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Some Comments on TFP and its Growth in India

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Abstract: This paper considers the prospects for constructing a model of TFP of investment, technological progress and growth of the technological share in TFP that determines the nature of economic growth. Two models are considered: a model emphasizing investment, technological progress and its impact on TFP and a model emphasizing a relation of investment, TFP and growth of technological share in TFP through the experience process. The claims in mode 1 and model 2 presented here differ from those in most standard economic literature: the relation between investment and TFP is considered, the relation between technological efficiency and technological progress is established and their effect on TFP is shown. A quotient between technological progress and investment is constructed that hampers the growth of technological progress. This gives a caution to the financial institutions about the enhancement of the quotient.

Keywords: Total Factor Productivity; Investment; Technological Progress; India; Technological Efficiency; Growth

JEL: B22; D22; D24; O32; O43.

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1. Introduction

Growth theory has paid a lot of attention to total factor productivity (TFP). It suggests that TFP is the primary driver of the national economy[2] (Barro & Sala-i-Martin 1995; 1997; Grossman & Helpman 1991; Shih & Chang 2009). In the year 2014, according to the report of the Ministry of Statistics and Programme Implementation of India, GSDP per capita income of Goa is the highest in the country, followed by Delhi, Chandigarh, Sikkim respectively. The poorer states are Assam, Tripura, Jharkhand, Manipur, Uttar Pradesh and Bihar. The per capita income of Goa is 3.01 times more than India's average and 7.18 times more than in the poorest state Bihar (see Table1 and Table 2). If we study the economic growth rate of different states then it would be reasonable to assume that economic growth depends on the changes of capital, labour and TFP.

It is observed that the average citizen of Sao Paulo of Brazil was 10.5 times richer than the average citizen of Piauí in the year 1970. The per capita income of Sao Paulo was four times higher than Mranhão, which was poorer than Piauí after declination of regional dispersion in the year of 2010 (Figueirdo & Nakabashi 2016). On the eve of the American Revolution, GDP per capita in the United States was approximately US$ 765 (in 1992 dollars) (Hulten 2001). Contrary, the median household income of Maryland, the richest state of USA, was US$ 75,847 and the median household income of the poorest state Mississippi was US$ 40,593 (Frohlich & Sauter 2016). There is also evidence of a dramatic increase in economic growth in recent decades in Turkey. The per capita income was 3,178 US$ in 1988 and this number was nearly doubled by 2007 when it reached 5,053 US$ (Adak 2009).[3]

The different equations of two models shown below identify the specific areas where the more stresses are needed to gear up the TFP of a country. It is also easy to grasp why few

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[2] A number of comparative growth studies h ave found that the great success of the East Asian Tigers was driven mainly by the increase in capital and labour rather than by TFP growth (Young 1992; 1995; Kim & Lau 1994; Nadiri & Kim 1996; Collins & Bosworth 1996). With diminishing marginal returns to capital, the dominant rate of capital implies that the East Asian Miracle is not sustainable wins down (Krugman 1994). The role played by TFP growth is actually larger and the saving / investment effect is proportionally smaller.

[3] New production systems can explain the sharp increase. These systems had been imported from developed industrial countries. The structure of Turkey changed dramatically in the late 1980s. Turkish local currencies became convertible, foreign investment, privatization, free trades and low import tax, free zones, export industry strategies expanded, telecommunication investment and transportation links such as high ways all came into the scene in those years.

countries are doing well by using TFP and what is the effect of TFP on the economy of a country (Van & Jong 1999, 2000; Koedjik & Kremers 1996).[4]

Now the question arises, what are the factors that cause these differences? What role does new investment play? Is it possible to assess the behaviour of technological share in TFP? We will discuss the different behaviours and its effects on TFP in our model. It is worthwhile reminding the reader that technological growth and share of technological growth are not identical.

