Technology as a channel of economic growth in India

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Abstract

After decades of slow growth since Independence from the British Raj, Indian economy registered its own small miracle, when growth rate of GDP per capita surpassed the long term growth rate of many advanced economies. What caused this miracle? In this paper, we search for an answer in the neoclassical growth model. We use productivity as measured by Solow residual as our exogenous shock. Our idea is to quantitatively measure to what extent fluctuations in productivity can account for observed fluctuations in macro economic aggregates in India. We find that exogenous fluctuations in productivity can well account for fluctuations in output during the boom periods of 1982 to 1988 and 1993 to 2002. However, fluctuations in productivity alone results in a much worse drop in output during 1988 to 1993 than observed in the economy.

1 Introduction

Since the eighties, the Indian economy has rapidly transformed itself from a poor economy known more for its uncontrollable population growth to an economy viewed by many as the new miracle. A brief look at the growth rate of GDP per capita bears testimony to this fact. During the period 1960 to 1979, the growth rate of GDP per capita stood at 1.1%. Since 1980, the growth rate has increased to 3.8%, which is higher than the long term growth rate of 2% observed in many industrialized countries, like United States.

In this paper, I ask the question "To what extent can changes in productivity quantitatively account for the observed changes in output per capita?" The common understanding is that the Indian economy saw an unprecedented spurt of software development, which coupled with a drastic changes in policy encouraging free markets and liberalization led to a rapid growth in productivity. This development, coupled with the fact that India is traditionally a cheap labor market, which now became a source of skilled labor, at least in the software arena, led to increases in output per capita.

Literature in this area has been comparatively sparse, though much debate has ensued as to what caused India's small miracle? There are quite a few papers which agree with the contribution of Indian IT sector as the catalyst of economic growth. On one hand we have Nirvikar Singh (2004) who argues the important role played by the Indian IT sector in promoting growth. This view, perhaps not surprisingly, finds great support among the IT pioneers of India. NR Narayan Murthy, Chairman of Infosys, one of the fastest growing IT companies that originated in India hails the changing climate in India by arguing that "...the economic reforms of 1991 changed the Indian business context from one of state-centered, control orientation, to a free, open market orientation - especially for hi-tech companies. It allowed Indian companies to start competing effectively on a global scale" at the Indian Economy Conference at Cornell University (2002) . On the other end of the spectrum, we have Dani Rodrick and Arvind Subramanian (2004) who investigate "... a number of hypotheses about the causes of this growth – favorable external environment, fiscal stimulus, trade liberalization, internal liberalization, the green revolution, public investment – and find them wanting." They argue that " .. growth was triggered by an attitudinal shift on the part of the national government towards a pro-business (as opposed to pro-liberalization) approach." So, it is probably safe to surmise that the debate as to the cause of growth is very much alive.

I take an alternative approach to the entire question by trying to quantitatively account for the extent to which the growth rate of GDP per capita can be explained by growth in aggregate productivity. To this end, I use a dynamic general equilibrium model with exogenous productivity as representative of the Indian economy. My objective is to see how output per capita, investment per capita and labour responds to an exogenous change in productivity.

My approach is the neoclassical approach of business cycle accounting popularized by Finn Kydland and Ed Prescott (1986). The economy is modeled as a dynamic general equilibrium where the only source of exogenous shocks is the changes in productivity. The neoclassical approach of Kydland-Prescott considers productivity in the simplest form: changes in Total Factor Productivity (TFP) as the residual of output after accounting for capital and labor contributions. In this sense, the approach does not provide any insight as to the sources of productivity growth or sectors where the growth might have originated. It is simply meant to capture if such exogenous changes in TFP can substantially explain changes in macroeconomic aggregates if TFP is the only exogenous shock to hit the economy.

The rest of the paper is organized as follows: in section 2, I provide an outline of the Indian economy since 1960 to 2004. In section 3, I outline the model. In this section, I also outline the methodology that I apply to solve the model for the policy variables, including the calibration technique to solve for the model parameters. Section 4 provides a summary of the results. Section 5 concludes the paper.

2 The Indian Economy

Let us begin our analysis with an examination of the National Income Accounts of India since 1960 to 2004. The variables of interest to us are output per capita, investment per capita and the evolution of labor throughout the period. In keeping with the tradition of neoclassical analysis, our population is the working age population, that is, population aged 15 to 64 years. Further, we are interested in seeing how the macro aggregates of the Indian economy diverged from the balanced growth path values of these aggregates. One of the problems that we encounter is that data on labor hours is restricted to be available only from 1982 onwards. Consequently, we summarized the period between 1960 and 1982 in figures and plot the evolution of the economy since 1982. We assume, like Prescott-Hayahsi (2002) that the long term growth rate of an economy poised to be on the balanced growth path is 2%. We detrend output per capita, investment per capita and government expenditure per capita by 2% and report the results. We further report the observed labor hours.

2.1 Output and Investment per capita

GDP per capita grew well below trend during the period 1960 to 1980 and it grew progressively worse between this period. Since 1980 the GDP per capita has started growing. Since 1994, the per capita growth rate of GDP has consistently been above 2% till the present period. Figure 2.1 shows GDP per capita with respect to a 2% trend between 1982 and 2002.

