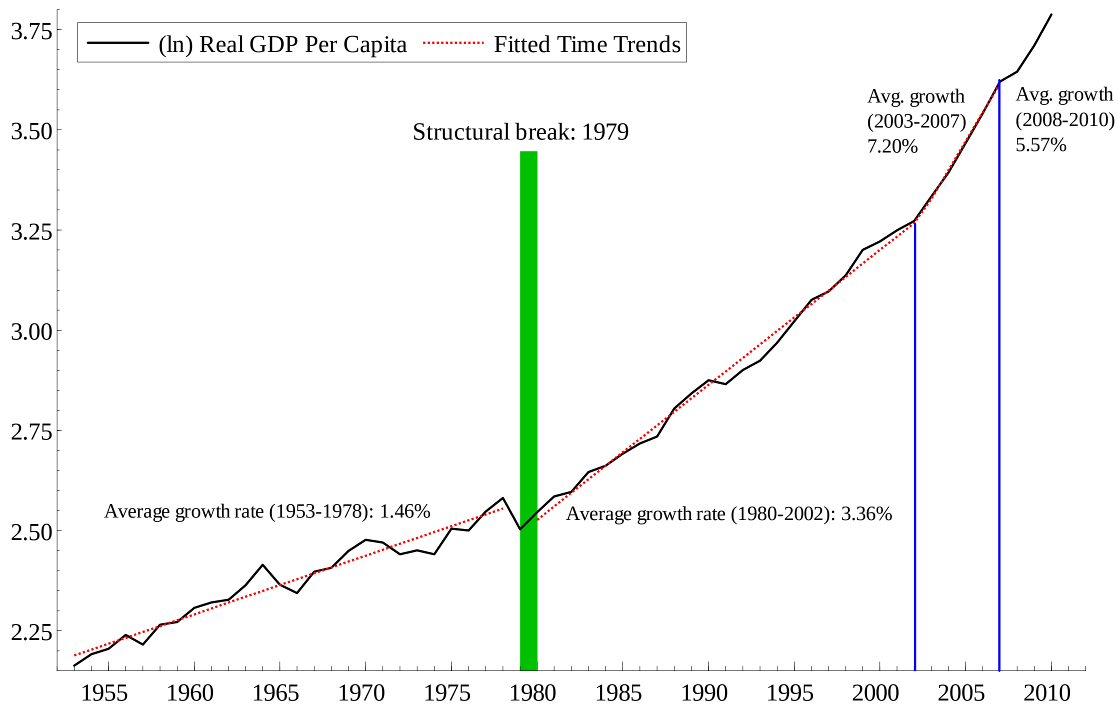
The main hypothesis of a 1980 growth transition in section 2.1 remains intact when we use real GDP per capita data from a different source (Reserve Bank of India) and over an extended sample period (1953-2010) in Figure 4. Consistent with the result obtained from Bai and Perron's (2003) multiple-breakpoint test in R-S (2005), Harvey and Koopman's (1992) break-point test used in this paper also indentifies a structural break in the growth rate of real GDP per capita in 1979[3].

By treating the negative growth rate in the year of the structural break (1979) as an outlier, Figure 4 shows that India's real GDP per capita grew at a relatively slow rate of 1.46% per annum in the first regime (1953-1978), but more than doubled to an average rate of 3.36% in the second regime (1980-2002). In accordance with the main hypothesis in R-S (2005), there appears to be no 'discernible' difference between the average growth rates in the 1980s and the post-1990 liberalisation period. During the 1980s (1980-1990) real GDP per

[3] Harvey and Koopman's (1992) break-point test was computed using Stamp 7 (see Koopman et al., 2006).

capita growth averaged 3.20% compared with an average rate of 3.92% in the post-liberalisation period (1991-2002).

Figure 4. India's Real GDP per Capita: 1953-2010



Notes:

1) The average growth rate in each regime (with the exception of the financial crisis years during 2008-2010) is obtained by estimating the following regression: $y_t = a + b_1 t + u_t$; where y_t is the natural logarithm (ln) of real GDP per capita income, t is a time trend, and u_t is an unobserved disturbance term. The b_1 estimate multiplied by 100 gives the average (instantaneous) growth rate.
2) Data Source (see Appendix A): Reserve Bank of India.

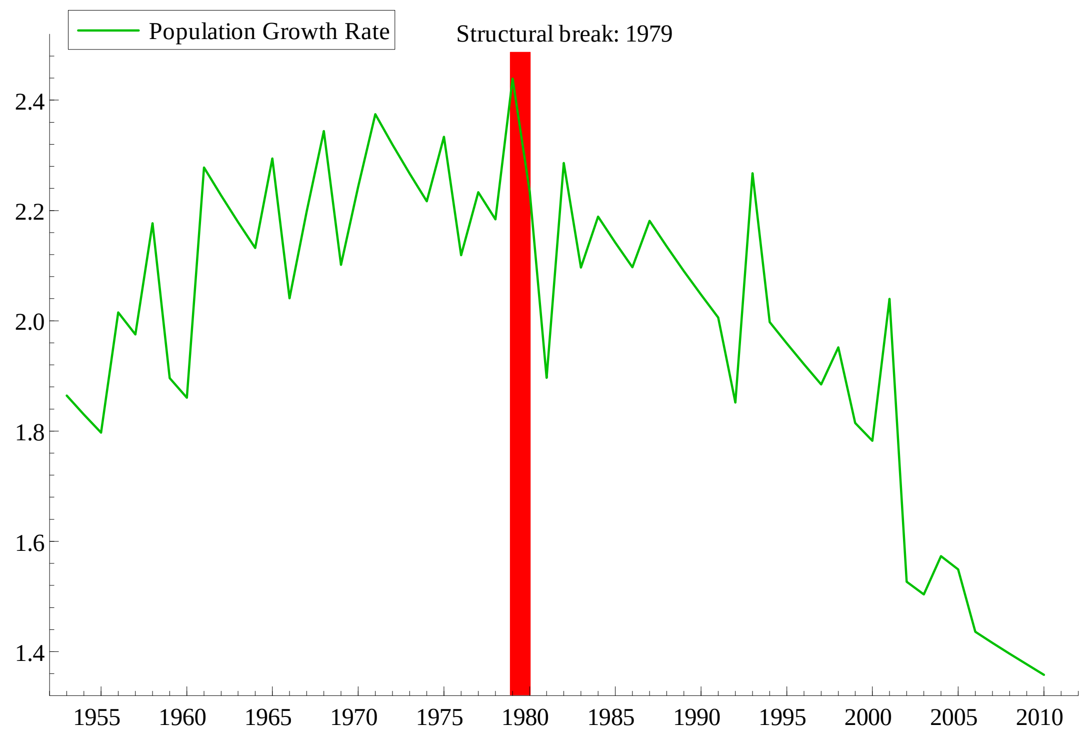
Based on Panagariya's (2008) analysis, 2003 represents another potential turning point in India's growth performance. Figure 4 shows that growth accelerated to a new record average rate of 7.20% over the period 2003-2007. This contention is reinforced by Lall (2003), who predicted a marked improvement in India's growth performance, following the deregulation of administered interest rates during 2000-2002 and the sharp drop in the user cost of capital. In spite of the turbulent years of the global financial crisis during the period

2008-2010, Figure 4 shows that the Indian economy still managed to grow at an average rate of 5.57%.

2.4 Structural Change in Population Growth

Figure 5 plots the evolution of India's population growth rate over the period 1953-2010. Consistent with the real GDP per capita series in Figure 4, Harvey and Koopman's (1992) test identifies a structural break in 1979. In the pre-1980 period population growth appears to be stationary or mean reverting, especially since 1961. In contrast, since the early 1980s population growth shows a sharp decelerating trend.

Figure 5. India's Population Growth Rate: 1953-2010



Notes:

1) The population growth rate is calculated as follows: $\tilde{g}_t^n \equiv [(\ln \text{Pop}_t - \ln \text{Pop}_{t-1}) \times 100]$, where Pop is population.

2) Data Source (see Appendix A): Reserve Bank of India.

2.5 The Stylised Facts of India's Growth Performance: a summary

Based on the preceding discussion, the key features of India's growth performance over the period 1953-2010 can be summarised as follows:

i) A growth transition that started in or around 1980. Excluding the turbulent years of the global financial crisis (2008-2010) and outlying growth in 1979, the period 1953-1978 represents India's slow-growing regime and the period 1980-2007 its faster-growing regime. (See Figures 1 and 4)

ii) India's growth transition during the 1980s and 1990s was primarily TFP driven. (See Figure 1 and Table 1).

iii) A structural shift in the composition of the total gross fixed investment rate since 1980, with a significant increase in private corporate equipment investment relative to structures investment. (See Figures 2 and 3)

iv) The start of another growth acceleration over the period 2003-2007. (See Figure 4).

v) A structural break in the population growth rate: the series appears to be stationary in the pre-1980 period, as opposed to the sharp decelerating trend since the early 1980s. (See Figure 5).

3. THE TFP-CAPITAL ACCUMULATION HYPOTHESIS

This section develops a TFP-capital accumulation hypothesis that is capable of modelling the stylised facts of India's growth performance summarised in section 2.5. The combined model presents an alternative to the orthodox TFP view, broadly defined as an influential body of literature (Easterly and Levine, 2001; Hall and Jones, 1999; Helpman, 2004; MSA, 2010; Romer, 2006) that views physical capital accumulation as relatively unimportant in the growth process due to its endogenous nature and capital's small share in total income. The general theoretical framework adopted in this section is based on learning by doing endogenous growth models (Romer, 1986, 1987) and textbook expositions such as those in Romer (2006) and Sørensen and Whitta-Jacobsen (2010). The next sub-section presents the main equations of the model and then uses Kaldor's (1957, 1961) technical progress function analysis to model the TFP-capital accumulation explanation of India's growth transitions. The following sub-sections derive the steady-state growth path of output per worker and the corresponding econometric specification that will be used in the empirical section. The final sub-section explains the choice of the variables in the empirical model.

