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Some comments on total factor productivity and its growth in India

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Abstract
Purpose: This paper considers the prospects for constructing a model of Total Factor Abstract:
Purpose: This paper considers the prospects for constructing a model of Total Factor Productivity (HenceTFP) of investment, technological progress and growth of the technological share in TFP.
Research Methodology: This paper tries to understand the driving factors of TFP by establishing the relations between the factors**.**
Results: Models consider emphasizing investment, technological progress and its impact on TFP and also on relation of investment with TFP and growth of technological share in TFP through the experience process. The claims in models provide a relation between investment and TFP; a relation between technological efficiency and technological progress is formed and their effect on TFP is also established.
Limitations: The limitations of the study are that we have considered selected parameters of TFP only. To study TFP completely a fuller model is needed where all the parameters would be considered.
Contribution: This study will help to understand TFP and its internal dynamics. 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.
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1. Introduction

Growth theory has paid a lot of attraction to total factor productivity (TFP). It suggests that TFP is the primary driver of the national economy (Barro & Sala-i-Martin, 1995; 1997; Grossman & Helpman, 1991; Munyawarara & Govender 2020; Smith 2020). The increasing performance of developing economics of Asian Tigers created a great interest among the economists. They tried to find out the driving factors of the rapid economic progress. But the study revealed that these developing economics was steered by capital and labour only not by the growth of TFP (Young, 1992; 1995; Kim & Lau, 1994; Nadiri & Kim, 1996; Collins & Bosworth, 1996). The definition of the law of diminishing marginal returns says that it is an effect of increasing input in the short run after an optimal capacity has been reached while at least one production variable is kept constant. An increase in the input of capital in the short run gives a smaller increase in output. This incident happened in the case of Asian Tigers and it slowed down the growth rate (Krugman 1994). Here lies the significance of TFP.

But the debate continues. Let us take the example of several countries in Asia. From the 1950s, the remarkable economic progress of Four Asian Tigers (viz. South Korea, Taiwan, Singapore and Hong Kong) surprised the economists. Rapid industrialization creates a high growth rate of more than 7% a year. The economy of Hong Kong stressed on the development of the textile industry from the 1950s.

It also had developed and extended to incorporate clothing, electronics and plastics materials to sell overseas. After the independence of Singapore, the government had established an economic development board to execute national economic strategies. The strategy was to encourage the manufacturing sector of the country by establishing industrial estates. It also tried to attract foreign investment to the country luring tax incentives. The involvement and initiatives of the government of Taiwan and South Korea set in motion since the 1960s. They followed the policies of Hong and Singapore by adopting export-oriented industrialization. By observing the economic progress of Japan the Asian Tigers went after the path paved by Japan by promoting infrastructure and education and achieved the same goal. Their economies had developed into high-income economies (Young, 1992). It gives a fresh thrust on whether the national economy solely depends on TFP. We must give a few examples here to show that TFP does really help the national economy to grow progressively.

One factor is that different countries operate at different levels of economic policies to boost economic growth. But the main factor of growth depends on TFP. We take a few examples to clarify the consequences. 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 the declination of regional dispersion in the year of 2010 (Figueirdo & Nakabashi, 2016). An increasing graph of GDP per capita of USA from the year 1774 to 1997 is shown by Hulten (Hulten, 2001). This indicates that the industrial revolution had played a key role to make GDP per capita US$ 1481.45 (measured in 2021 dollars) of USA in the year 1774 to US$ 68.309 in the year 2021. 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). In the current discussion of TFP and its impacts on economic growth, a strong increase in economic growth in Turkey is observed. The striking benefits of economic growth propelled the per capita income from 3,178 US$ in 1988 to 5,053 US$ (Adak 2009) by 2007. With the change of economic structure of Turkey viz. overseas investment, encouragement on privatization, exchangeable of local currencies, free trade policy and low import tax gave a quick upsurge in financial conditions since the late 1980s. The changed economic system also gave impetus to free zones, investment in telecommunications and transportation also.