A similar trend of growth is observed when we look at investment per capita after accounting for the long term trend. The difference is that while growth rate of output per capita worsened between 1960 to 1980, we do not see such an experience for investment per capita. It remained pretty stable till 1980 but has substantially picked up since then. So during 1960 to 1980, if increased investment did not translate to increased output, the problem might be in productivity. Figure 2.2. captures investment trend since 1982.

2.2 Share of government expenditure in GDP

What is also interesting in the Indian context is the observed ratio of Government expenditure to GDP. We find that share of government expenditure in GDP increased since 1960 throughout the eighties. The share fell briefly during the early part of the nineties. Government has played a major role in Indian development since the planning period and fiscal policy was a big part of it. The problem was that increased government expenditure could not translate to increased economic growth. The trend in government expenditure since 1982 is captured in Figure 2.3

2.3 Employment and labor hours

Tracing the evolution of employment and labor hours in India possesses an unique challenge The data on employment is available only from the organized sector and in India a large proportion of the population is either self-employed or employed in the unorganized sector. Similarly, data on labor hours is only restricted to the organized sector. We can gather data on working population as a percentage of total population from Bureau of Labor Statistics. The years for which it is available is 1982 onwards. Our definition of working population is population aged 15 to 64 years. Further we have data on percentage unemployed. We calculate employment by subtracting unemployed from working population. As for labor hours, we assume that any labor has 100 hours a week at his or her disposal For our analysis, hours worked is taken as hours worked in manufacturing.

We denote labor as

$$l(t) = \frac{E(t) * H(t)}{N(t) * 100}$$

$$where \frac{E(t)}{N(t)} : employment\ as\ a\ fraction\ of\ working\ population\ and$$

$$\frac{H(t)}{100} : labor\ hours\ as\ a\ fraction\ of\ total\ hours$$

From our analysis, we find that $l(t)$ increases from .4 to .44 between 1982 to 2002. This is depicted in Figure 2.4.

3 Indian Economy from a Growth Theory Perspective

3.1 Model description

Our economy consists of a continuum of infinitely lived representative agents who have one unit of time endowment. They value consumption and leisure and earn wage and rental income. They spend their after tax income on consumption and save the rest in form of capital used for future production. I assume tax to be lumpsum. Further, we assume there is just one good that is used for consumption and investment. The consumer maximizes the present discounted value of lifetime utility subject to the budget constraint. Therefore, the representative consumer's problem can be written as:

$$Max \sum_{t=0}^{\infty} \beta^t u(c_t, 1-l_t)$$
$$subject\ to:$$
$$1.c_t + k_{t+1} - (1-\delta)k_t \leq w_t l_t + r_t k_t - T_t \ \forall t$$
$$2.nonnegativity\ constraints$$

where c_t : is the consumption in period t, l_t : labor in period t, k_t : capital in period t, w_t : is the wage rate in period t, r_t : rental rate in period t. We further denote the rate of time preference as β.The rate of depreciation of capital stock is denoted by δ. There is a representative firm that owns the production technology. The firm is owned by the consumers who get the proceeds from the firm. The firm's problem can be written as:

$$Max\ y_t - w_t l_t - r_t k_t$$
$$subject\ to:$$
$$y_t \leq F(k_t,\ l_t, z_t)\ \forall t$$

where y_t : denotes output in period t, and z_t : denotes productivity.

Apart from consumers and the representative firm, the economy also has a government that balances budget every period so that government expenditure every period G_t is equal to the lumpsum taxes, $T_{t.}$ Further, the resource constraint of the economy every period is given by:

$$c_t + k_{t+1} - (1-\delta)k_t + G_t \leq T_t$$

The equilibrium in the economy can be summarized as consisting of a set of allocations, $\{c_t,\ l_t,\ k_{t+1},\ y_t\}_{t=0}^{\infty}$ and a set of prices $\{w_t,\ r_t\}_{t=0}^{\infty}$ such that the representative consumer maximizes present discounted value of lifetime utility subject to budget and nonnegativity constraints as outlined in consumer's problem; the representative firm maximizes profits every period subject to technology constraint. Further, every period the government balances the budget and resource constraint is satisfied.

3.2 Solution procedure

To solve the model, we first have to decide on the functional forms. For purpose of our analysis we assume that utility function is of the form:

$$u(c_t, l_t) = \log c_t + \alpha_1 \log(1 - l_t)$$

We assume the production function to be Cobb-Douglas with labor augmented technology:

$$F(k_t, l_t) = k_t^{\theta}(z_t l_t)^{1-\theta}$$

We solve for the first order conditions using the functional forms specified above. Further, we also allow for population growth and assume that population grows every period at the rate η.