3.1 The Key Equations of the Model

The production function with constant returns to scale is given by

$$Y_t = (K_t)^{\alpha}(A_t L_t)^{1-\alpha}, \qquad 0 < \alpha < 1 \tag{1}$$

where t denotes time, Y_t is real output, K_t is capital input, A_t is 'technology' or 'knowledge' input, and L_t is labour input.

The stock of knowledge at time t is modelled as

$$A_t = B_t K_t^{\phi}, \qquad 0 \le \phi < 1 \tag{2}$$

where ϕ is a learning by doing or capability parameter that measures the new knowledge and skills workers gain from using and installing new capital. A positive learning by doing parameter ($0 < \phi < 1$) implies that new technology is embodied in new machinery and equipment. When workers and managers use new capital with embodied technical progress, it triggers a process of learning by doing, which makes them more knowledgeable on how to adapt and use modern technologies in the most efficient way. In this framework, knowledge accumulation is endogenous with respect to capital accumulation (De Long and Summers, 1992). With disembodied technical progress and a resulting learning by doing parameter of zero ($\phi = 0$), technology or knowledge becomes completely unexplained ($A_t = B_t > 0$), and we go back to the underlying assumption of the original Solow (1957) model.

The capital accumulation equation can be written as

$$K_{t+1} = sY_t + (1-\delta)K_t, \qquad \text{given } K_0 \tag{3}$$

where s is the saving/investment rate, δ is the rate at which existing capital depreciates, and K_0 is the initial value of the capital stock.

The labour force and technology grow at the exogenous and constant rates g^n and g^B, respectively:

$$L_{t+1} = (1+g^n)L_t, \qquad \text{given } L_0 \tag{4}$$

$$B_{t+1} = (1+g^B)B_t, \qquad \text{given } B_0 \tag{5}$$

where g^n is the population growth rate, and L_0 and B_0 are the initial values of the labour force and technology, respectively. Since equation (4) assumes that the growth rate of the labour force is equal to the population growth rate, $(L_{t+1}/L_t) - 1 = g^n$, the discussion hereafter shall interchangeably refer to output growth in per worker or per capita terms.

3.2 The Basic Set UP of the TFP-Capital Accumulation Hypothesis

Substitute (2) into (1) and simplify to obtain

$$Y_t = K_t^{\alpha+\phi(1-\alpha)} B_t^{1-\alpha} L_t^{1-\alpha}. \tag{6}$$

When $0 < \phi < 1$, the aggregate production function in (6) exhibits increasing returns, because the sum of the exponents on capital and labour, $1 + \phi(1 - \alpha)$, exceeds one. An interesting feature of the increasing returns to scale model in (6) is that population growth becomes the source of *sustained* growth in output per worker (see Sørensen and Whitta-Jacobsen, 2010). However, as will be discussed in more detail in section 5.4, growth narratives do not identify shifts in population growth as the initiating force behind India’s major growth transitions. Furthermore, as will be shown more formally in section 3.5, it is empirically difficult to distinguish between the positive long-run growth effect of population growth and its negative transitory effect, which both appear in the same model. It is therefore convenient for now to assume a constant labour force in equation (4): $L_t = L$. One important implication of this assumption is that, with zero population growth, the model needs an alternative source of sustained growth. This is done in equation (2) through the B_t term, which models some of the technological progress as unexplained: $B_t = B_0(1 + g^B)^t$.

With these assumptions in place, equation (6) in approximate growth rates becomes

$$\tilde{g}_t^y = [\alpha + \phi(1-\alpha)]\tilde{g}_t^k + (1-\alpha)\tilde{g}^B, \tag{7}$$

where $\tilde{g}_t^y$ is the growth rate of output per worker; $\tilde{g}_t^k$ is the growth rate of capital per worker; and $\tilde{g}^B$ is the exogenous growth rate of technology. The tilde denotes the approximate growth rate of variable *x:* $\tilde{g}_t^x \equiv \ln x_t - \ln x_{t-1}$.

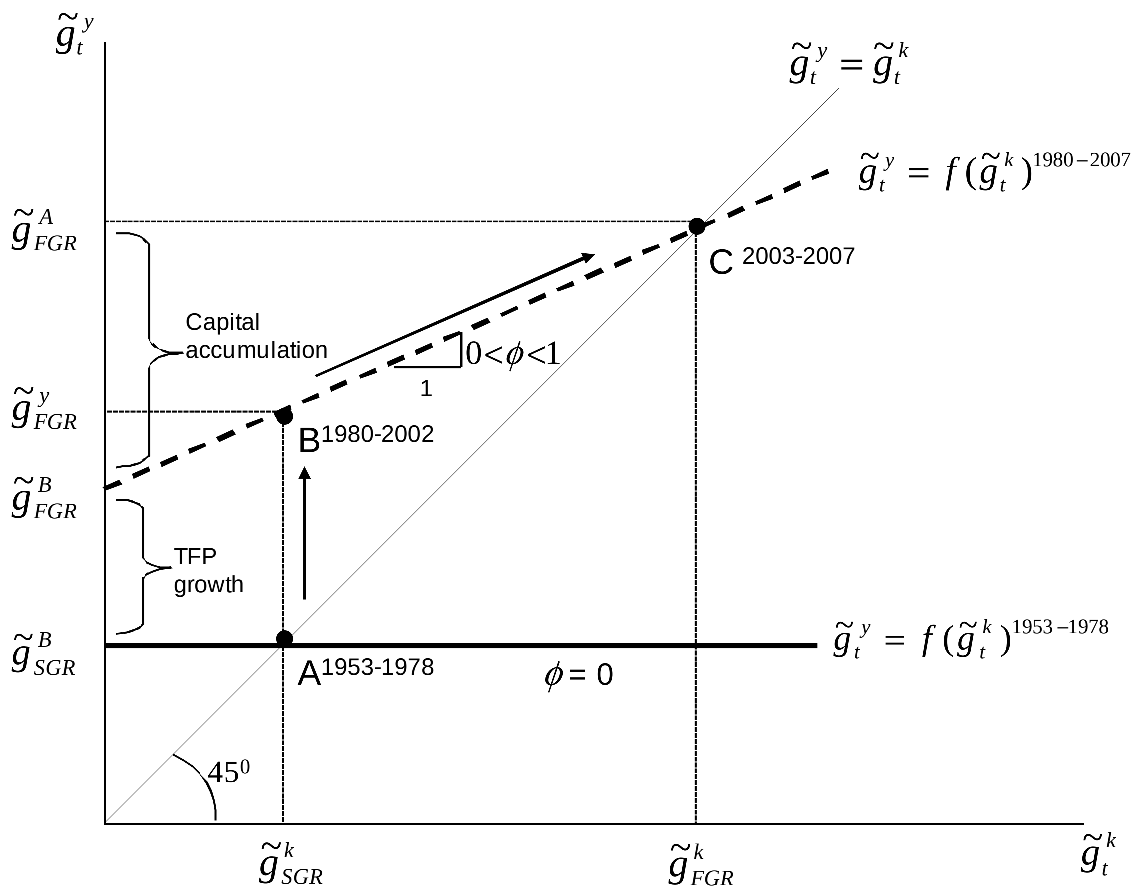
Consider the long-run growth implications of equation (7). The α parameter is equal to capital's share in total income, and captures the sensitivity of output per worker growth with respect to capital per worker growth for a *given* rate of technological progress. Because technological progress is exogenous, the α parameter only measures the transitory growth effect of capital accumulation. This is true in the original Solow model (1957) and also the learning by doing model when $0 < \phi < 1$. Individual firms in the learning by doing model do not deliberately try and affect the rate of technological progress when they accumulate more capital. As a result, the α parameter in learning by doing models also measures transitory growth for a given rate of technological progress. However, technological progress in the learning by doing model arises as an accidental by-product of capital accumulation, which is measured by the ϕ parameter. The long-run impact of capital accumulation will therefore depend on the magnitude of the learning by doing parameter, ϕ. Setting $\alpha = 0$ in equation (7), we have

$$\tilde{g}_t^y = \phi(\tilde{g}_t^k) + \tilde{g}^B. \tag{8}$$

3.3 The TFP-Capital Accumulation Hypothesis of India's Growth Transitions

To explicitly model the long-run growth implications of the TFP-capital accumulation hypothesis in the Indian economy, it is informative to plot the relationship in equation (8) on a graph. It is further useful to borrow a concept from Kaldor's (1957, 1961) original growth model, and refer to the relationship in equation (8) as a 'technical progress function'.

Figure 6. The TFP-Capital Accumulation View of India's Growth Transitions



Consider India's technical progress function during its slow-growing regime (1953-1978) in Figure 6. The technical progress function expresses output per worker growth ($\tilde{g}_t^y$) on the vertical axis as a function of capital per worker growth ($\tilde{g}_t^k$) on the horizontal axis: $\tilde{g}_t^y = f(\tilde{g}_t^k)^{1953-1978}$. The position of the technical progress function depends on the exogenous rate of technological progress, $\tilde{g}^{B}_{SGR}$, where *SGR* stands for slow-growing regime. The slope of the function measures the degree of embodied technical progress and associated learning by doing effects. Assuming that technical progress is completely disembodied in the slow-growing regime, the learning by doing parameter is equal to zero (ϕ=0) and the function becomes a horizontal line.

Suppose India operated on a balanced growth path during its slow-growing regime (*SGR*) at point A in Figure 6[4]:

$$\tilde{g}^{y}_{SGR} = \tilde{g}^{k}_{SGR} = \tilde{g}^{B}_{SGR} \quad (9)$$

Consistent with the original Solow (1957) model, output per worker and capital per worker grow at the rate of exogenous technological change. Now consider stylised fact (i) in section 2.5, which highlights India's growth shift out of its slow-growing regime during 1953-1978 into a faster-growing one over the period 1980-2007. From an initial equilibrium position at point A in Figure 6, India's 1980 growth transition can be modelled as an upward shift in the technical progress function, with the unexplained rate of technological progress increasing from $\tilde{g}^{B}_{SGR}$ in the slow-growing regime to $\tilde{g}^{B}_{FGR}$ in the faster-growing regime (*FGR*).