The different equations of two models shown below identify the specific areas where more stresses are needed to gear up the TFP of a country. It is also easy to grasp why few 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). GDP growths with little inflation and with elevated opportunity in the service sector give the Dutch economy an experience of faster growth during the period 1973 to mid-1980s. At that time the long-term interest rate is lowest among the nearby countries and the growth of per capita income is lagging behind the productivity growth. The reverse is observed after the 1980s when the growth of productivity has lost its pace. Liberalization of product markets with the privatization of public transport and by eliminating the barriers of rules and regulations in the service sector make some contributions in the growth sector. These indicate that reductions in trade- barriers were followed by significant increases in productivity. Data and empirical analysis of 11 EU member states over 1980-1994 reach (Koedijk & Kremers, 1996) a perennial claim that a positive relationship sustains between productivity growth and product market rule.

This indicates clear thinking that perfectly economic policy and investment specified technology are needed to hold the growth of TFP in the developing countries. Sometimes the burden of international debt is so high that unless something is done the economy of that country will be collapsed and be mortgaged as experienced by India.

The Indian economy observed an obstacle in 1991, a time of significant discussion about the country's long-run performance and policy. An unprecedented payments crisis and a negative growth of 0.6 percent in the industrial sector occurred. It was a time when there was money enough for only thirteen days of normal imports. The policies of de-licensing, trade - liberalization, foreign direct investment policies taken at that crucial time were planned simply to fight economic situations and a considerable acceleration in manufacturing TFP growth in India happened (Bollard et al. 2013).

Table 1. Gross State Domestic Product (GSDP) at Current prices

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

The industry recovered shortly in 1994 - 95 and 1995 - 96 with double-digit growth and 7.1 percent in 1996 – 97 following the liberalization and reforms policies. The strong positive effects of openness in the economy found at different sectors such as in 2010 Indian emigrants are estimated to be sending home remittances totalling $ 55 billion constituting 4 .5 per cent of GDP (Ratha et al. 2011). Though there are many sectors that influence the Indian economy, few are important and reliable also. But the growth is not even everywhere and the challenge is to identify why.

Data on GSDP are obtained from the Ministry of Statistics and Programme Implementation of India in the year 2014 gives that per capita income Goa is the highest in the country. Delhi, Chandigarh and Sikkim go after 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 per capita income and 7.18 times more than the poorest state Bihar (See Table1 & 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 in capital, labour and TFP. Now the question is how can that be?

This paper tries to answer the obvious factors that cause these differences and the role of new investment in TFP. The focus of this paper is on the behaviour of technological share in TFP, and this has begun to coalesce around reducible factors of economic policies by constructing the well apt frameworks. We will discuss the different behaviours of investments and their effects on TFP in our model. It is worthwhile reminding the reader that technological growth and share of technological growth is not the same thing and the reader must be cautious about the two. Here we have discussed various types of investment and their effects on TFP. Investing investment without any vision and the haphazard application of technology is not always sufficient to develop the total factor productivity. Investment and use of technical efficiency must then be properly used by analyzing the situation of the economic condition of the country.

Section 2 presents the literature review and hypothesis development of TFP. This review includes current literature on TFP. Section 3 depicts the research methodology and basic model of this paper. Section 4 includes results and discussions of different models. It represents model 1, model 2, model 3 and model 4. 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 the 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 the function of investment. Growth as a share of technological progress in TFP depends on this quotient and it hampers the growth of technological progress. Model 3 discusses the various properties TFP when it progresses with investment. Model 4 shows the different properties of technological share in TFP at the time of varying investments. Section 5 concludes with the limitation and study forward.

2. Literature review and hypothesis development

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. With the purpose of expediting TFP; the concept of overseas ventures and modern types of machinery has emerged from their suggestions. The overseas ventures have so many effects in different sectors such as the purchasing capacity of people and export system that the government and planners must develop sustainable economic integration policies with the coming flow of global finance. But the question comes here that a populous country like India where an unbalanced development and poverty exist in each and every nook and corner of the society, is it possible to escort the fruits of progress to every household of the population? One can answer the question that it is possible though not directly but indirectly. As it is known, a large overseas investment, in a definite sector makes an avenue of extension in other sectors. Hence it is necessary to select the sectors where to invest the overseas capital to get the maximum output from the investment and also to measure the flow of foreign investment.