Section 2 presents a review of the literature on TFP. This review includes current literature on TFP. Section 3 depicts the basic models of this paper. This basic model represents model 1 and model 2. Model 1 derives the relationship between TFP, investment and technological progress. It also shows the power of investment on TFP. Model 2 characterises the growth of share of technological progress in TFP and shows that it depends on investment and on technological progress. It also introduces a quotient of technological progress in TFP and function of investment. Growth as a share of technological progress in TFP depends on this quotient and it hampers the growth of technological progress. Section 4 concludes.

2. Literature

There are countless papers on TFP. We confine the discussion to the most relevant for our paper. A recent study by a group of economists (Malik et. al. 2021) investigates the potential relationship and significance determinants of TFP in India for the period 1980 to 2016. They suggest, in order to accelerate TFP, governments and policymakers need to design and/or to implement an increase of financial access to the private sector. At the same time, government should maintaining price stability and the exports of higher value products, as well as an increased economic integration in the global economy in order to benefit from foreign investment flows, which brings new technology. Choi and Beak (2017) calculate the productivity spill over effects from India's foreign direct investment and controlling for trade, in the framework of the co-integrated vector auto regression (CVAR). In a somewhat different twist, Mankiw et al. (1992) examine whether the Solow model is consistent with the

[4] Since the late 1980s, the Dutch economy has outperformed neighbouring countries in higher employment, GDP growth in combination with low inflation and with the lowest long-term interest rates in the European Union. Productivity growth has been faster than per capita income growth between 1973 and the mid 1980s but the opposite appeared to be the case since then. Liberalization of product markets privatization of public transport, the abolition of regulations in many areas of services had a great impact on growth. The monitoring of Koedijk and Kremers (1996) finds a significant relation between productivity growth and product market regulation for 11 EU member states over the period 1980 to 1994 and opens a fruitful avenue for further research.

international variation in the standard of living and also examines the Solow model for convergence in standards of living, that is, for whether poor countries grow faster than rich countries. Using data from Chilean manufacturing plants for the period 1992 to 2005 and by difference-in-differences methodology Alvarez and Fuentes (2018) analyze the effects of the minimum wage on a firm's productivity and find that an increase in the minimum wage has a negative effect on TFP due to the existence of labour adjustment costs. From the Ethiopian Census Data, Essers et al. (2020) provides new empirical evidence on the relative productivity disadvantage of female – owned firms compared with male – owned firms in a developing country and the difference is 12% in levels of TFP. Vassdal and Holst (2011) measure change in TFP for production of Atlantic salmon in Norway from 2001 to 2008 by using Malmquist Productivity Index (MPI) and get an ambiguous result. Their result shows that TFP change measured by MPI increases from 2001 to 2005, but thereafter regressed. This is due to a regress in the technical change component of the MPI. This indicates that the industry has reached a level of technological sophistication from where it is difficult to make substantial progress. Saleem et al. (2019) try to find out the driving factors behind TFP in Pakistan. They show that innovation significantly contributes to economic growth and production level in Pakistan. These different findings generate intense discussions. Hence, we try to find out the relations between TFP and different dynamic causes in the rear of TFP.

3. Models

In the existing discussion on TFP, technological progress and growth of the share of technological progress in TFP, there is a common notion of the economists dealing with TFP: each and everyone tries to measure TFP by different methods with a claim that their method bears a truth only. They do not fully address the different wings of TFP such as embodied technology, disembodied technology, technological efficiency and technological progress at certain time and their effects on TFP. Why does it happen? The key factor is that most of the researchers emphasize on measuring TFP by the conventional formulas and paths according to the methodology of Klenow and Rodriguez (1997) and it has been used since the last 20 years. Many economists adopt growth accounting methodology (Easterly and Levine 2001; Bosworth and Collins 2003) which calculate the differences in per capita GDP (Mankiw et al. 1992; Hall and Jones 1999). Fuentes and Morales (2011) propose a latent variable approach that is a state space method to estimate TFP, and a dynamic general equilibrium model to measure the technological progress is constructed by Carlaw and Kosempel (2004). The Malmquist index of total factor productivity change is the product of technical efficiency change and technological change, which is also a popular approach to measure TFP change between two data points over time (Jajri 2007) and has been discussed for many years.