At the same time, the slope of the technical progress function becomes steeper, with the learning by doing parameter increasing from $\phi = 0$ in the slow-growing regime to $0 < \phi < 1$ in the faster-growing regime. The increase in the degree of embodied technical progress and learning by doing captures stylised fact (iii) in section 2.5, which states that private corporate equipment investment increased sharply relative to structures investment since 1980. Indeed, if equipment investment is the main carrier of technology, as argued in De Long and Summers (1992, 1993), then the structural shift in the composition of investment implies a rise in the degree of learning by doing since 1980.

[4] An economy is on a balanced growth path if output per worker grows at the same rate as capital per worker. From Table 1 it can be seen that this is not an unrealistic assumption over the period 1970-1980, with average growth rates of 0.69% and 0.61% in output per worker and capital per worker, respectively.

The increase in output per worker growth from A to B in Figure 6 captures the TFP-driven nature of India's growth transition during the 1980s and 1990s, as summarised under stylised fact (ii) in section 2.5. Note that point B lies above the 45-degree line, so output per worker growth exceeds capital per worker growth[5]: $\tilde{g}^{y}_{FGR} > \tilde{g}^{k}_{SGR}$. Although a proportion of output per worker growth at point B can be attributed to physical capital accumulation, as measured by the slope change in the technical progress function ($\tilde{g}^{y}_{FGR} - \tilde{g}^{B}_{FGR}$), the bulk of the initial growth shift comes from a rise in TFP growth ($\tilde{g}^{B}_{FGR} - \tilde{g}^{B}_{SGR}$). More precisely, it is assumed that India's initial growth transition was largely productivity driven from 1980 until 2002, right up until the start of the second growth acceleration in 2003 (see Figure 4).

It is important to note that point B in Figure 6 represents a sub-optimal 'equilibrium' position rather than an interim point. Counterfactually, as an interim point, output per worker growth in excess of capital per worker growth at point B would increase the profit rate and induce firms to invest more. A faster rate of capital accumulation would instantaneously move the economy from point B (follow the arrow) to the new equilibrium position at point C.

However, India got stuck in a sub-optimal equilibrium position at point B over the period 1980-2002. This contention is strongly supported by Felipe et al.'s (2008) growth accounting exercise, which shows that India's average profit rate was much higher than China's during the 1980s and 1990s. Despite India's large investment potential, an unfavourable/uncertain domestic investment environment discouraged firms to reinvest their profits (see Felipe et al., 2008).

Stylised fact (iv) in section 2.5 emphasises the beginning of another growth acceleration over the period 2003-2007. The theoretical framework in Figure 6 assumes that

[5] Strictly speaking, the actual point on the new technical progress function should sit slightly more to the right of point B. The growth figures in Table 1 suggest that capital per worker growth during the 1980s and 1990s did increase somewhat from its level in the pre-1980 period. Point B, however, assumes that capital per worker growth during 1980-2002 remained unchanged from its pre-1980 level. For ease of exposition, but without loss of generality, the analysis will refer to point B as the sub-optimal equilibrium condition that prevailed during 1980-2002.

rapid output per worker growth over this period was driven by a faster rate of capital accumulation due to a more favourable domestic investment environment[6]. Or put in another way, a more favourable domestic investment climate served as an incentive for firms to reinvest their profits accumulated during the first phase of the growth transition. A faster rate of capital accumulation can be modelled as a movement *along* the technical progress function from point B to point C in Figure 6.

The long-run equilibrium output per worker growth rate ($\tilde{g}^{y}_{FGR}$) in the faster-growing regime at point C is equal to the rate of technological progress ($\tilde{g}^{A}_{FGR}$) and capital per worker growth rate ($\tilde{g}^{k}_{FGR}$):

$$\tilde{g}^{y}_{FGR} = \tilde{g}^{k}_{FGR} = \tilde{g}^{A}_{FGR} \qquad (10)$$

The difference in the rate of technological progress in the faster-growing regime relative to the slow-growing regime, $\tilde{g}^{A}_{FGR} - \tilde{g}^{B}_{SGR}$, is composed of two growth-inducing sources, as illustrated in Figure 6: 1) an exogenous TFP part equal to $\tilde{g}^{B}_{FGR} - \tilde{g}^{B}_{SGR}$, and 2) an endogenous capital accumulation part equal to $\tilde{g}^{A}_{FGR} - \tilde{g}^{B}_{FGR}$. Unlike the original Solow model, not all of the change in technological progress is exogenous; some of it is endogenous to capital accumulation.

Two special features of the capital accumulation part of the model are worth emphasising. First, the steeper slope of the technical progress function in the faster-growing regime implies that physical capital accumulation determines the rate of technological progress and therefore the long-run growth rate of output per worker as the economy moves from point B to point C in Figure 6. Second, the movement along the upward sloping technical progress function from B to C is the result of an increase in the *aggregate*

[6] This assumption is supported by Panagariya's (2008) contention that faster output growth over this period coincided with increasing saving/investment rates, and Lall's (2003) observation of a significant reduction in the user cost of capital over the period 2000-2002.

saving/investment rate and *economy-wide* capital stock. Intuitively, it is highly plausible to postulate that the productive potential of investment in equipment and machinery can only materialise if it is supported by investment in structures, such as factories, office buildings, infrastructure and housing. Residential investment may be a crucial supportive component of investment in a poor developing country. For example, Brito and Pereira (2002) and Harris and Arku (2006, 2007) identify a causality link that runs from housing investment to human capital accumulation and growth.

3.4 The Steady-State Growth Path of Output Per Worker

From equations (1)-(4), the steady-state *level* of output per worker ($y_{FGR,t} \equiv Y_{FGR,t} / L_{FGR,t}$) along a balanced growth path at point C in Figure 6 can be derived as

$$y_{FGR,t} = \left(\frac{s}{\left\{ \left[\left(1 + g^B_{FGR}\right)\left(1 + g^n\right) \right]^{\frac{1}{1-\phi}} - (1 - \delta) \right\}} \right)^{\frac{\beta}{1-\beta}} L_0^{\frac{\phi}{1-\phi}} B_0^{1+\frac{\phi}{1-\phi}} \left(1 + g^A_{FGR}\right)^t, \quad 0 < \phi < 1 \qquad (11)$$

where $\beta = \alpha + \phi(1 - \alpha)$ is the elasticity of output with respect to capital in equation (6) and $g^A_{FGR} = (1 + g^B_{FGR})^{1+\frac{\phi}{1-\phi}} (1 + g^n)^{\frac{\phi}{1-\phi}} - 1$. The steady-state growth path of output per worker in (11) is similar to the model derived in Sørensen and Whitta-Jacobsen (2010, p. 222), except for one important difference. The long-run growth rate (g^A_{FGR}) is not only sustained through population growth (g^n), as in the Sørensen and Whitta-Jacobsen (2010) model, but also a TFP part (g^B_{FGR}). Note that, similar to the original Solow (1957) model, g^n also appears in the denominator to capture the negative/positive transition dynamics of faster/slower population growth.

3.5 Econometric Specifications

To arrive at an econometric specification of equation (11), take logs to obtain:

$$\ln(y_{FGR,t}) = c + \frac{\beta}{1-\beta}\ln(s) + \kappa(t) + \varepsilon_t\,, \tag{12}$$

where ε_t is an error term and t is a time trend. The intercept term is equal to

$$c \equiv -\frac{\beta}{1-\beta}\ln\left\{\left[\left(1+g_{FGR}^{B}\right)\left(1+g^{n}\right)\right]^{\frac{1}{1-\phi}} - (1-\delta)\right\} + \frac{\phi}{1-\phi}\ln\left(L_0\right) + \left[1+\frac{\phi}{1-\phi}\right]\ln(B_0) \tag{13}$$

and the long-run growth rate of the model is equal to

$$\kappa \equiv \tilde{g}_{FGR}^{A} \equiv \left[1+\frac{\phi}{1-\phi}\right]\tilde{g}_{FGR}^{B} + \left[\frac{\phi}{1-\phi}\right]\tilde{g}^{n}\,, \tag{14}$$

where the tilde denotes the approximate growth rate of a variable. Consistent with Figure 6 and the discussion of equation (10), equation (14) shows that the rate of technological progress ($\tilde{g}_{FGR}^{A}$) in the faster growing regime at point C is composed of an exogenous TFP component, $\tilde{g}_{FGR}^{B}$, and an endogenous capital accumulation component that works through the learning by doing parameter, ϕ.

Although population growth also enters as a potential determinant of long-run growth in (14), there are several reasons why it may not be a growth-inducing source in the Indian economy over the sample period analysed in this paper. First, growth narratives of the Indian economy (see section 5.4) do not identify changes in population growth as the trigger behind its 1980 growth transition. Second, it follows that the decelerating trend in population growth since the early 1980s, as observed in Figure 5 and summarised under stylised fact (v), is to some extent the endogenous outcome of faster income growth. Moreover, even if there are feedback effects from population growth to income growth, it may still not be a significant determinant in equation (12), thus implying that $g^{n} \approx \tilde{g}^{n} \approx 0$ in equations (13) and (14). Because decelerating population growth in equation (11) generates positive transition dynamics but a negative long-run growth effect, the net effect of population growth in equation (12) may be close to zero. This assumption is consistent with the graphical exposition in Figure 6, which excludes population growth as a determinant of India's long-run growth rate in its faster-growing regime.