To measure the flow of overseas investment in trade and economy, Choi and Beak, (2017) calculate the productivity spillover effects using the cointegrated vector autoregression (CVAR) method. The growth of foreign direct investment leads to the natural question of how growth affects poor countries. This is a challenging area of research as it needs to measure and compare the standards of living of a country with international standards. In turning to this problem, Solow Model gives a clearer idea of the growth rate of poor countries and rich countries. Mankiw et al. (1992) investigate the question of whether the rich counties are lagging behind the poor countries with respect to the standard of living at the time of growth by Solow model.

A policy that increases the minimum wage of labour is worthless because it creates a depressing effect on the productivity of a plant. The paper by Alvarez and Fuentes, (2018) observes the role of labour adjustment cost and its negative impact on TFP at the time of rising minimum wage. They reached the decision by studying the Chilean manufacturing plants data for the period 1992 to 2005 by using a statistical technique namely difference in differences methodology. By analysing the Ethiopian Census Data, the relation between the gender of a firm owner and the level of TFP is highlighted by Essers et al. (2020). Their findings, based on comparative studies of productivity, suggest that a female-owned firm is lagging behind a male-owned - firm and a 12% difference level of TFP is observed between two firms.

Vassdal and Holst, (2011) use Malmquist Productivity Index (MPI) to measure a change in TFP for production of Atlantic salmon in Norway from 2001 to 2008 and get an ambiguous result. Their result shows that TFP change measured by MPI fits with increasing rate from 2001 to 2005, but reverted afterwards. For policy purposes and implementation, it is essential to know which factor is responsible for TFP setback during the period 2005 to 2008. Their findings show that the technical efficiency component of MPI is as strong as in the period 2001 to 2005 but the technical change component is walking backwards. The results undertaken shed light on the balanced growth of technical efficiency component and unbalanced growth of technical change component of TFP. This study also reveals that technological advancement recedes when it gets caught in superiority traps. Here lies the question of the practicability of a policy. The cases we have discussed earlier shows us the rapid development that happens at the time of the initial flow of overseas investment but it reverted after some time. Hence a feasible policy is needed to overcome the above embarrassing situation. Saleem et al. (2019) try to find out the driving factors behind TFP in Pakistan. The study focuses on innovation and its effects on economic growth and production that drags the economy in a smoother way.

Hypothesis development

We have observed from the above literature that economists focus on foreign direct investment primarily on the growth of TFP. This leads to the motivation, to analyze the causes of the growth of different countries rich and poor behind the rise of TFP in which policy implications play a role to influence the growth also. There are also countries in which the growth of TFP is reverted after a few years. Few economists have tried to reconcile this with their model but have found it difficult to settle the reasons behind it. Then our essential assumption that creates these problems is to find out those controlled factors of TFP and try to find a relation among them. In analyzing these conditions it is convenient to frame a hypothesis about the dynamic reasons behind the growth or decline of TFP and then try to analyze it. We precede the hypothesis here that TFP, in general, can be encircled with the investment and technological progress in different ways which shows the very activity to understand the growth of TFP. The indication so far mentioned from economic literature above, is of course, only suggestive. The aim of this paper is to formulate the hypothesis more precisely and draw from it a number of economic claims. Hence, we try to find out the relations between TFP and different dynamic causes in the rear of TFP in our models.