Now the representative consumer's problem reduces to:

$$Max \ \sum_{t=0}^{\infty}(\beta\eta)^t(\log c_t + \alpha_1 \log(1 - l_t))$$
$$subject\ to:$$
$$1.c_t + \eta k_{t+1} - (1-\delta)k_t \leq w_t l_t + r_t k_t - T_t \ \forall t$$
$$2.nonnegativity\ constraints$$

The firm's problem reduces to:

$$Max\ y_t - w_t l_t - r_t k_t$$
$$subject\ to:$$
$$y_t \leq k_t^{\theta}(z_t l_t)^{1-\theta}\ \forall t$$

and government's problem remains the same. The resource constraint reduces to :

$$c_t + \eta k_{t+1} - (1-\delta)k_t + G_t \leq T_t$$

We want to solve the model using the technique of log linearization around the steady state, so we have to transform the model variables by discounting them with the long term growth rate g_z.The model can be summarized by the following first order conditions, where hat denotes a variable discounted by the long term growth rate, for example $\widehat{x}_t = \frac{x_t}{(1+g_z)^t}$:

$$\begin{aligned}
1.\frac{\alpha}{1-\theta} &= \frac{\widehat{w}_t(1-l_t)}{\widehat{c}_t} \\
2.\beta E_t \frac{\widehat{c}_t}{\widehat{c}_{t+1}}\{\widehat{r}_{t+1}+1-\delta\} &= (1+g_z) \\
3.(1-\theta) &= \frac{\widehat{w}_t l_t}{\widehat{y}_t} \\
4.\theta &= \frac{\widehat{r}_t k_t}{\widehat{y}_t} \\
5.\widehat{y}_t &\leq \widehat{k}_t^{\theta}(\widehat{z}_t l_t)^{1-\theta} \\
6.\widehat{c}_t + \eta(1+g_z)\widehat{k}_{t+1} - (1-\delta)\widehat{k}_t + \widehat{G}_t &\leq \widehat{T}_t
\end{aligned}$$

For our model solution, we first need to calibrate the model to match the model parameters to the moments of the data.

3.3 Data description and Model calibration

The data is collected from World Bank data of World Development Indicators. We collect the labor data from Bureau of Labor Statistics. The data for India is only available from 1982 onwards. Given the data restrictions, we restrict the data analysis to the period 1982 to 2002.

Moments of the data (taking averages of the period 1982 to 2002):

$$\begin{gathered}
c/y = .69 \\
x/y = .19 \\
wl/y = .64 \\
l = .433 \\
\eta = .0235 \\
g_z = .02
\end{gathered}$$

Table 1: Moments of the data, average over the period 1982 to 2002

I am assuming that the long run growth rate of the economy is 2% which is the long run growth rate of United States. Another problem is that we do not have the capital output ratio of the economy. In absence of such a ratio, we pick the depreciation rate δ to be 25%, the rate allowed by the Indian tax code on physical capital. One other problem is calculating the share of GDP going to labor. We assume the value from growth literature. We can conduct robustness check for different values of theta. The calibrated parameters of the model reduces to:

$\theta = .36$
$\alpha = 1.22$
$\beta = .77$
$\delta = .25$

Table 2: Calibrated value of model parameters

Once we calibrate the parameters of the model, we can find the steady state values which enables us to log-linearize the model. We want to use the King, Plosser and Rebelo (1988) technique to solve for the policy parameters. When we loglinearize the equations our system reduces to:

$$7. \widetilde{y}_t - \theta * \widetilde{k}_t - (1-\theta) * (\widetilde{z}_t + \widetilde{l}_t) = 0$$

$$8. \widetilde{y}_t - (\frac{c}{y}) * \widetilde{c}_t - \eta * (1+g_z)\frac{k}{y}\widetilde{k}_{t+1} + (1-\delta) * \frac{k}{y}\widetilde{k}_t - \frac{g}{y}\widetilde{g}_t = 0$$

$$9. \frac{\alpha}{1-\theta}\widetilde{y}_t - \frac{\alpha}{1-\theta}\widetilde{c}_t - \frac{y}{cl}\widetilde{l}_t = 0$$

$$10. \theta\frac{y}{k}E_t(\widetilde{y}_{t+1} - \widetilde{k}_{t+1}) + \frac{1+g_z}{\beta}E_t(\widetilde{c}_t - \widetilde{c}_{t+1}) = 0$$

The solution procedure is to use the Method of Undetermined Coefficients. In equations (7) to (10) there are three control variables: $\{\widetilde{y}_t, \widetilde{c}_t, \widetilde{l}_t\}$,one endogenous state variable, $\widetilde{k}_t$ and two exogenous state variables, $\widetilde{z}_t$ and $\widetilde{g}_t$.For our analysis, we assume that log deviation of productivity from its steady state value $\widetilde{z}_t$ and log deviation of government expenditure from its steady state value, $\widetilde{g}_t$ follow an Vector Autoregressive process of order one, such that:

$$11. \widetilde{z}_{t+1} = \rho_z * \widetilde{z}_t + \epsilon_{zt+1},\ \epsilon_{zt} \sim n(\epsilon_z, \sigma_z^2)$$

$$12. \widetilde{g}_{t+1} = \rho_g * \widetilde{g}_t + \epsilon_{gt+1},\ \epsilon_{gt} \sim n(\epsilon_g, \sigma_g^2)$$