The learning by doing specification in equation (12) is hypothesised to be the appropriate model in India's faster-growing regime (1980-2007), whereas the Solow (1957) model is assumed to be the relevant theoretical framework in India's slow-growing regime (1953-1978). To derive the Solow model's steady-state level of output per worker along a balanced growth path at point A in Figure 6, set $\phi = 0$ in equation (11) and take logs to obtain:

$$\ln(y_{SGR,t}) = d + \frac{\alpha}{1-\alpha}\ln(s) + \tilde{g}^{B}_{SGR}(t) + \xi_t \, , \qquad (15)$$

where ξ_t is an error term and the long-run growth rate ($\tilde{g}^{B}_{SGR}$) in the slow-growing regime is exogenously given, as depicted by the horizontal technical progress function in Figure 6. The intercept term is given by

$$d \equiv -\frac{\alpha}{1-\alpha}\ln\left(g^{n} + g^{B}_{SGR} + \delta + g^{n} g^{B}_{SGR}\right) + \ln(B_0) \, . \qquad (16)$$

Equation (15) looks similar to the Solow model derived in Mankiw et al. (1992), except for two key differences. First, the Solow specification in (15) is formulated in discrete time, whereas the Mankiw et al. (1992) model is in continuous time. Second, population growth appears as a constant term in equation (16), as opposed to Mankiw et al.'s (1992) model, in which population growth is a variable to be estimated. The inclusion of population growth as a constant term is motivated by stylised fact (v) in section 2.5, which states that population growth appears to be a stationary variable in the pre-1980 period. Without permanent shocks to population growth, which in econometric terms is only contained in a non-stationary variable, it is not possible to test the prediction of the Solow model in the slow-growing regime: that is, whether a *permanent* shock to population growth has a permanent level effect on output per worker. For now, population growth is assumed to be constant in equation (16). This proposition will be analysed in more detail in sections 4 and 5.

3.6 Specifying the Variables in Equations (12) and (15)

It is important to reiterate that the capital accumulation part of the model, which is modelled as a movement along the technical progress function from B to C in Figure 6, is all about capital accumulation in an economy-wide sense. In section 3.3, it was emphasised that the long-run growth potential of equipment investment can only be realised if it is supported by other types of investment. It follows that equations (12) and (15) should be estimated with the *total* saving/fixed investment rate as the explanatory variable.

The analysis has thus far interchangeably referred to the saving/investment rate on the assumption that the economy is closed. In an open economy, however, the appropriate variable is the aggregate saving rate. Following Feldstein and Horioka's (1980) hypothesis in an open-economy context, an increase in the saving rate (domestic resources) may not necessarily lead to an equivalent increase in the investment rate (see Romer, 2006). The inclusion of the aggregate saving rate rather than the investment rate in equations (12) and (15) will therefore explicitly measure whether resources generated from the domestic economy are effective in raising living standards.

Finally, the assumption that population growth is equal to labour force growth in equation (4) implies that it is invariant whether equations (12) and (15) are estimated with output in per worker or per capita terms. However, the assumption of equation (4) will only hold if the labour force participation rate is constant. If the participation rate varies substantially over time, then the production function framework of the model implies that it is preferable to use output per worker (Hoeffler, 2002; Temple, 1999).

To test the underlying assumption of equation (4), real GDP per capita and real GDP per worker data for India were obtained from Penn World Table Version 7.1 (PWT 7.1). The correlation coefficient between the growth rates of real GDP per capita and real GDP per worker gives a value of 0.98 over the period 1953-2007, which seems to validate the key assumption of equation (4). Nevertheless, as noted by Hoeffler (2002: p. 144), these results may reflect substantial measurement errors in the construction of the labour force series.

If it is assumed, given the available data, that the growth rates of the labour force and population are roughly equal, then the next step is to decide whether to use real GDP data from India's own national accounts or PWT accounts. Based on the argument advanced in Temple (1999) that GDP data from a country's own national accounts may be more accurate than PWT data, all the data in this paper are obtained from India's own national accounts[7]. Since population and GDP data are readily available from the Reserve Bank of India, per capita instead of per worker values are used in equations (12) and (15).

4. ECONOMETRIC METHODOLOGY AND EMPIRICAL HYPOTHESIS

4.1 Econometric Methodology

The econometric methodology employed in this paper follows the structural cointegrating vector autoregressive (VAR) approach first developed by Johansen (1988, 1992) and later advanced in Garratt et al. (2000); Pesaran et al. (2000); and Pesaran and Shin (2002). The statistical framework for the structural cointegrating VAR approach is the following general vector error-correction model (VECM):

$$\Delta y_t = a_{0y} + a_{1y}t - \mathbf{\Pi}_y y_{t-1} + \sum_{i=1}^{p-1} \mathbf{\Gamma}_{iy}\Delta y_{t-i} + \Psi_y w_t + v_t \,, \qquad (17)$$

[7] India's national-accounts data are compiled by the Central Statistical Organisation (CSO), which, in turn, is published by the Reserve Bank of India.

where y_t is a vector of I(1) endogenous variables, and w_t is a vector of I(0) exogenous variables and event-specific dummy variables. The matrix $\mathbf{\Pi} = \alpha_y \beta'$ contains the cointegrating relationships, where the α_y matrix represents the error-correction coefficients, or the speed of adjustment towards long-run equilibrium, and β represents the matrix of long-run coefficients.

4.2 VECM Specification and Hypothesis

Following the specifications of the learning by doing model in equation (12) and the Solow model in equation (15), the vector of endogenous I(1) variables can be written as y_t' = $[\ln(y_{p/c}), \ln(s)]$, where s is the gross domestic saving to nominal GDP ratio, and $y_{p/c}$ is real GDP per capita. Appendix A provides a detailed description of the variables and data source. Based on the TFP-capital accumulation model in Figure 6, the models are estimated over the following sub-samples: (a) *SGR*: 1953-1978; (b) *FGR(I)*: 1980-2002; and (c) *FGR (II)*: 1980-2007, where *SGR* stands for slow-growing regime and *FGR* for faster-growing regime.

Empirical support for the TFP-capital accumulation hypothesis will show that the Solow model in equation (15), with a learning by doing parameter close to zero, fits the data over the *SGR*. In contrast, the learning by doing specification in equation (12) is the relevant model in *FGR(I)* and *FGR(II)*. Note that *FGR(II)* includes the 1980 growth transition and the second growth acceleration since 2003. It is hypothesised that the learning by doing model in *FGR(I)* and *FGR(II)* is structurally invariant. Because the economy operates on the same technical progress function across the two regimes, as shown in Figure 6, the parameter estimates should be the same, irrespective of whether the learning by doing model is estimated over *FGR(I)* or *FGR(II)*. Structural invariance, in turn, suggests that the saving rate and real GDP per capita variables co-break over *FGR(II)*. In other words, the growth acceleration during 2003-2007 is not the result of a structural shift in the parameters of the model, but rather because the saving rate and real GDP per capita co-break in the same direction. It follows that structural invariance of the models over *FGR(I)* and *FGR(II)* provides evidence of a movement *along* the technical progress function from B to C in Figure 6, which supports the capital accumulation part of the model over the period 2003-2007.

Temporary deviations from trend growth in each regime are modelled by specifying the following three vectors of event-specific dummy variables: $w'_{SGR,t} = (D_{65})$; $w'_{FGR(I),t} = (D_{(83)}, D_{(88,99)}, D_{91})$; and $w'_{FGR(II),t} = (D_{(83,03)}, D_{(88,99)}, D_{91})$. All the dummy variables are associated with known events. For example, D_{65} takes the value of unity in 1965 and zero otherwise to capture the beginning of the 1965-1967 macroeconomic crisis, a severe drought and war with Pakistan, as described in Panagariya (2008). The combined dummy variable, $D_{(83,03)}$, takes the value of unity in 1983 and 2003, and zero otherwise. Rapid output growth in 1983 may be associated with India winning the cricket world cup, while faster growth in 2003 signifies the beginning of another growth acceleration, following the sharp drop in the cost of capital (see Lall, 2003). The advantage of using a combined dummy variable is that it captures the impact of two different events in one variable, thus preserving degrees of freedom. Throughout, a combined dummy variable is constructed when the test results show that the parameter estimates of the two separate dummy variables are not significantly different from one another. Thus, imposing these two dummy variables into one term involves no loss of information. Appendix A provides a description of all the dummy variables together with additional references that describe the outlying events in more detail.

The VECM in equation (17) implies that the non-stationary I(1) variables in the y_t vector cointegrate to form a stationary I(0) process. As a pre-test, before cointegration tests are performed to validate the VECM representation in (17), it is first necessary to establish whether the variables included in y_t are I(1). To test the order of integration of the variables, unit root tests developed by Ng and Perron (2001) and Kwiatkowski et al. (1992) are conducted over the different sub-samples identified above (not reported here)[8]. The Kwiatkowski et al. (1992) test gives the most consistent results, and suggests that the variables in levels, $\ln(y_{p/c})_t$ and $\ln(s)_t$, are I(1), but their first differences, $\Delta\ln(y_{p/c})_t$ and $\Delta\ln(s)_t$, are I(0).

The Kwiatkowski et al. (1992) unit root test also shows that the natural logarithm of population growth, defined as $\ln(\tilde{g}^n)_t$, is a non-stationary I(1) variable over the different sub-samples. At first, this would seem to contradict stylised fact (v) in section 2.5, which states that population growth appears to be a stationary I(0) variable in the pre-1980 period. However, it is well known that unit root tests have low power when there is a structural break in the series (see Maddala and Kim, 1998). In addition to the 1979 structural break in the population growth rate series reported in Figure 5, Harvey and Koopman's (1992) break-point test also detects a break in 1960. Nevertheless, instead of basing the analysis on additional unit tests that allow for structural breaks, the role of population growth can be examined more directly in a theory-consistent framework by re-specifying the vector of I(1) endogenous variables in equation (17) as $y_t' = [\ln(y_{p/c}), \ln(s), \ln(\tilde{g}^n)]$. Based on the estimates obtained from this alternative specification (not reported here), it is apparent that the population growth rate variable is spuriously related to per capita income in the *SGR*, while in *FGR(I)* and *FGR(II)* the variable is an insignificant determinant of per capita income. In section 3.5 several reasons were advanced why population growth may not be a significant long-run determinant in equations (12) and (15). These reasons are re-examined in section 5.