3. Research methodology

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 a 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 for the last 20 years. Growth accounting methodology is further handy for considering growth, which is a specific phenomenon. As the sources of growth depend on inputs of production, advances in the technological efficiency and its share in inputs; innovations that generate new products and accomplishes boost in the productivity sector (Easterly and Levine 2001; Bosworth and Collins 2003). Openness to technological surge, economic factors and trade have the prospective to generate to each of the sources of growth and productivity. However, to achieve the desired results of growth, under the influential factors, need to be properly understood. If there is an input that minimises the variation of tax policies, education policies, political stability then the growth of output will grow steadily in a closed economy (Mankiw et al., 1992; Hall and Jones, 1999). Fuentes and Morales, (2011) propose a latent variable approach to estimate the growth rate of TFP and capital. This said decomposition and a dynamic general equilibrium model to measure technological progress are constructed by Carlaw and Kosempel, (2004). An interconnected relationship between the change of technical efficiency and technological change of total factor productivity is observed by economists long before. It should be noted that the measure of TFP change is dependent on the product of the two factors i. e. technical efficiency and technological change and it is popularly known as Malmquist index of total factor productivity. This popular approach to measure TFP change shows that if one of the factors is weak then TFP will be affected seriously and this incident is reflected in the case of Malaysia. As technical efficiency is not as strong as technological change during the period 1971 to 2004, a significant depressing impact on TFP growth is noted by Jajri, (2007) by analysing the decomposed empirical data.

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 the 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 between TFP, disembodied technology and embodied technology. The relation between technological efficiency and technological progress is studied here. It is known that discussion on the 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.

Model

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,

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

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

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

$$\omega_D(K) = \int W_D(K)\,dK \qquad (3)$$

$$\omega_E(K) = \int W_E(K)\,dK \qquad (4)$$

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

Now solve for $K^{/}$ from (7),
$K^{/} = \xi^{-1}(\xi(K) - T_P(K))$. (8)

Now by substituting (8) into (5) we get,
$A(K) = \psi(K) - \psi\{\xi^{-1}(\xi(K) - T_P(K))$. (9)

This equation of TFP relates to 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.

4. Data analysis and interpretation

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

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

An analysis of equation (10) and claim 1 can explain the real reason of rising of Asian tigers. It is not an economic wonder but only a high rate of an investment over a considerable period shows the development of the economy at the time of primary growth of technological progress. When both investment and technological progress take place simultaneously then TFP grows rapidly.

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

Claim 3: The result is the 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
$A(K) = (\alpha + \beta) K (1 - e^{-T_P(K)/\gamma})$. (11)

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

The results indicate here that a 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 an 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,

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

such as

$$T_E(K') = \gamma \left(K - \frac{A}{\alpha + \beta}\right)^{-i}. \qquad (13)$$

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,

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

Hence,

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

Now it will be interesting to derive share of the 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,

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

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

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),

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

Then,

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

We also get,

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

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

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

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

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

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

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

Here we derive an interesting result.

***Claim 8*:** The growth of share of technological progress solely depends on technological progress.

Model 3.
Now suppose, W_D (K) = λ_D (K), W_E (K) = λ_E (K), where λ_D and λ_E are weights of disembodied and embodied technologies. This shows that TFP is progressing with capital. We set an increasing technological efficiency. We take, T_E (K) = ςK^j, ς is constant and j > 0. Then,
$\psi(K) = (\lambda_D + \lambda_E) K^2$, $\xi(K) = \frac{\varsigma}{j+1} K^{j+1} = \eta\, K^{j+1}$, where $\eta = \frac{\varsigma}{j+1}$ is also constant.

Then equation (9) becomes,

$A(K) = (\lambda_D + \lambda_E) K^2 (1 - \left(1 - \frac{T_P(K)}{\eta\, K^{j+1}}\right)^{\frac{2}{j+1}})$. (24)

Here we also get from equation (7),
$T_P(K) = \xi(K) - \xi(K^{/}) < \xi(K) = \eta\, K^{j+1}$.

Now if j = - 1, then ξ (K) = ς log K. Then TFP reduces to
$A(K) = (\lambda_D + \lambda_E) K^2 \{1 - \exp(1 - \frac{T_P(K)}{\varsigma \log K})\}$. (25)

Again, if we set j = - 2, then $\xi(K) = -\frac{\varsigma}{K}$. Then TFP reduces to
$A(K) = (\lambda_D + \lambda_E) K^2 \{1 - \left(1 + \frac{K\, T_P(K)}{\varsigma}\right)^{-1}\}$. (26)
The equations (24), (25) and (26) are also TFP functions.