Our paper picks up this idea and addresses the aspect that their survey did not highlight. We focus on technological progress by investing K at time t, technological efficiency at time t and the growth of share of technological progress in TFP. Judging by the different discussions and the number of influential publications by different firms and governmental institutions, this paper tries to find out a relation among TFP, disembodied technology and embodied technology. The relation between technological efficiency and technological progress is studied here. It is known that discussion on share of technological progress is considerably more effective in policy making as well as also in academic circles. This is also fully considered here. This paper tries to grapple the real character of TFP and its growth.

Policies of institutions, say government or firms, can have positive effects on technology but we are trying to construct an equation that exhibits the share of technological growth in TFP.

Let K be an investment to gear up TFP. A unit of TFP is generated when investment has reached from $K^{/}$ to K. Suppose, A (K) is the TFP in producing a unit by investing K at time t. W_D (K) is the amount of disembodied technology used in producing a unit with an investment of K at time t. W_E (K) constitutes the amount of embodied technology used in producing a unit with an investment of K at time t. T_P (K) is technological progress by investing K at time t and, finally, T_E (K) is the technological efficiency at time t.

Here W_D (K) and W_E (K) are both non-decreasing functions and so is A (K). Then, regardless of capital and labour wage, it always resembles a developing character. Then, it, in producing one unit of TFP at time t, is always a combination of one unit of disembodied and one unit of embodied technology. Then,

$$A(K) = \int_{K/}^{K} W_D(K)\ dK + \int_{K/}^{K} W_E(K)\ dK . \quad (1)$$

$$T_P(K) = \int_{K/}^{K} T_E(K)\ dK . \quad (2)$$

Here A, W_D, W_E, T_P and T_E are all functions of time t. Since K is known at time t but $K^{/}$ is unknown, we solve $K^{/}$ from equations 1 and 2. Let us define

$$\omega_D(K) = \int W_D\ (K)\ dK \quad (3)$$

$$\omega_E(K) = \int W_E\ (K)\ dK \quad (4)$$

then,

$$A(K) = (\omega_D(K) + \omega_E(K)) - (\omega_D(K^{/}) + \omega_E(K^{/}))$$

$$= \psi(K) - \psi(K^{/}) \qquad (5)$$

where

$\psi(K) = \omega_D(K) + \omega_E(K)$ and $\psi(K^{/}) = \omega_D(K^{/}) + \omega_E(K^{/})$.

Again set,

$$\xi(K) = \int T_E(K)\, dK . \qquad (6)$$

Then,

$$T_P(K) = \xi(K) - \xi(K^{/}). \qquad (7)$$

Now solve for $K^{/}$ from (7),

$$K^{/} = \xi^{-1}(\xi(K) - T_P(K)). \qquad (8)$$

Now by substituting (8) into (5) we get,

$$A(K) = \psi(K) - \psi\{\xi^{-1}(\xi(K) - T_P(K)). \qquad (9)$$

This equation of TFP relates technological progress and therefore it shows that TFP increases or decreases according to the behaviour of obtainable technological progress. It is known that the availability of finance is a restrictive issue then $K^{/}$ can be solved from equation (5). We have taken $K^{/} \leq K$. If this is not the case then the growth rate would be hampered due to inconsistency of configuration of the model.

Model 1

Suppose, $W_D(K) = \alpha$, $W_E(K) = \beta$, where α and β are both constants. This indicates that TFP is stagnant. In this case, technological efficiency will decline sharply. We take here $T_E(K) = \gamma K^{-i}$, γ is constant and $i > 0$. Then,

$\psi(K) = (\alpha + \beta) K$, $\xi(K) = \frac{\gamma K^{1-i}}{1-i} = \delta K^{1-i}$, where $\delta = \frac{\gamma}{1-i}$ is also a constant.