[8] The unit root test results were obtained using EViews 7.

Since the spurious results in the *SGR* suggest that the population growth rate variable is I(0), it is excluded from the long-run y_t vector[9]. Alternatively, to model potential short-run effects, the first difference and one-period lag of the population growth rate variable is included in the w_t vector of equation (17) during the *SGR*. The w_t vector in the *SGR* can therefore be specified as $w'_{SGR,t} = [D_{65}, \Delta\ln(\tilde{g}^n)_{t-1}]$. Given the insignificant, rather than spurious results obtained during the *FGR(I)* and *FGR(II)* regimes, population growth is excluded from the y_t and w_t vectors for these regimes.

Finally, to determine the appropriate lag length of the VECM in equation (17), the analysis begins with an unrestricted VAR model (p = 3) in each growth regime. For the *SGR* regime, Akaike's and Schwartz's Bayesian information criteria (not reported here) choose an order 2 model, and for the *FGR(I)* and *FGR(II)* regimes an order 1 model[10]. We therefore proceed by setting p = 2 and p = 1 for the respective growth regimes in equation (17). In addition, the intercept terms are restricted to lie in the cointegrating space with no trends, such that $a_{1y} = 0$ and $a_{0y} = \mathbf{\Pi}\mu_y$ in equation (17).

Note that, for pure statistical reasons, the structural cointegrating VAR approach requires either the intercept or the trend to lie in the cointegrating space, but not both (see Pesaran and Pesaran, 1997: pp. 132-135)[11]. The long-run relationships in equations (12) and (15), on the other hand, include both an intercept and trend, with the trend coefficient measuring the long-run growth rate of the economy. Because the structural cointegrating

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[9] The next section shows that there is a theory-consistent cointegrating relationship between the saving rate and per capita income in the *SGR*. The population growth rate variable, however, only enters significantly in the cointegrating relationship when a trend is included. However, the signs on the population growth rate and saving rate variables are positive and negative, respectively, which is inconsistent with theory. This suggests that the relationship between population growth and per capita income may be spurious, given that population growth is possibly an I(0) variable, whereas the saving rate and per capita income variables are I(1).

[10] Unless stated otherwise, all the estimation results in this paper were computed using Microfit 4.0 (Pesaran and Pesaran, 1997).

[11] When $\mathbf{\Pi}_y$ is rank deficient, the solution of y_t will contain quadratic trends unless the time trends are restricted to lie in the cointegrating space. Similarly, when $\mathbf{\Pi}_y$ is rank deficient, y_t will contain a linear deterministic trend unless the intercept terms are restricted. In the present application, the long-run impact of the trend terms is insignificant, so the intercept terms are restricted to lie in the cointegrating space.

VAR model with restricted intercepts and no trends is the preferred specification, the long-run growth rate is captured through the intercept term.

5. ECONOMETRIC EVIDENCE

5.1 Cointegration Analysis

The VECM representation in equation (17) assumes that there is a cointegrating relationship between the I(1) variables included in $y_t' = [\ln(y_{p/c}), \ln(s)]$. The trace ($\lambda_{\text{trace}}$) test statistics in Table 2 provide evidence at the 5% significance level of a unique cointegrating vector (r = 1) in each growth regime. Evidence of cointegration in each regime shows that the empirical models in equations (12) and (15) represent long-run equilibrium relationships.

Table 2: Cointegration Tests

		***SGR*: 1953-1978**		
Hypothesis		$\hat{\lambda}_{\text{trace}}$		
H_0	H_A	Statistic	95% CV	90% CV
r = 0	r = 1	33.61**	20.18	17.88
		***FGR(I)*: 1980-2002**		
Hypothesis		$\hat{\lambda}_{\text{trace}}$		
H_0	H_A	Statistic	95% CV	90% CV
r = 0	r = 1	80.58**	20.18	17.88
		***FGR(II)*: 1980-2007**		
Hypothesis		$\hat{\lambda}_{\text{trace}}$		
H_0	H_A	Statistic	95% CV	90% CV
r = 0	r = 1	106.45**	20.18	17.88

Notes:
1) The critical values (CVs) of the λ_{trace} test statistics are obtained from Pesaran et al. (2000).
2) ** denotes significance at the 5% level.

The cointegrating vectors can be identified as per capita income equations by normalising on $\ln(y_{p/c})$. With the identifying restrictions imposed, the error-correction mechanism (*ecm*) in each growth regime can be written as follows (standard errors in parentheses):

$$ecm_{SGR,t} = \ln(y_{p/c}) - \underset{(0.086)}{0.492} \times \ln(s) - \underset{(0.171)}{3.469}, \tag{18}$$

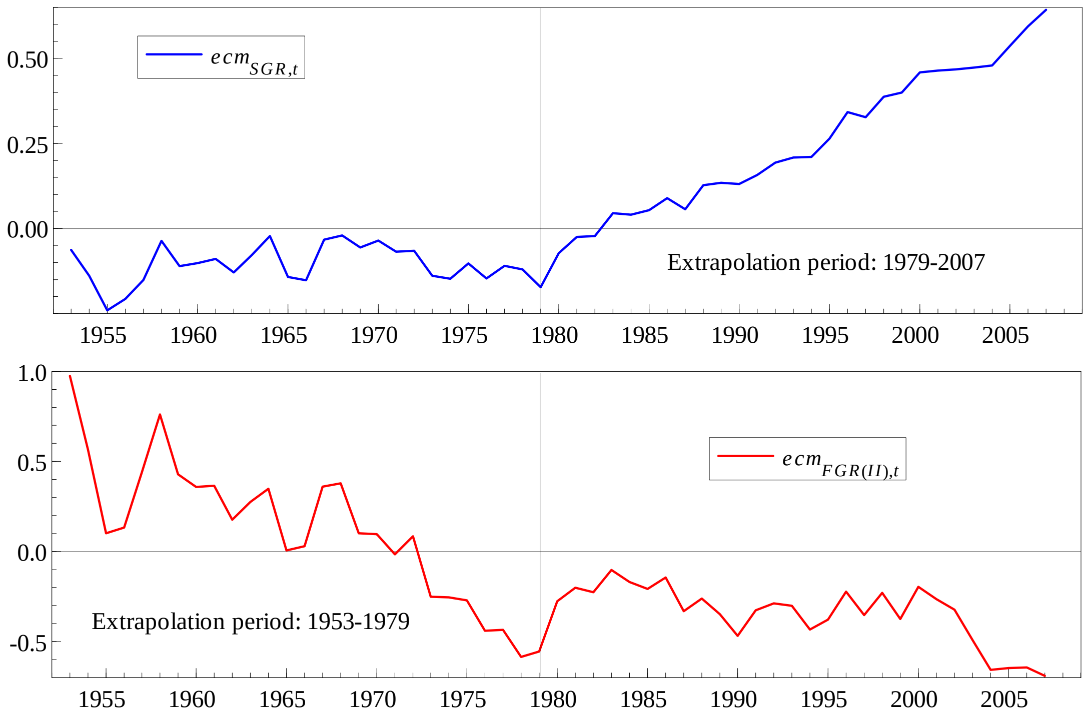
$$ecm_{FGR(I),t} = \ln(y_{p/c}) - \underset{(0.154)}{1.993} \times \ln(s) - \underset{(0.292)}{6.302}, \tag{19}$$

$$ecm_{FGR(II),t} = \ln(y_{p/c}) - \underset{(0.131)}{2.043} \times \ln(s) - \underset{(0.252)}{6.352}, \tag{20}$$

where as before *SGR* denotes the slow-growing regime (1953-1978); *FGR(I)* the faster-growing regime (1980-2002); and *FGR(II)* (1980-2007) the faster-growing regime that includes the 1980 and 2003 growth accelerations. The steady-state relationships can be derived from equations (18)-(20) by solving for per capita income. From these relationships it can be seen that the saving rate variable is correctly signed and significant at the 1% level in each cointegrating vector.

An informative way of relating the cointegrating vectors to the TFP-capital accumulation hypothesis in Figure 6 is to extrapolate the error-correction mechanisms in equations (18) and (20). The forward extrapolation period for $ecm_{SGR,t}$ is 1979-2007, and the backward extrapolation period for $ecm_{FGR(II),t}$ is 1953-1979. Figure 7 plots the error-correction mechanisms over time.

Figure 7. Extrapolating the Error-Correction Mechanisms



From the top panel in Figure 7 it can be seen that $ecm_{SGR,t}$ represents a stationary, cointegrated relationship over the period 1953-1978, but thereafter drifts upwards and becomes non-stationary over the extrapolation (forecast) period 1979-2007. The bottom panel of Figure 7 shows that $ecm_{FGR(II),t}$ is stationary during the period 1980-2007, but non-stationary over the extrapolation (forecast) period 1953-1979.

The main message contained in Figure 7 is that the Indian economy operated on different technical progress functions across the *SGR* and *FGR(II)* periods. The empirical evidence is thus far consistent with the multiple-regime framework of the TFP-capital accumulation hypothesis in Figure 6. In addition, within the theory-consistent framework of the structural cointegrating VAR model, the extrapolation exercise also identifies the date of the regime change (1979-1980), which is consistent with the analysis in section 2 and the literature cited in the same section[12].

5.2 Long-Run Exogeneity Tests

A key empirical issue is to determine whether the saving rate is an exogenous determinant of per capita income in equations (12) and (15). Evidence of cointegration in the previous section implies that long-run causality must exist in at least one direction (Granger, 1988). Since all the variables in the system are treated as endogenous, formal tests have to be conducted to test their exogeneity. Long-run exogeneity tests can be performed by testing the significance of the error-correction mechanisms in the VECM (Johansen and Juselius, 1992). Recall from the VECM representation in equation (17) that the matrix $\mathbf{\Pi} = \alpha_y \beta'$ contains the error-correction coefficients (α_y). More precisely, if Δy_i is unresponsive to the underlying error-correction mechanism so that $\alpha_i = 0$, then y_i can be regarded as *weakly exogenous*. Alternatively, when $\alpha_i \neq 0$, then y_i is endogenous with respect to the error-correction mechanism.