Claim 9: The equation (24) shows that an increase in K with T_P (K) constant increase A (K) and again increase in T_P (K) and K will increase A (K).

From equation (25) we derive the following claim.
Claim 10: When technological efficiency is inversely related to investment than the ratio $\frac{T_P(K)}{\varsigma \log K}$ is also an increasing function. The equation shows that investment takes a greater speed and it increases TFP also.

The equation (26) gives the following claim.
Claim 11: When technological efficiency is a decreasing function of investment then the progress of TFP solely depends on investment only.

Again these equations show that special types of formulations always try to increase A (K) in any situation. Since TFP affects the output of a production function then it shows that the present formulations lay more pressure on production functions without extra investment. It is also seen that further amounts of capital, technological progress, embodied and disembodied technologies are used more efficiently here than previous ones.

Model 4.

Let θ_1 be a proportional increase in technological development for a farm relative to technological efficiency.

Now from equation (5) and ψ (K) = $(\lambda_D + \lambda_E)\,K^2$ in model 3 we get,

$$K^{/} = \left((\lambda_D + \lambda_E)\,K^2 - \frac{A}{\lambda_D + \lambda_E}\right)^{\frac{1}{2}} \qquad (27)$$

such as

$$T_E\,(K^{/}) = \varsigma\left((\lambda_D + \lambda_E)\,K^2 - \frac{A}{\lambda_D + \lambda_E}\right)^{\frac{j}{2}} \qquad (28)$$

and

$$\theta_1 = \frac{(\lambda_D + \lambda_E)\left((\lambda_D + \lambda_E)\,K^2 - \frac{A}{\lambda_D + \lambda_E}\right)^{\frac{1-j}{2}}}{\varsigma}. \qquad (29)$$

Now,

$$\frac{\theta_1\,T_P\,(K)}{A\,(K)} = \frac{(\lambda_D + \lambda_E)^{\frac{3-j}{2}}\,K^{\frac{j^2+3}{2}}\,\eta\,\left(\frac{1}{A} - \frac{1}{K^2\,(\lambda_D + \lambda_E)^2}\right)^{\frac{1-j}{2}}\left(\frac{1}{A} - \frac{(\lambda_D + \lambda_E)\,K^{1-j}}{A} - \frac{1}{(\lambda_D + \lambda_E)\,K^{j+1}}\right)^{\frac{j+1}{2}}}{\varsigma} \qquad (30)$$

$$= \frac{(\lambda_D + \lambda_E)^{\frac{3-j}{2}}\,K^{\frac{j^2+3}{2}}\,\eta\,\left(1 - \frac{A}{K^2\,(\lambda_D + \lambda_E)^2}\right)^{\frac{1-j}{2}}\left(1 - (\lambda_D + \lambda_E)\,K^{1-j} - \frac{A}{(\lambda_D + \lambda_E)\,K^{j+1}}\right)^{\frac{j+1}{2}}}{A\,\varsigma}. \qquad (31)$$

Claim 12: The share of technological progress in TFP depends on the ratio $\frac{K^{\frac{j^2+3}{2}}}{A}$.

Again it is known that

T_P (K) = η K^{j+1} – η $(K^{/})^{j+1}$.

Hence,

$$K^{/} = \left(K^{j+1} - \frac{T_P\,(K)}{\eta}\right)^{\frac{1}{j+1}} \qquad (32)$$

and

$$\theta_1 = \frac{(\lambda_D + \lambda_E)\left(K^{j+1} - \frac{T_P\,(K)}{\eta}\right)^{\frac{1}{j+1}}}{\varsigma} \qquad (33)$$

give

$$\frac{\theta_1\,T_P\,(K)}{A\,(K)} = \frac{\frac{T_P\,(K))}{K}\left(1 - \frac{T_P\,(K)}{\eta\,K^{j+1}}\right)}{\varsigma\left\{1 - \left(1 - \frac{T_P\,(K)}{\eta\,K^{j+1}}\right)^{\frac{2}{j+1}}\right\}}. \qquad (34)$$

Claim 13: The share of technological progress depends on $\frac{T_P\,(K))}{K}$ and $\frac{T_P\ (K)}{\mathrm{K}^{\mathrm{j+1}}}$. They hamper the growth of technological progress.