The solutions to our unknowns will take the form:

$$
\begin{gathered}
13.\widetilde{y}_t = \widetilde{y}(\widetilde{s}_t, \widetilde{k}_t) \\
14.\widetilde{c}_t = \widetilde{c}(\widetilde{s}_t, \widetilde{k}_t) \\
15.\widetilde{l}_t = \widetilde{l}(\widetilde{s}_t, \widetilde{k}_t) \\
16.\widetilde{k}_{t+1} = \widetilde{k}(\widetilde{s}_t, \widetilde{k}_t) \\
where \\
\widetilde{s}_t = (\widetilde{z}_t, \widetilde{g}_t)
\end{gathered}
$$

Or translating in matrix form:

$$
\begin{aligned}
\widetilde{v}_t &= RR * \widetilde{k}_t + SS * \widetilde{s}_t \\
& \quad where \\
\widetilde{v}_t &= (\widetilde{y}_t,\ \widetilde{c}_t,\ \widetilde{l}_t) \\
\widetilde{k}_{t+1} &= PP * \widetilde{k}_t + QQ * \widetilde{s}_t
\end{aligned}
$$

For our analysis, we first calculate the productivity z_t, where $z_t = \frac{y_t^{\theta}}{k_t^{\frac{\theta}{1-\theta}} l_t}$.

As Figure 2.5 indicates, productivity discounted for a long term trend of 2% shows an initial increase from 1985 to 1988 and thereby registers a decline till 1993 after which it starts increasing once again.

4 Solution

4.1 Growth Accounting

We start by the results of a simple growth accounting. We can use the production function and a little manipulation to decompose growth rate in output into four parts:

$$y_t = k_t^{\theta}(z_t * l_t)^{1-\theta}$$
$$\Rightarrow y_t^{1-\theta} = \left(\frac{k_t}{y_t}\right)^{\theta}(z_t * l_t)^{1-\theta}$$
$$\Rightarrow y_t = \left(\frac{k_t}{y_t}\right)^{\frac{\theta}{1-\theta}}(z_t * l_t)$$
$$where$$
$$\frac{k_t}{y_t} : \text{capital intensity factor}$$
$$z_t : \text{TFP factor}$$
$$l_t : \text{labor factor}$$

Given the trend in productivity, we can divide the time period in three parts: 1982 to 1988, 1988 to 1993, and 1993 to 2002.

Year	1982:1988	1988:1993	1993:2002
Output	21.96	-4.73	13.76
Capital intensity factor	-12.2	14.83	-.4
TFP factor	26.83	-16.83	12.63
Labor factor	9.53	-.24	1.4

Table 3: Growth rate in variables and their decomposition

Table 3 points out to a rather interesting phenomenon. It appears like growth in output has been primarily driven by growth in TFP factor along with growth in labor. Capital intensity factor has moved in opposite direction to output. We therefore next trace the transition dynamics with respect to TFP factor. For our analysis, we take $\rho_z = \rho_g = .95$.We have already solve for policy variables and calculated TFP as a Solow Residual. We solve for the policy functions using the standard Uhlig toolkit, which gives us the relevant coefficients. We now feed in the TFP process in our model and estimate the model's estimation of output and capital-output ratio.

The policy functions are summarized by the matrices as listed in Table 4 :

$$PP = 0.6169$$
$$QQ = [0.5125, \ -0.0376]$$
$$RR = [0.2789, \ .5024, \ -.1267]$$
$$SS = \begin{matrix} 0.7021 & 0.0463 \\ 0.5310 & -0.0813 \\ 0.0970 & 0.0724 \end{matrix}$$

Table 4: Coefficients of policy functions as calculated by Uhlig toolkit

4.2 Transition Dynamics

The objective of the analysis is to quantitatively estimate the impact of productivity shocks on the Indian economy. We further use our analysis to account for the evolution of GDP per capita in the Indian economy since 1982 using TFP only exogenous factor. In other words, during 1982 to 2002 if TFP was the only exogenous factor that deviated from its balanced growth path value, how would GDP per capita, capital-output ratio and labor evolve? To what extent would it quantitatively trace the evolution of GDP per capita, capital-output ratio and labor as observed in data?

In our analysis, we divide the period of study into three subperiods as we did for growth accounting: 1982:1988, 1988:1993, 1993:2002. During 1982: 1988, data shows that output per capita increased by 21.96% as compared to a 2% long term trend. During the same period, capital intensity factor went down by 12.2% and labor increased by 9.53%. Feeding in exogenous TFP shocks in our model, we find that output per capita increased by 22.01%, accompanied by a 7.28% fall in capital intensity factor and a 3.76% increase in labor.

The performance during the "slow period" of 1988 to 1993 is also traced similarly. Data shows a fall in output per capita by 4.73% and a fall in labor by .24%. Capital-intensity factor actually registered an increase by 14.83%. Feeding in exogenous TFP shocks, we find output per capita declines by 11.07% accompanied by 2.79% fall in labor and a 10% increase in capital intensity factor.