Table 3 reports the long-run exogeneity tests conducted within an unrestricted error-correction model framework.

[12] The literature overview in section 1 (see footnote 1) also includes some opposing views. The strongest claim against a growth transition in or around 1980 comes from Ghate and Wright (2012) (hereafter GW). According to GW, India experienced a growth transition in the late 1980s, following non-trivial policy reforms that preceded the major liberalisation measures during the post-1990 period. GW's empirical evidence, however, is based on a systematic growth shift that occurred across 14 broad industrial sectors and 15 major states. In contrast, the 1980 growth shift in this paper is related to aggregate GDP data, which in all likelihood was not systematic across different sectors and states (see the panel data evidence in Rodrik and Subramanian, 2005). In short, GW's evidence of a systematic growth shift since the late 1980s does not rule out a large aggregate, but unsystematic, growth shift in 1980.

Table 3: Long-Run Exogeneity Tests based on Error-Correction Models

	***SGR*: 1953-1978**		***FGR(I)*: 1980-2002**		***FGR(II)*: 1980-2007**	
Equation	$\Delta\ln(y_{p/c})_t$	$\Delta\ln(s)_t$	$\Delta\ln(y_{p/c})_t$	$\Delta\ln(s)_t$	$\Delta\ln(y_{p/c})_t$	$\Delta\ln(s)_t$
$\Delta\ln(y_{p/c})_{t-1}$	0.128 [0.395]	1.425 [0.058]	–	–	–	–
$\Delta\ln(s)_{t-1}$	–0.128** [0.011]	0.191 [0.396]	–	–	–	–
$\Delta\ln(\tilde{g}_n)_{t-1}$	–0.199*** [0.003]	0.056 [0.844]				
$ecm_{SGR,t-1}$	–0.208*** [0.000]	0.158 [0.439]	–	–	–	–
$ecm_{FGR(I),t-1}$	–	–	–0.098*** [0.000]	0.002 [0.954]	–	–
$ecm_{FGR(II),t-1}$	–	–	–	–	–0.111*** [0.000]	0.042 [0.222]
D_{65}	–0.066*** [0.010]	0.078 [0.494]	–	–	–	–
D_{83}			0.023** [0.017]	–0.037 [0.547]		
$D_{(83,03)}$	–	–	–	–	0.024*** [0.001]	0.026 [0.564]
$D_{(88,99)}$	–	–	0.036*** [0.000]	0.050 [0.268]	0.035*** [0.000]	0.039 [0.389]
D_{91}	–	–	–0.057*** [0.000]	–0.074 [0.253]	–0.061*** [0.000]	–0.093 [0.155]
$\mathbf{R^2}$	0.52	0.17	0.79	0.11	0.86	0.06
$\hat{\sigma}$	0.022	0.10	0.008	0.060	0.008	0.061
F_{ar}	0.036 [0.850]	0.452 [0.509]	1.055 [0.318]	1.310 [0.267]	1.753 [0.199]	0.756 [0.393]
F_{reset}	0.824 [0.375]	0.724 [0.405]	1.759 [0.201]	1.917 [0.183]	0.020 [0.888]	0.453 [0.507]
χ_n^2 **(2)**	0.316 [0.854]	1.033 [0.596]	0.884 [0.642]	1.197 [0.549]	4.645 [0.098]	1.787 [0.409]
F_{het}	1.431 [0.243]	0.318 [0.577]	0.072 [0.790]	1.011 [0.326]	0.010 [0.918]	0.191 [0.665]

Notes:

3) *p*-values are given in brackets [·]. *** denotes significance at the 1% level and ** at the 5% level.
4) R^2 is the coefficient of determination and $\hat{\sigma}$ is the residual standard deviation. The diagnostic tests are given as F_j, which indicates an F-test against the alternative hypothesis *j* for: first-order serial correlation (F_{ar}); functional form misspecification (F_{reset}); heteroscedasticity (F_{het}). χ_n^2 is a chi-square test for normality. For more details, see Pesaran and Pesaran (1997).

There is a consistent finding across all the different growth regimes: the error-correction mechanism (*ecm*) enters significantly in the per capita income equation but insignificantly in the saving rate equation. Put in another way, per capita income adjusts towards its long-run equilibrium value but not the saving rate. Thus, the empirical results confirm the exogenous nature of the saving rate in equations (12) and (15)[13].

The insignificance of all the diagnostic tests at conventional levels in Table 3 indicates that the long-run exogeneity results are statistically robust. This contention is further supported by a wide range of constancy and structural stability tests conducted in each sub-sample, which all prove to be insignificant at the 1% level[14].

5.3 Structural Change in the Learning by Doing Parameter and the TFP Part of the Model

The steady-state relationships are obtained by solving the cointegrating vectors in equation (18)-(20) for per capita income. Columns (1) and (2) of Table 4 record the intercept and saving rate elasticity estimates of the solved per capita income equations. Note that the saving rate elasticity estimates in column (2) are equal to $\hat{\beta}/(1-\hat{\beta})$ in equation (12), where $\hat{\beta}$ is the elasticity of output with respect to capital. Column (3) gives the solved capital elasticity estimate ($\hat{\beta}$) for each growth regime. Since the production function in equation (6) shows that $\hat{\beta} = \alpha + \phi(1-\alpha)$, it is possible to derive an implied value for the learning by doing parameter (ϕ) if the usual assumption is made that capital's share in total income is around

[13] Based on the discussion in section 3.6, the exogeneity of the saving rate shows that per capita income is financed out of domestic resources. From these results, however, it is not possible to deduce whether domestic resources (saving) are generated through a reduction in the propensity to consume, or whether an increase in investment spending (financed out of domestic credit) generates its own saving through per capita income changes. To test this, Nell (2012) proposes an identification scheme conducted within a structural cointegrating VAR modelling framework that explicitly controls for the open-economy saving/investment relationship. In the present context, it is only relevant to establish/confirm that an increase in domestic resources and a faster rate of capital accumulation determines per capita income.

[14] Recursively estimated structural stability tests based on 1-step Chow tests, break-point Chow tests and forecast Chow tests are performed on each individual equation and the system as a whole. None of the tests are significant at the l% level. All the stability tests were obtained using PcGive 11: Volume II (Doornik and Hendry, 2006).

one-third ($\alpha = 0.33$) in each growth regime. Column (5) reports the implied learning by doing parameter estimate for each growth regime.

Table 4: Structural Change in the Learning by Doing Parameter (ϕ)

	(1)	(2)	(3)	(4)	(5)
Growth Regime	***Intercept***	$\hat{\beta}/(1-\hat{\beta})$	$\hat{\beta} = \alpha + \phi(1-\alpha)$	***Assumed:*** α	***Implied:*** ϕ
***SGR*:1953-1978**	3.469	0.492	0.33	0.33	0
***FGR(I)*:1980-2002**	6.302	1.993	0.67	0.33	0.50
***FGR(II)*:1980-2007**	6.352	2.043	0.67	0.33	0.50

Note:

1. The standard errors of the intercept terms in column (1) and the saving rate elasticities in column (2) are reported in equations (18)-(20). From these estimates it can be seen that the intercept terms and saving rate elasticities are significant at the 1% level in all the growth regimes.

The discussion will now focus on the intercept and learning by doing parameter estimates in columns (1) and (5), respectively, and how these values relate to the TFP-capital accumulation hypothesis in Figure 6. Consider the large increase in the intercept coefficient in the *FGR(I)* relative to the *SGR*. Since the specification of the VECM in section 4.2 implies that the intercept term includes the value of the long-run growth rate in each regime, the intercept shift can be associated with an upward shift in the technical progress function in Figure 6. The upward shift in the technical progress function, in turn, is associated with of an increase in TFP growth.

At the same time, the value of the learning by doing parameter in column (5) increases sharply from zero in the *SGR* to 0.50 in the *FGR(I)*. The empirical evidence shows that the Solow model in equation (15), with a learning by doing parameter equal to zero, is the relevant specification in India's *SGR*, whereas the learning by doing model in equation (12) is the appropriate specification in India's *FGR(I)*. Also note that, consistent with the Solow growth model framework, Table 3 reports a strong negative effect running from population growth ($\Delta \ln(\tilde{g}_n)_{t-1}$) to per capita income growth in the *SGR*[15].

The structural shift in the learning by doing parameter in Table 4 across the *SGR* and *FGR(I)* regimes is modelled as an increase in the slope coefficient of the technical progress function in Figure 6. Faster growth at point B in the *FGR(I)* relative to point A in the *SGR* is therefore the result of an increase in TFP growth and an increase in the slope coefficient of the technical progress function, as shown in Figure 6. Although capital accumulation contributed to the initial growth shift, as measured by the change in the slope coefficient of the technical progress function, the dominant impact of TFP growth has already been verified by the growth statistics in Table 1, which show that the shift in output per worker growth during the 1980s and 1990s was much larger than capital per worker growth. This scenario is illustrated in Figure 6, in which TFP growth accounts for most of the initial growth shift from point A to point B[16].

5.4 Explaining India's Initial TFP-driven Growth Shift

Before the analysis turns to the capital accumulation part of the model, it is informative to identify the underlying causes of India's initial TFP-driven growth shift out of its slow-growing regime during 1953-1978 into a faster-growing one over the period 1980-2002. Most growth narratives highlight the gradual relaxation of import control measures in

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[15] Given the I(0) nature of population growth in the *SGR*, its impact on per capita income is only temporary (see the discussion of equation (15) in section 3.5 and the analysis in section 4.2). Population growth is also an insignificant long-run determinant in the learning by doing model during the *FGR(I)* and *FGR(II)* regimes. Recall from the discussion of equation (12) in section 3.5 that the net impact of population growth in the learning by doing model is ambiguous. More specifically, the decelerating trend in India's population growth rate observed since the early 1980s may have induced a negative long-run effect, which was equally offset by positive transition dynamics.