Provided $i \neq 1$, (9) becomes,

$$A(K) = (\alpha + \beta) K \{1 - (1 - \frac{T_P(K)}{\delta K^{1-i}})^{\frac{1}{1-i}}\} \quad (10)$$

Claim 1: An increase in investment, with technological progress constant, increases total factor productivity; a simultaneous increase in technological progress will further increases total factor productivity.

Claim 2: If $i < 1$, i.e. technological efficiency increases with investment then it gives an increase in technological progress and investment increase the ratio $\frac{T_P(K)}{\delta K^{1-i}} > 1$ and ultimately gives an increase in TFP.

Claim 3: The result is same as claim 2 for TFP when technological efficiency decreases with investment i.e. $i > 1$.

We also get from equation from equation (7),

$T_P(K) = \xi(K) - \xi(K') \leq \xi(K) = \delta K^{1-i}$.

Now if $i = 1$, then $\xi(K) = \gamma \log K$. TFP then reduces to

$$A(K) = (\alpha + \beta) K (1 - e^{-T_P(K)/\gamma}). \quad (11)$$

Claim 4: Here the result is same as in claim 1.

The results indicate here that special type of TFP formulation always tries to increase at the time of a stagnant situation. This present formulation also shows more pressure on TFP function than investment to gear up the technological progress.

Model 2

Let θ be a proportional increase in technological development relative to technological efficiency.

Now from equation (5) and $\psi(K) = (\alpha + \beta) K$ in case 1 we get,

$$K' = K - \frac{A}{\alpha + \beta} \quad (12)$$

such as

$T_E(K^/) = \gamma\,(K - \frac{A}{\alpha + \beta})^{-i}$.   (13)

The technological development for K is $W_D(K^/) + W_E(K^/)$ where the total efficiency is $\theta\, T_E(K^/)$. Hence

$$W_D(K^/) + W_E(K^/) = \theta\, T_E(K^/)$$

or,

$$(\alpha + \beta) = \theta\, \gamma\, (K - \frac{A}{\alpha + \beta})^{-i}.$$

Hence,

$$\theta = \frac{(\alpha + \beta)\left(K - \frac{A}{\alpha + \beta}\right)^{i}}{\gamma}. \quad (14)$$

Now it will be interesting to derive share of technological progress of TFP, i.e. $\frac{\theta\, T_P(K)}{A(K)}$. Now from $\xi(K) = \delta K^{1-i}$ and $T_P(K) = \xi(K) - \xi(K^/)$ we get,

$T_P(K) = \delta\, \{K^{1-i} - (K - \frac{A}{\alpha + \beta})^{1-i}\}$, for $i \neq 1$ and therefore

$$\frac{\theta\, T_P(K)}{A(K)} = \frac{(\alpha + \beta)}{1-i}\left\{\left(\frac{K}{A}\right)^{1-i} . \left(\frac{K}{A} - \frac{1}{\alpha + \beta}\right)^{i} - \left(\frac{K}{A} - \frac{1}{\alpha + \beta}\right)\right\} \text{ for } i \neq 1. \quad (15)$$

Claim 5: The growth of share of technological progress in TFP is dependent on the ratio of investment and TFP.

Now we want to find $K^/$ by using equation (7),

$$K^/ = \left(K^{1-i} - \frac{T_P(k)}{\delta}\right)^{\frac{1}{1-i}}. \quad (16)$$

Then,

$$\theta = \frac{(\alpha + \beta)\left(K^{1-i} - \frac{T_P(K)}{\delta}\right)^{\frac{i}{1-i}}}{\gamma}. \quad (17)$$

We also get,

$$\frac{\theta\, T_P(K)}{A(K)} = \frac{\left(\left(\frac{T_P(k)}{k^{1-i}}\right)^{\frac{1-i}{i}} - \frac{1}{\delta}\left(\frac{T_P(k)}{k^{1-i}}\right)^{\frac{1}{i}}\right)^{\frac{i}{1-i}}}{\gamma\left\{1-(1-\frac{T_P(k)}{\delta K^{1-i}})\right\}^{\frac{i}{1-i}}}. \qquad (18)$$

Claim 6: Growth of share of technological progress in TFP depends on the quotient of $\frac{T_P(k)}{K^{1-i}}$ and it hampers the growth of technological progress. The boost of proportion $\frac{T_P(k)}{K^{1-i}}$ makes the technological progress reduce.