Model results of the "booming period" of 1993 to 2002 also yield some interesting insights. During this period, output per capita increased by 13.76%. It was a period of growth all around. Labor increased by 1.4% and capital-intensity factor only declined slightly by -.4%. The model with exogenous TFP shocks shows an increase in output per capita by 12.17%, and an increase in labor by 1.34%. The model also registers a fall in capital-intensity factor by 1.72%

In summarizing the results of all the three subperiods, we can deduct that productivity did play an important role in the evolution of Indian economy, especially during the earlier years of 1982 to 1988 and later booming period of 1993 to 2002. However, the performance of TFP shocks in accounting for macro aggregates during the slowdown of 1988 to 1993 is not very satisfactory. Though the direction of movement matches the direction of movement from the data, the magnitude of fluctuations in the model is far more than the magnitude of fluctuations in the data. This begs the question, if only TFP shocks would have spelt even more disaster for the economy during the slowdown, what kept the economy from further deterioration? The present paper cannot answer that questions and leaves this observation as an interesting puzzle for future researchers.

5 Conclusion

The performance of the Indian economy since independence from the "British Raj" in 1947 has been dubbed by Dani Rodrick as "Hindu growth". The term highlights an economy that is not a miracle, neither a debacle. But since early eighties, Professor Rodrick was proved wrong as Indian economy started booming and the growth rate of GDP per capita registered an average 3.8% increase between 1982 and 2002 which has surpassed the long term growth rate of 2% of the developed economies.

In this paper, our aim was to quantitatively account for the performance of the Indian economy since 1982 from a growth theory perspective. We employed the technique of growth accounting pioneered by Prescott and Kydland and Prescott (1986) who feed in exogenous technical shocks to a growth model after calibrating the model parameters to match moments of the data. At the crux of the analysis is the idea that if there was no deviation of technology from its steady state path economy would be at equilibrium. As technology deviates from steady state value, macroeconomic aggregates also respond to technical deviations by deviating from their steady state values. To what extent can only technical deviations account for movements in macro aggregates?

We applied the technique to India during the period 1982 to 2002. The period restriction is because of the availability of employment and hours data which we get only from 1982 onwards.

Our results indicate that productivity as measured by TFP did play an important role in the Indian economy especially during the booms. However, during 1988 to 1993, Indian economy experienced a sharp drop in productivity which was not reflected to the same degree in output per capita. Simple growth accounting shows that capital intensity increased during this period which might be a factors in preventing a sharp output drop.

Our paper opens up many interesting question, as it looks at the Indian economy from growth theory perspective. We do not explore the primitives behind TFP fluctuations which we take as exogenous. Neither do we account for possible improvements in factor utilization, which when accounted for leads to a decline in TFP's contribution to the economy. It would be interesting to check the results if we can account for factor utilization. Growth theory as used in this paper is limited in that it also does not include other channels of shock like financial frictions or labor market frictions. An extended model like Business Cycle Accounting of V V Chari, Patrick Kehoe and Ellen McGrattan (2002) would provide richer answers.