[16] Note that the slope change ($\Delta\phi$) of the technical progress function increases the weight of capital per worker growth relative to TFP growth in equation (8). However, the large increase in output per worker growth relative to capital per worker growth in Table 1 implies that, even if the learning by doing parameter increased to a maximum value of one, TFP growth would still dominate the initial growth shift.

the late 1970s and mid-1980s together with a government-led expenditure strategy as the key initiating forces (Athukorala and Sen, 2002; Nell, 2012, 2013; Panagariya, 2005, 2008; Sen, 2007).

An important implication of India's restrictive trade regime in the pre-1980 period was the use of outdated and less productive technologies by domestic firms (Panagariya, 2005; Pursell, 1992). Less stringent import control measures in the late 1970s and mid-1980s allowed the importation of more modern equipment investment goods with embodied technical progress (Athukorala and Sen, 2002; Sen, 2007). At the same time, because domestic producers of capital goods were faced with greater competition, the relative price of equipment decreased sharply since the late 1970s (see Figure 9 in Sen, 2007). These favourable supply-side factors induced firms to raise their investment in equipment relative to structures, as captured by stylised fact (iii) in section 2.5. From the demand side, the surge in government spending during the 1980s made it profitable to use increasing returns to scale technologies in the production process (Murphy et al., 1989; Nell, 2013).

The growth strategy during the 1980s, however, was unsustainable (Nell, 2013; Panagariya, 2005, 2008). Because export growth did not match faster import growth, foreign debt gradually accumulated over time and eventually led to the balance-of-payments crisis of 1991. The sweeping deregulation measures in the post-1990 period, which among others included major trade liberalisation measures, played an important role in sustaining the growth shift initiated during the 1980s. The surge in export growth during the post-1990 liberalisation period generated foreign exchange earnings to pay for the import requirements for growth (Nell, 2013).

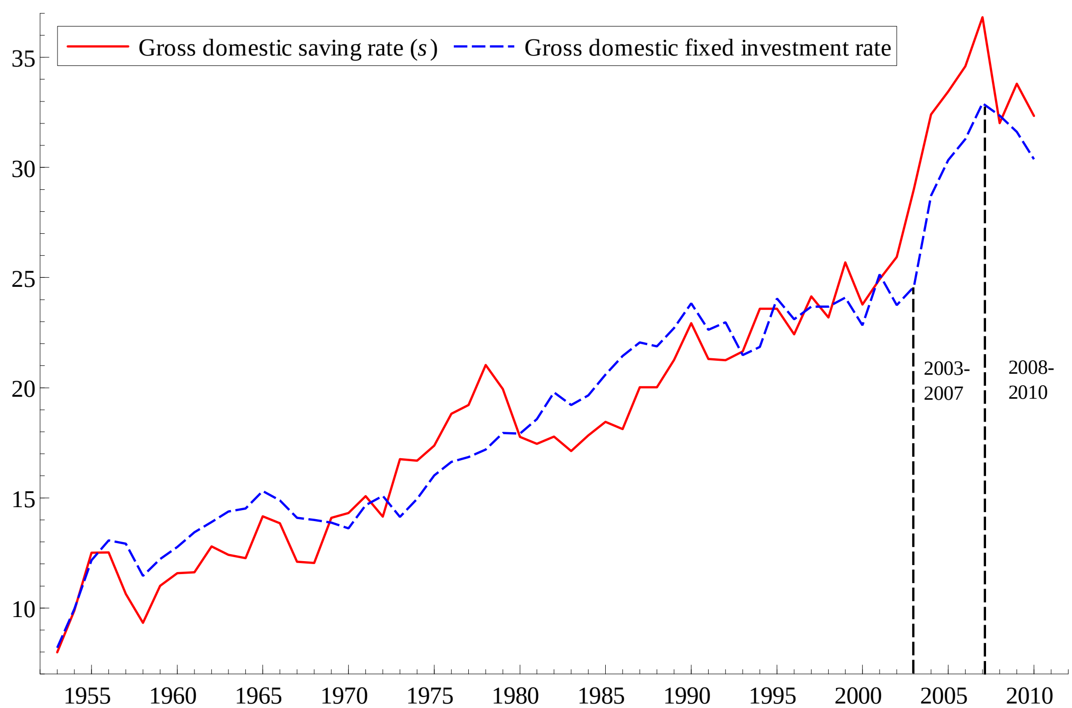
The growth narrative presented above is consistent with the empirical results obtained for the *SGR* and *FGR(I)* regimes in Table 4. Disembodied technical progress, with a corresponding learning by doing parameter estimate of zero, captures India's restrictive trade regime during the period 1953-1978. Embodied technical progress, with an associated learning by doing parameter of 0.50 over the period 1980-2002, on the other hand, reflects the impact of greater trade openness and how the Indian economy managed to achieve this on a sustainable basis. Thus, the upward shift and increase in the slope coefficient of the technical progress function in Figure 6 models the growth effect of India's integration into the world economy.

5.5 The Capital Accumulation Part of the Model: co-breaking

While the first phase of India's growth transition from point A to point B in Figure 6 is closely related to India's integration into the world economy, the second phase from B to C is all about the long-run growth effect of capital accumulation. Faster output per worker growth relative to capital per worker growth at point B in Figure 6 implies a rising profit rate over the *FGR(I)* regime. This prediction of the TFP-capital accumulation model is supported by Felipe et al.'s (2008) descriptive analysis, which shows that the profit rate increased along a rising trend line during the 1980s and 1990s. The main implication is that firms were unwilling to reinvest their profits during the *FGR(I)* period due to an unfavourable/uncertain domestic investment climate, as outlined in Felipe et al. (2008). Evidence of uninvested profits, an exogenous saving rate in Table 3 and a learning by doing parameter estimate of 0.50 in Table 4 implies that the Indian economy had a large amount of untapped long-run growth potential during the *FGR(I)* regime, which could have been unleashed through a faster rate of capital accumulation. The movement along the technical progress function from B to C in Figure 6 shows the potential long-run growth effect of a faster rate of capital accumulation.

Recall from the empirical hypothesis outlined in section 4.2 that structural invariance of the learning by doing model over the *FGR(I)* and *FGR(II)* regimes can be interpreted as evidence of a movement along the technical progress function from B to C in Figure 6, which supports the capital accumulation-driven part of the model. From Table 4 it can be seen that the estimates in columns (1) and (5) are virtually identical across the *FGR(I)* and *FGR(II)* regimes. Moreover, the long-run causality tests in Table 3 show that the saving rate maintains its exogenous nature over the two sub-samples. Thus, the 2003-2007 growth acceleration contained in the *FGR(II)* regime must have been caused by an exogenous shock to the saving rate, rather than a structural shift in the parameter estimates of the model.

Figure 8. India's Saving and Investment Rates, 1953-2010



Note:

1) Data Source (see Appendix A): Reserve Bank of India.
2) Harvey and Koopman's (1992) break-point test identifies level breaks in both series in the early and late 2000s.

Figure 8 shows a large trend break in both the gross domestic saving rate and gross domestic fixed investment rate over the period 2003-2007, which coincides with the growth acceleration observed in Figure 4. Structural invariance and co-breaking between the real

GDP per capita and saving/investment rate series provide strong evidence of a capital accumulation-driven growth transition over the period 2003-2007.

But what exactly encouraged firms to save and invest a larger fraction of their profits accumulated during the *FGR(I)* phase of the growth transition? The answer is a more favourable domestic investment climate during the 2003-2007 period relative to the *FGR(I)* regime. Consider the following extract from an article written in the *Business Standard* by Rajiv Lall (August 2003) who – then managing director of Warburg Pincus – had this to say about the cost-reducing effect of lower interest rates on the Indian economy:

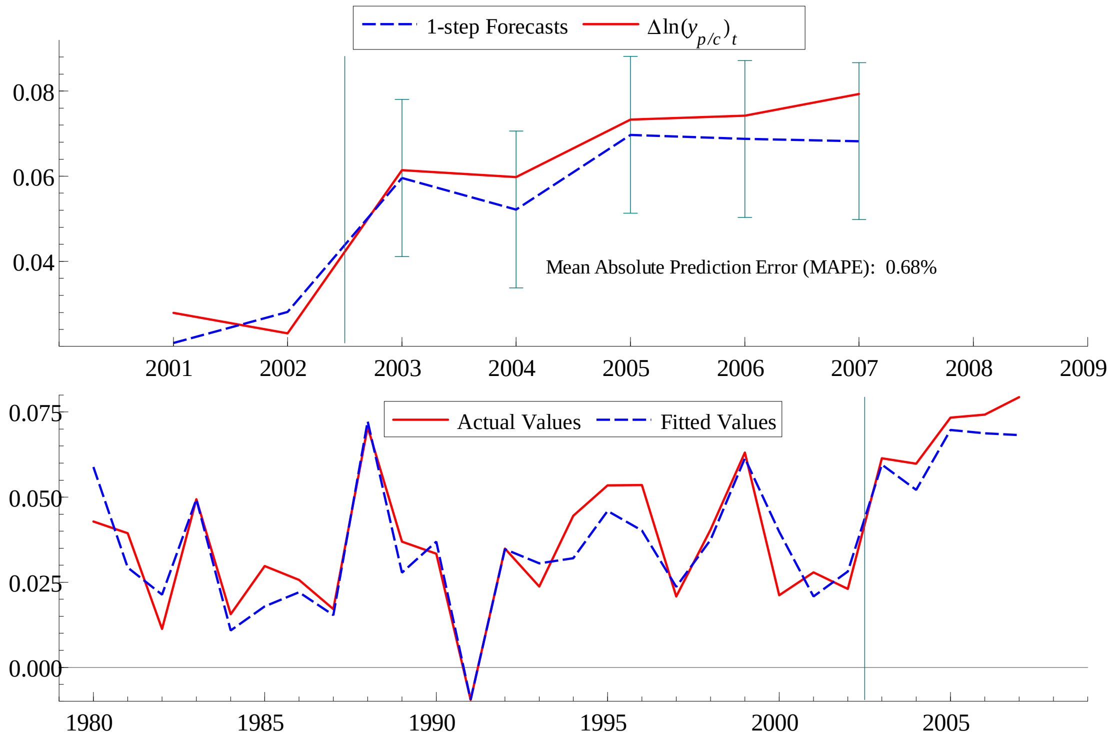
> *"Ten, five, even three years ago I would have, and did, make the bet that China's growth rate would outperform India's. Today, I would have to be more circumspect. My bet is that India will begin to outperform China within the next five years. What accounts for this change in perspective?... by far the most significant development in the Indian macro story is the declining cost of capital. It is difficult to exaggerate the impact that falling interest rates have had on the functioning of the Indian economy… Over the past three years, borrowing rates have declined by about 600 basis points for most medium to large sized enterprises in the country… Given that borrowing costs for larger corporates have fallen as much as 40 per cent in the past three years, profits before tax for these companies have more than doubled, raising returns on equity to well above the cost of capital. Suddenly, even manufacturing activity is looking like an attractive proposition in India" (Lall, 2003).*

In short, the significant drop in the cost of borrowing may have increased the risk-adjusted return on capital, which served as an incentive for firms to reinvest their profits.