Now we try to find out the case for j = - 1. For K and A (K),

$$\theta_1 = \frac{\{((\lambda_D + \lambda_E)\,K)^2 - A\}}{\varsigma} \quad (35)$$

and

$$\frac{\theta_1\,\mathrm{T_P}\,(\mathrm{K})}{A\,(K)} = \{\frac{\left((\lambda_D + \lambda_E)K\right)^2}{A} - 1\}\log\frac{\frac{K}{A}}{\sqrt{\frac{(\lambda_D + \lambda_E)\,K^2}{A} - \frac{1}{\lambda_D + \lambda_E}}}. \quad (36)$$

Claim 14: The technological share in TFP depends on $\frac{K}{A}$. If the ratio increases then technological share increases and when it decreases the share decreases also.

Now for K and $\mathrm{T_P}$ (K), we get

$$\mathrm{K}^{/} = \mathrm{K}\,e^{\frac{-T_P\,(K)}{\varsigma}} \quad (37)$$

$$\theta_1 = \frac{(\lambda_D + \lambda_E)\,K^2\,e^{-\frac{2\,T_P\,(K)}{\varsigma}}}{\varsigma} \quad (38)$$

and

$$\frac{\theta_1\,\mathrm{T_P}\,(\mathrm{K})}{A\,(K)} = \frac{e^{-\frac{2\,T_P\,(K)}{\varsigma}}}{\varsigma\,\{\,1 - \exp\,(1 - \frac{\mathrm{T_P}\,(\mathrm{K})}{\varsigma\log \mathrm{K}}\,\}}\ . \quad (40)$$

Claim 15: Here the growth of technological share in TFP depends only on $T_P\ (K)$ and $\frac{\mathrm{T_P}\,(\mathrm{K})}{\log \mathrm{K}}$ only.

Now for j= - 2 we obtain for K and A (K),

$$\theta_1 = \frac{(\lambda_D + \lambda_E)\,((\lambda_D + \lambda_E)\,K^2 - \frac{A}{\lambda_D + \lambda_E})^{\frac{3}{2}}}{\varsigma} \quad (41)$$

$$\mathrm{T_P}\,(\mathrm{K}) = \varsigma\,\{\frac{1}{\sqrt{(\lambda_D + \lambda_E)K^2 - \frac{A}{\lambda_D + \lambda_E}}} - \frac{1}{K}\} = \frac{\varsigma\,(\mathrm{K} - \sqrt{(\lambda_D + \lambda_E)K^2 - \frac{A}{\lambda_D + \lambda_E}}\,)}{K\,\sqrt{(\lambda_D + \lambda_E)K^2 - \frac{A}{\lambda_D + \lambda_E}}} \quad (42)$$

$$\frac{\theta_1\,\mathrm{T_P}\,(\mathrm{K})}{A\,(K)} = \mathrm{K}\,(\lambda_D + \lambda_E)\,((\lambda_D + \lambda_E)\frac{K}{A} - \frac{1}{\lambda_D + \lambda_E})\,(1 - \sqrt{(\lambda_D + \lambda_E) - \frac{\frac{1}{\mathrm{K}}}{\frac{\mathrm{K}}{\mathrm{A}}\ (\lambda_D + \lambda_E)}}\ ). \quad (43)$$

Claim 16: Here the technological share in TFP depends on K and $\frac{\mathrm{K}}{\mathrm{A}}$.

Now for K and $\mathrm{T_P}$ (K), we get

$$\mathrm{K}^{/} = \frac{K\varsigma}{\varsigma + \mathrm{K}\,\mathrm{T_P}\,(\mathrm{K})} \quad (44)$$

$$\theta_1 = \frac{\lambda_D + \lambda_E}{\varsigma}\left(\frac{K\varsigma}{\varsigma + K\,\mathrm{T_P}\,(\mathrm{K})}\right)^3 \quad (45)$$

$$\frac{\theta_1\,\mathrm{T_P}\,(\mathrm{K})}{A\,(K)} = \frac{1}{\varsigma\left(1 + \frac{K\,\mathrm{T_P}\,(\mathrm{K})}{\varsigma}\right)^2}\ . \quad (46)$$

Claim 17: Here the growth of technological share in TFP depends on $K\,T_P\,(K)$. When $K\,T_P\,(K)$ increases then the growth of technological share in TFP decreases and hampers the growth of technological share.