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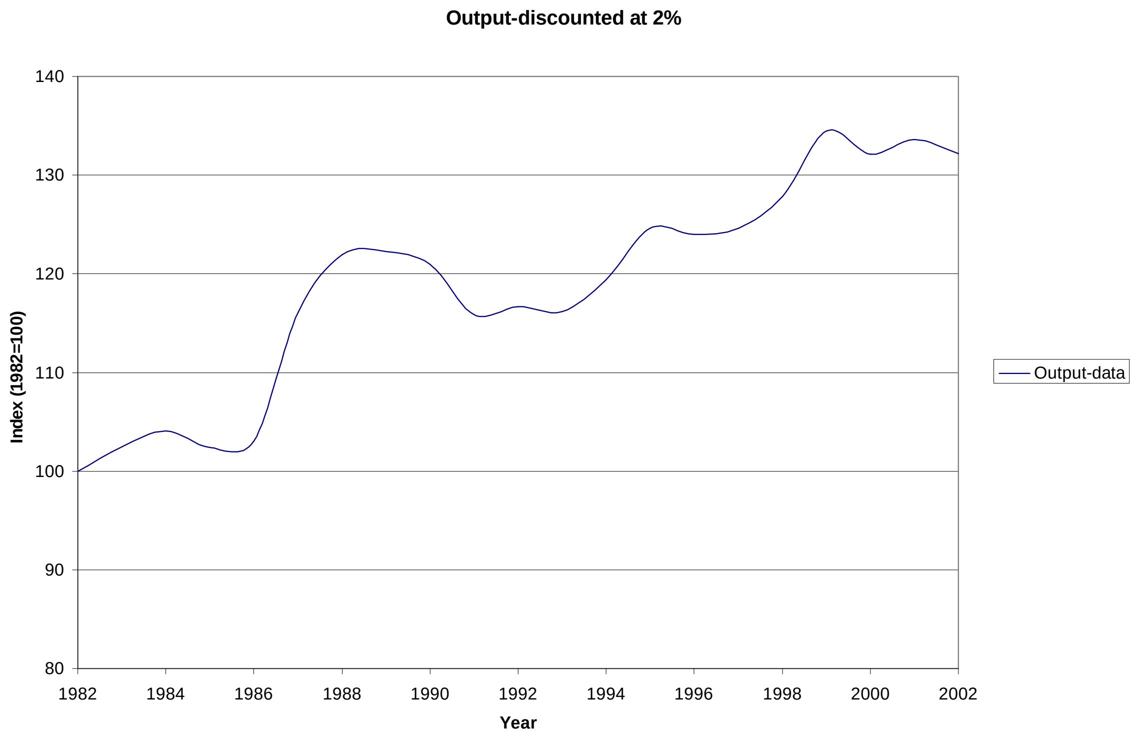
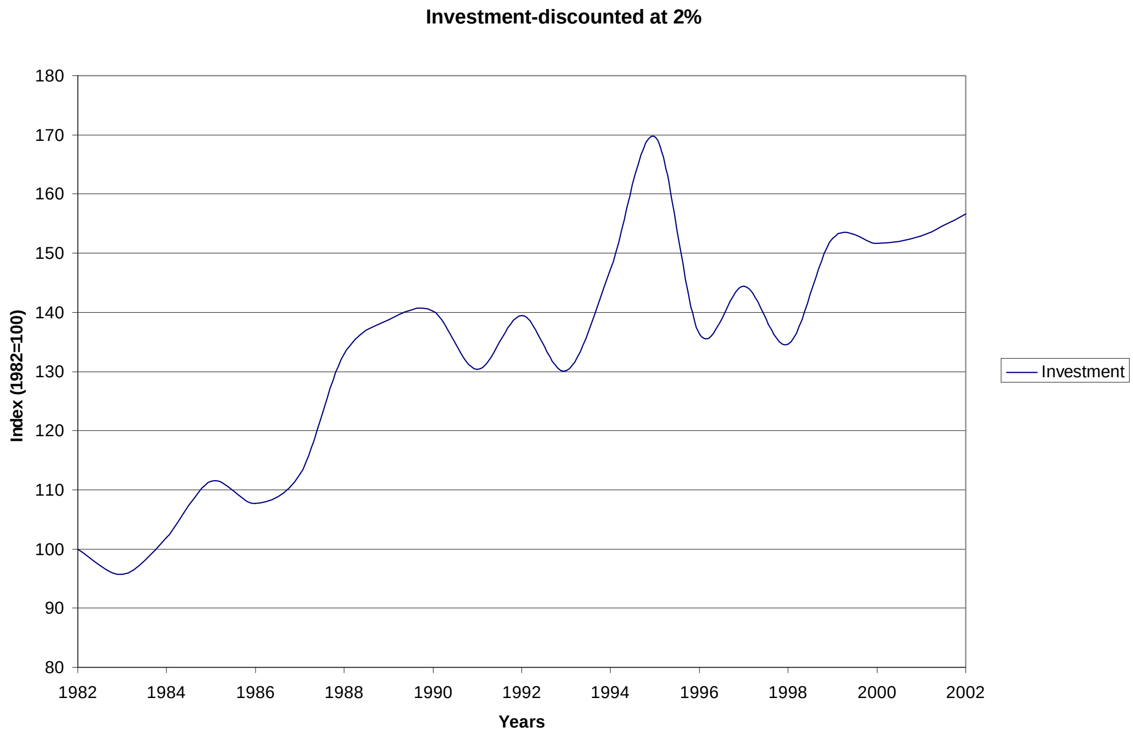

Output-discounted at 2%
140
130
120
110
100
90
80
Index (1982=100)
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year
Output-data

Figure 2.1



Investment-discounted at 2%
180
170
160
150
140
130
120
110
100
90
80
Index (1982=100)
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Years
Investment

Figure 2.2.


Govt. expenditure as a ratio of output
0.145
0.14
0.135
0.13
0.125
0.12
0.115
0.11
0.105
0.1
Ratio
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Years
g/y