5.6 The Capital Accumulation Part of the Model: forecasts and growth accounting

An alternative and more direct way to test whether the 2003-2007 growth acceleration represents a movement along the technical progress function is to examine the forecasting properties of the *FGR(II)* error-correction model in Table 3. The *FGR(II)* model is estimated over the period 1980-2002 and one-step ahead forecasts for $\Delta\ln(y_{p/c})_t$ are generated over the period 2003-2007. The top panel of Figure 9 reports the one-step ahead forecasts scaled by their 95% confidence bar intervals (see Doornik and Hendry, 2006). The model accurately predicts India's growth acceleration over the period 2003-2007, with every actual value falling well within the 95% confidence intervals of the individual forecasts. The bottom panel of Figure 9 shows how well the fitted values of the model trace the actual values of the real GDP per capita growth rate.

Figure 9. One-Step Ahead Forecasts, 2003-2007



The good forecasting properties of the *FGR(II)* model confirm the capital accumulation-driven nature of India's growth acceleration during the period 2003-2007. The sharp drop in the user cost of capital mentioned in Lall (2003) encouraged firms to save and invest a larger fraction of their accumulated profits. The exogenous shock to the saving rate led to a faster rate of capital accumulation and moved the Indian economy along its technical progress function from point B to point C in Figure 6.

Note that the impact of the saving shock in the *FGR(II)* model is captured by the error-correction mechanism or cointegrating vector in equation (20). The good forecasting performance of the model in Figure 9, with a low mean absolute prediction error of 0.68%, is directly related to the large saving rate elasticity in the *FGR(II)* regime. The magnitude of the saving rate elasticity corresponds to a capital elasticity estimate of 0.67 in column (3) of Table 4. This estimate gives a large weight to capital accumulation as a determinant of per capita income growth. Alternatively, if the analysis had followed the conventional practice in growth accounting and *a priori* assumed a capital elasticity estimate of 0.33, then the forecasting performance of the *FGR(II)* model would have deteriorated markedly: a large proportion of the growth acceleration would have been relegated to the error term or, in growth accounting terms, would have been TFP driven. This underlines the importance of estimating the elasticity of output with respect to capital, rather than assuming that the elasticity is equal to capital's share in total income, as is often done in growth accounting exercises.

Finally, because the forecasts of the *FGR(II)* error-correction model are obtained from an *initial* steady-state position at point B in Figure 6, some proportion of the average growth rate of 7.20% over the period 2003-2007 is long run, as shown by the movement along the technical progress function in Figure 6, and the rest is short-run. The capital elasticity estimate of 0.67 ($\hat{\beta} = \alpha + \phi(1-\alpha)$) in the error-correction mechanism is composed of the learning by doing parameter estimate and capital's share in total income. The technical progress function analysis in Figure 6, on the other hand, isolates the long-run effect by assuming $0 < \phi < 1$ and $\alpha = 0$. Although it is important, from a policy perspective, to realise that an investment-friendly domestic environment can generate a long-lasting impact on per capita income growth, the prospective policy maker should not be concerned if some of the growth is transitory. Indeed, as emphasised in Temple (2003), if transitory growth raises the *level* of per capita income by a substantial amount, then the distinction between long-run effects and transitory dynamics becomes less important from a policy perspective.

5.7 The Global Financial Crisis (2008-2010) and Implications for Future Growth

India's impressive growth acceleration over the period 2003-2007 was unexpectedly interrupted by the global financial crisis of 2008. Real GDP per capita growth slowed down from an average rate of 7.20% over the period 2003-2007 to 2.42% in 2008. To weather the initial impact of the crisis, the Indian government initiated a broad stimulus package that included tax cuts and increases in expenditures (De, 2012). The Indian economy quickly recovered from the initial downturn and recorded real per capita income growth rates of 6.53 and 7.76% in 2009 and 2010, respectively.

From Figure 8, however, it can be seen that the recovery coincided with a steady decline in the gross domestic fixed investment rate from 33% in 2007 to 30.4% in 2010. Because the capital accumulation part of the model in Figure 6 is about the growth-inducing effect of fixed investment, the *FGR(II)* error-correction model in Table 3 cannot predict the recovery in the 2009-2010 period. In effect, the decrease in the fixed investment rate implies that the economy regressed from point C to point B in Figure 6, whereas in reality growth recovered to its pre-crisis rates.

The reason why there is an apparent contradiction is because the stimulus package encouraged firms to run down their stock of inventories. The inventory investment rate increased from a low of 2% in 2008 to rates of 5% and 4.70% in 2009 and 2010, respectively. Firms, of course, cannot deplete their stock of inventories indefinitely. Thus, the ability to maintain high saving/fixed investment rates and keep the economy as close as possible to point C in Figure 6 will continue to be one of the driving forces of India's future growth performance.

6. CONCLUSIONS

Against the ambiguous backdrop of previous studies, this paper has re-examined the role of physical capital accumulation in the Indian economy over the period 1953-2010. As an alternative to the orthodox TFP view in the growth literature, the analysis introduced a combined TFP-capital accumulation hypothesis. The novelty of the combined model is that it examines an economy's growth performance in a multiple-regime framework, as opposed to the single regime frameworks of most studies, and is therefore tailor-made to analyse the relative importance of TFP and physical capital accumulation across India's different growth regimes.

The main results show that the original Solow model, with a learning by doing parameter estimate of zero ($\hat{\phi} = 0$), provides a good description of India's slow-growing regime (1953-1978), whereas a learning by doing model with $\hat{\phi} = 0.50$ fits its faster-growing regime (1980-2007). The discussion in section 5.4 suggests that the increase in the learning by doing parameter estimate is closely related to trade openness, and how the Indian economy managed to become more open on a sustainable basis.

The structural change across the two regimes/models involved two phases. The first phase of the growth shift during the period 1980-2002 was primarily TFP driven. However, empirical evidence of uninvested profits (also see Felipe et al., 2008), a positive learning by doing parameter estimate ($\hat{\phi} = 0.50$) and an exogenous saving rate during the first phase of the growth shift implies that physical capital accumulation became a potential determinant of long-run growth. The second phase of the growth shift transpired over the period 2003-2007 when a significant reduction in the user cost of capital encouraged firms to reinvest their profits accumulated during the first phase. The error-correction model, conditional on the saving rate as an exogenous variable and with a capital elasticity estimate of 0.67, accurately predicts the 3.84 percentage points increase in per capita income growth over this period. Finally, in section 5.7 it was argued that the ability of policy makers to maintain high saving/fixed investment rates will continue to dictate the pace of future growth, despite the turbulent years of the global financial crisis since 2008.

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APPENDIX A, Table A1 – INDIA'S VARIABLE DEFINITIONS AND DATA SOURCES

The data cover the period 1950-2010. However, due to lagged and differenced variables the sample period is reduced to 1953-2010.

Variable	Description	Source
$\ln(y_{p/c})$	Natural logarithm of real GDP per capita at market prices (Base year: 2004-2005)	Reserve Bank of India
$\ln(s)$	Natural logarithm of gross domestic saving as a share of nominal GDP at market prices	Reserve Bank of India
Gross domestic fixed investment rate	Aggregate fixed investment as a share of nominal GDP at market prices	Reserve Bank of India
Pop	Population	Reserve Bank of India
$\ln(\tilde{g}_t^n)$	Natural logarithm of the population growth rate	$\tilde{g}_t^n \equiv [(\ln \text{Pop}_t - \ln \text{Pop}_{t-1}) \times 100]$
Dummy: D_{65}	Equals 1 in 1965; 0 otherwise	Represents the macroeconomic crisis of 1965, a severe drought and war with Pakistan. See Panagariya (2008).
Dummy: D_{83}	Equals 1 in 1983; 0 otherwise	Outlying (positive) growth in 1983. Associated with India winning the cricket world cup.
Combined Dummy: $D_{(83,03)}$	Equals 1 in 1983 and 2003; 0 otherwise	Outlying growth in 1983 and the beginning of another growth acceleration in 2003, following the sharp drop in the user cost of capital (see Lall, 2003).
Combined Dummy: $D_{(88,99)}$	Equals 1 in 1988 and 1999; 0 otherwise	Outlying growth in 1988 and 1999. Faster growth in 1988 reflects the impact of significant policy reforms that were initiated since the mid-1980s (Panagariya, 2005, 2008). Rapid growth in 1999 captures the effect of another wave of major trade liberalisation measures that were introduced in the late- to mid-1990s, and the resulting surge in equipment investment in Figure 3 of this paper. Also see Table 6 (p. 207) and Table 4 (p. 208) in Rodrik and Subramanian (2005) for data on India's protection measures.
Dummy: D_{91}	Equals 1 in 1991; 0 otherwise	Balance-of-payments crisis and outlying (negative) growth in 1991. (See Panagariya, 2008).