Next, we want to observe the case for i = 1.For K and A (K), we have

$$\theta = \frac{((\alpha+\beta)K - A(K))}{\gamma}. \qquad (19)$$

$$\frac{\theta\, T_P(K)}{A(K)} = \left(\frac{(\alpha+\beta)K}{A(K)} - 1\right)\log\left(\frac{\frac{K}{A}}{\frac{K}{A} - \frac{1}{\alpha+\beta}}\right). \qquad (20)$$

Claim 7: When i =1 that means technological efficiency reduces to a logarithmic function of investment then growth of share of technological progress in TFP depends on ratio of capital and TFP only.

Again we obtain the equation in terms of K and T_P (K) and get

$$K' = K\, e^{-\frac{T_P(K)}{\gamma}}. \qquad (21)$$

$$\theta = \frac{(\alpha+\beta)K}{\gamma\, e^{\frac{T_P(K)}{\gamma}}} \qquad (22)$$

$$\frac{\theta\, T_P(K)}{A(K)} = \frac{T_P(K)}{\gamma\,(e^{\frac{T_P(K)}{\gamma}} - 1)}. \qquad (23)$$

Here we derive an interesting result.

Claim 7: The growth of share of technological progress solely depends on technological progress.

4. Conclusion

While most of the current literature on TFP focuses on measurement and empirical evidences, in this paper we have accentuated a previously unexplored aspect of TFP. We consider the role of investment, technological progress, technological efficiency, and growth of technological share in TFP. In a world where economists are considering mainly Malmquist Productivity Index and Solow Residual to measure TFP we have tried to explore the inherent relations between TFP and other driving forces.

We have investigated the investment and the behaviour of technological progress impacts of improving TFP even at the time of stagnant situation. In our model ratio of technological progress and investment played an important role to improve TFP. In a more plausible model, we have found a quotient of technological progress and the function of investment that hampers the growth of share of technological progress in TFP. Government and firm owner must be careful about the quotient. In other cases, capital and TFP are intertwined with each other. A fuller model is required in the near future to improve our model that would take account of other additional variables of TFP.

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Appendix

Table 1: Gross State Domestic Product (GSDP) at Current Prices (as on 31.05.2014), Planning Commission Government of India, 15 July 2014.

Rank	State / Union Territories	GSDP per capita (nominal)	Data Year
1	Goa	Rs 466,322 (US $ 7,300)	2016-17
2	Delhi	Rs 365,882 (US $ 5,700)	2016-17
3	Chandigarh	Rs 275,454 (US $ 4,300)	2015-16
4	Sikkim	Rs 277,282 (US$4,300)	2015-16
5	Puducherry	Rs 236,450 (US$3,700)	2016-17
6	Maharashtra	Rs 225,892 (US$3,500)	2017-18

Table 2: Gross State Domestic Product (GSDP) at Current Prices (as on 31.05.2014), Planning Commission Government of India, 15 July 2014.

Rank	State / Union Territories	GSDP per capita (nominal)	Data Year
28	Assam	Rs 80,625 (US$1,300)	2017-18
29	Tripura	Rs 77,351 (US$1,200)	2014-15
30	Jharkhand	Rs 73,031 (US$1,100)	2015-16
31	Manipur	Rs 58,442 (US$910)	2014 - 15
32	Uttar Pradesh	Rs72,300 (US$1,100)	2017-18
33	Bihar	Rs 63,200 (US$990)	2017-18