Figure 2.3

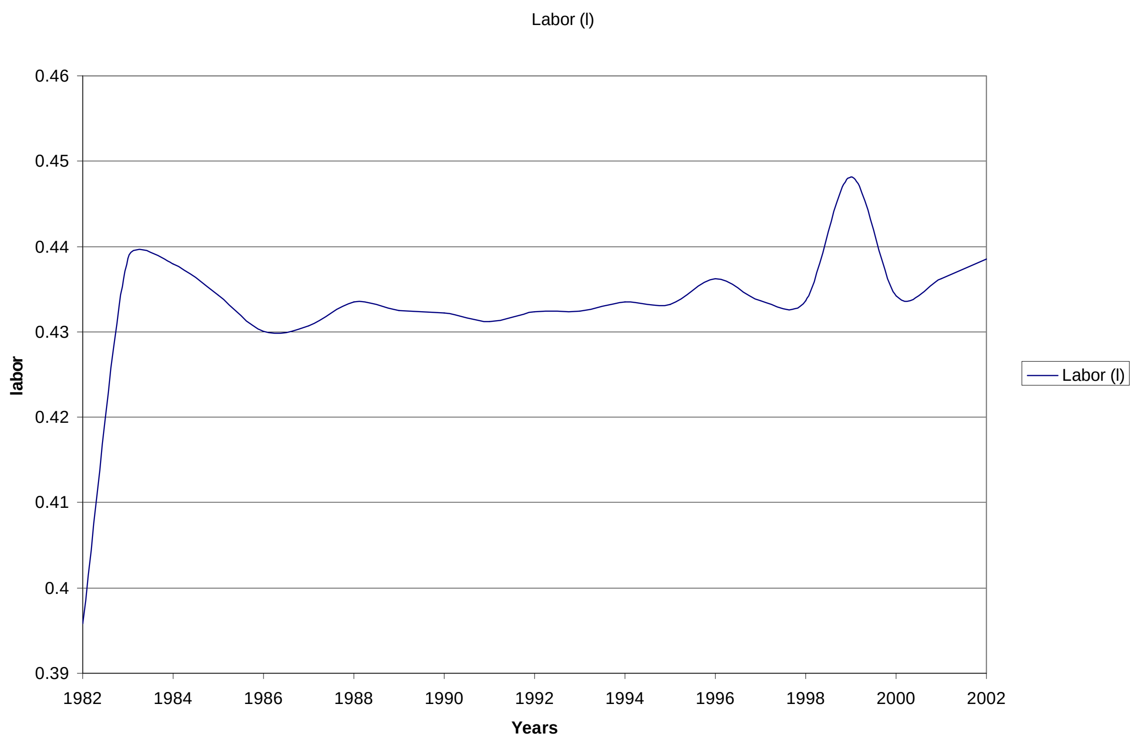

Labor (l)
0.46
0.45
0.44
0.43
0.42
0.41
0.4
0.39
labor
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Years
Labor (l)

Figure 2.4

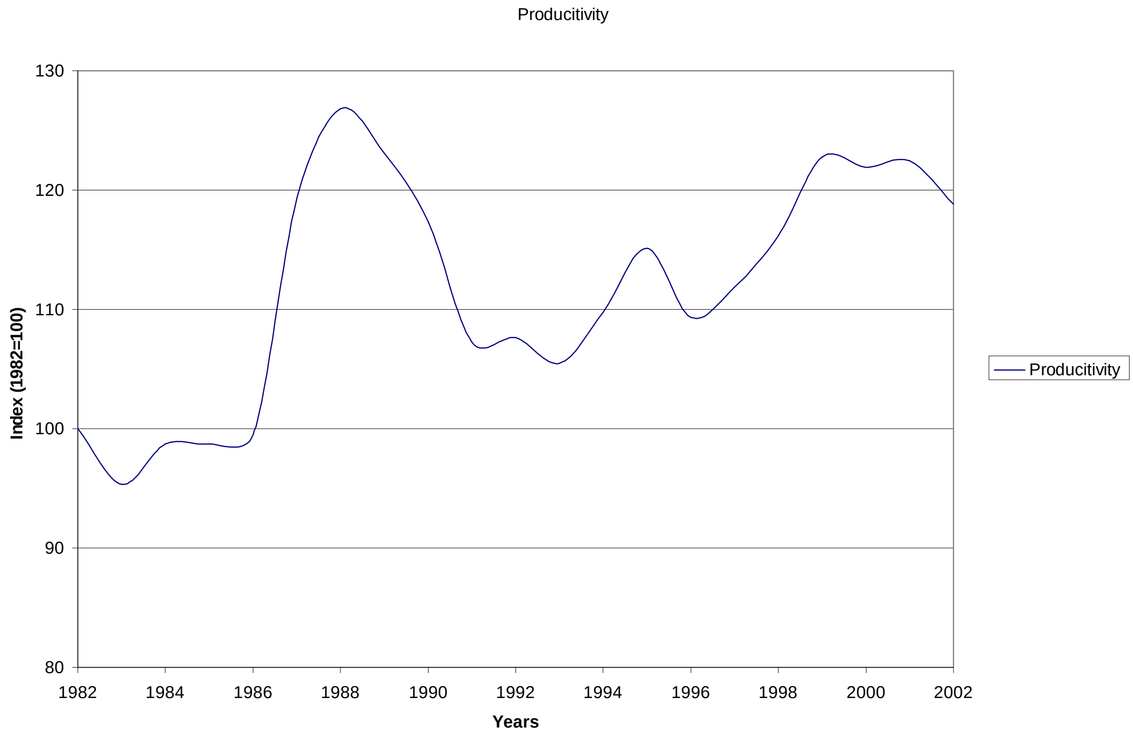

Producitivity
130
120
110
100
90
80
Index (1982=100)
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Years
Producitivity