Discussion

It is noticeable that claims 1 to 4 show a relationship among investment, technical efficiency, technological progress and a typical ratio of technological progress and investment. That ratio predicts the condition of whether TFP will increase or not. The ratio is a new one in the literature of economics and it provides novel evidence of a relationship between TFP and its drivers. Claims 1to 4 explore the different relations of TFP such as TFP with technological progress and investment as in claim 1 and also in claim 4 as a special case; a relation is established between technological efficiency and technological progress with investment in claim 2 and a special case is established in claim 3 by investigating a previously unexplored area of total factor productivity. These claims are relevant because they enlighten new lights on productivity that come with it when only capital accumulation is failed to explain the observed growth but research and development, technological efficiency, technological progress with capital build the necessary clarification and ultimately emphasize the role of institutions (Acemoglu & Robinson 2012).

As it is established in claims 1 to 4 that institutions play a pivotal role in economic growth and development, claim 5 examines the dependent factors of growth of technological share in TFP by creating a unique ratio of investment and TFP. Claim 6 represents the role of a balance wheel by constructing an exclusive quotient that tells the nature of growth of technological share in TFP. If the quotient increases it will hamper the development of technological progress and mere investment will not be able to drag out TFP from the set trap. Claims 7 and 8 have two roles. For a particular case, Claim 7 establishes a relation between technological efficiency and investment logarithmically and it tells what the condition behind the development of backwards countries lies behind the high growth rates, bigger plants and enterprises which are conducive to innovation, knowledge creation and entrepreneurship (Özak 2018). On the issue of how to acquire growth of technological share, Claim 8 shows that there are no other factors but technological progress itself indicating the rapid application of information and communication technology (Hence ICT) in TFP growth. We find a steadily increasing performance of technological progress as suggested by Gordon (2016) which can be explained from Claim 8 here.

One practical implication is that investment is a significant cause of TFP overflow with technological progress. Venturini (2017) studied the case in the ICT sector only. The role of technology and investment in increasing TFP is observed in Claim 9 and the relation established here is applied to all sectors of economics. Within the advanced countries growth rates of TFP tends to be stable and it is possible when efficiency becomes stagnant. The same is true for poorer countries when technological efficiency attains and sustains a minimum value. The mere investment will not be able to better the situation but investment-specific technology will be able to revive the condition. Our results are consistent with the empirical findings of Schmitt- Grohe′ and Uribe (2011) and Ben Zeev and Khan (2015). Pieri et al. (2017) finds that technology is effective in reducing inefficiency and generates inter-industry overflows. In Claims 10 and 11 we are demanding so.

In Claim 12 when investment increases and TFP is constant then the share of technological progress in TFP increases; when investment is stagnant and TFP is constant then the share of technological progress in TFP declines automatically. Again we have deduced two ratios in Claim 13 that hamper the growth of technological progress in TFP at the time when both the ratios increases altogether. As a special case of Claim 13, a ratio between investment and TFP is constructed to get the share of technological progress in TFP in Claim 14. In Claims 15 to 17 we have deduced different relations of share of technological progress in TFP with different parameters such as investment, technological progress etc. A growth hampering ratio is also formed. The key points of the Claims shown above involve mobility of growth of technological share in TFP and investment.

5. Conclusion

While most of the current literature on TFP focuses on measurement and empirical evidence, 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 the share of technological progress in TFP. Government and firm owners must be careful about the quotient. In other cases, capital and TFP are intertwined with each other.

Limitations and study forward

It is important to note that there are many static and floppy economic variables in economies. We have not considered these variables in our investigations. We have only taken investment, technological progress and technological share in TFP and ignored other factors of economies. To know the economy of a country 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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