Figure 2.5

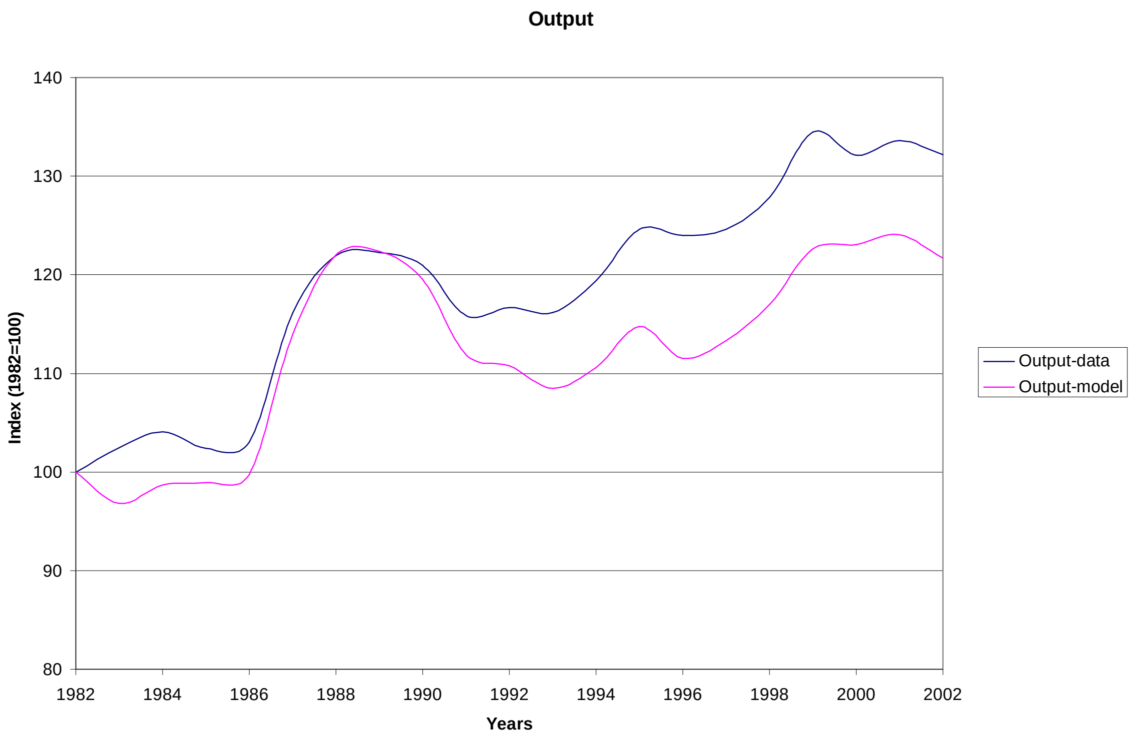


Figure 1: Figure 4.1

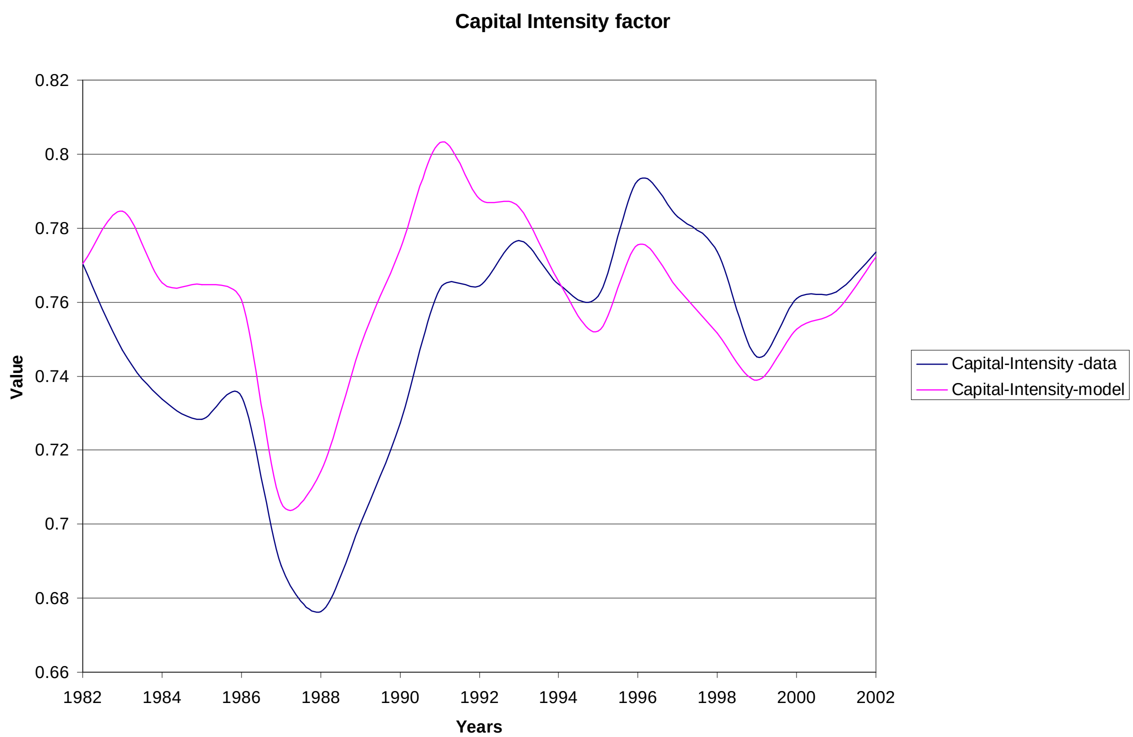


Figure 2: Figure 4.2

Figure 3: Figure 4.3