ISSN: 2834-7706

Research Article

Journal of Mathematical Techniques and Computational Mathematics

Effects of Inputs of a Firm on TFP

Partha Pratim Dube

Garalgacha Surabala Vidyamandir, West Bengal, India.

***Corresponding author**
Partha Pratim Dube, Garalgacha Surabala Vidyamandir, West Bengal, India.

Submitted: 21 Jan 2023; **Accepted:** 06 Feb 2023; **Published:** 18 Feb 2023

Citation: Dube, P. P. (2023). Effects of Inputs of a Firm on TFP. *J Math Techniques Comput Math*, 2(2), 104-109.

Abstract

Purpose: *We approach here the question of dynamical behavior of Total Factor Productivity (Hence TFP) and inputs of firms by constructing theoretical relations of economic parameters that considers economic growth.*

Results: *This article develops a relationship of TFP and its dependent variables; a partial differential equation of TFP is established here and a set of relations of inputs are considered also. A recurrence relation and a second order differential equation of inputs are established here.*

Limitations: *It is not proper setting to study TFP and inputs of a firm fully since all the parameters are not considered here.*

Contribution: *The dynamical behavior of TFP and inputs of a firm found in this paper suggest that policymakers should seriously consider the investment, embodied technology and other factors of TFP for better business policy. The study of inputs focuses the additional valuable guidelines for policy reforms by establishing various relations between inputs and different economic parameters.*

Introduction

Today, GDP per capita of Luxembourg, the richest country in the world, is 173 times of the poorest country Burundi. Economists around the globe have been trying to find out the inherent factors behind the differences since 1950s [1]. Consequent studies pointed out the importance of investments in the useful economic system and the effective embodied technology in generating progress of total factor of productivity (Now TFP) but different types of inputs (such as: human capital as it is characterized by skills, knowledge and experience acquired by an individual or group and research and development, fuelled by huge capital flows and trade booms) used to gear up the TFP have certainly been vital also [2, 3]. TFP is also influenced by labor and ecosystems negatively. All these factors except embodied technology are marked by other factors in this paper.

The factors affecting TFP in this paper is based on four parts. The first is that new and properly used investment lies at the core of TFP growth. Continued well- directed investment with inputs and other factors lead to the steady state optimal growth of the economy [4-6]. The second factor is that inputs happen in every portion of the economy due to the actions of research and development (Now R& D) and human capital on TFP. Inputs play an indispensable function in the economic growth system whereby development of R & D and human knowledge and skill increase output with realistic worth. The third factor is embodied technology. The change of embodied technology requires investment to affect TFP. The relationship between investment and embodied technology is an open question. Technological advances made equipment's less expensive and faster such as the development of computers. New computers are easier and faster; powerful and efficient for telecommunication than old one. Economic growth is dragged behind by labor intensive technology and ecosystem. Other factors play a watchful role to develop eco – friendly growth of TFP in a complex world.

Most models of TFP and its growth rely on growth of capital, labor and output of the economy by using Cobb- Douglas function. But they do not consider different factors affecting TFP and also ignore the economic policy and its effect on TFP and time also. We consider here a ratio between new TFP and old TFP and try to understand the properties behind it in the introductory part of the model in Section III. This property is taken to be the defining characteristics of developed TFP.

In the model 1, a relation between TFP and its factors is established. This relation shows that TFP takes an exponential shape as time proceeds. In model 2, a partial differential equation of TFP with respect of investment and time is established; a recurrence relation of inputs is also formed; rate of change in inputs is also established and an equation measuring how the rate of change of inputs change itself is also established by creating a second order derivative.

TFP creates several different options. Firms or countries do not merely conduct a single type of activity associated with TFP but rather perform several activities such as trade, new investment (it may be foreign direct investment) etc. There is a growing need for new technologies and new investments in different areas of technologies by the firms or countries. It is possible to calculate the effect of new investment in its subdivision of inputs also if new investment is known.

Literary Review

Almost all economists accept that role of technology in the growth of economics contribute significantly. Abramovitz and Solow studied the relation between the technological change and economic growth empirically and realized its importance in capital formation [1, 2]. All of this work addresses the state of knowledge which assumes that economic system is always in the definite realist state and hopes that unexplained portion about the realist state of economic system will be explored as time proceeds. This leads to the fact that knowledge is growing with time. Economic growth depends on exogenous variable and the quantity of knowledge is so vast that it is hard to measure with intellectual satisfaction. It is argued at that point that a disagreement comes in terms of uses of embodied technology by Jorgenson as time advances [3]. Jorgenson provided an account of the underlying reasons for deep disagreements on economic growth and to express these in an analytical with a practical frame. The relation between total factor productivity and rate of embodied technical change is the conventional, illustrative, area which depends on assumptions of models only.

Miller & Upadhyay studied the economic growth in the light of human capital and openness by analyzing a thirty year - panel of eighty-three countries around the world [7]. There is a positive effect by human capital on TFP at 10- percent level for high- and middle-income countries; however, under this model it is observed that human capital bears a negative effect on TFP for the low-income countries especially African countries but TFP experiences a positive effect when human capital and openness act together in the case of African countries. Their data also shows that there is no significant indication of effect of human capital and openness on TFP in the case of Asian countries and high-income countries but a negative effect is observed in the case of high-income countries when openness crosses its limit. These results indicate that effects of openness and human capital on TFP do not bear a positive role always.

In order to dig out the sources of growth of TFP it was a question whether occupational choice and credit constraint had an effect on price dynamics and wealth distribution at the micro level. Jeong & Townsend studied TFP of Thailand for a period of 1976 to 1996 empirically and found that financial deepening and occupational shift explained most part of the aggregate TFP growth [8]. As with the growth – inequality relationships, more convincing insights and key factors behind it were derived from Thailand case studies. Indeed, much of this paper could be observed as trying to expose precisely the importance of TFP generated inputs in a firm.

Resource misallocation effects highlight the aggregate TFP concerns about worsening (Restuccia & Rogerson 2013; David & Venkateswaran 2019) [9, 10]. Particularly in India and China, a comprehensive view of manufacturing firms of higher marginal products provides expansion of heavy plants at the cost of shrinking or elimination of inefficient firms. Firm – level data also suggest the perennial claim that gaps in marginal products of capital in India could take a leading role in framing the low manufacturing TFP in India [11]. Effects of capital liberalization, financial frictions and misallocation are fostered by some visible and well promoted studies in the developing countries with important discussions about how much the firm's input to misallocation quantify the aggregate productivity [12-16]. The hypothesis is constructed here that firm's input in general can be ascribed to productivity which gives rise to problems for which responses are selected with time function. The evidence so far mentioned from economic literature is only suggestive. The aim of this paper is to formulate the firm's input more precisely and draw from it a number of implications.

At the time of discussion with bubbles and TFP, Miao & Wang conclude that the increase in TFP is caused by the additional capital to productive firms but conversely the fail of bubbles leads to deteriorate the efficiency of investment also [17]. Their findings show that the relation between stock price bubbles and capital is positive and highly significant as bubbles assist to lift TFP. It is indicative from their findings that efficiency of investment depends on economic policy and technology that is especially on the advancement embodied technological progress [18-21]. These should enable to form a hypothesis that firm's input depends on TFP, embodied technology and other factors also. The results about the movement of the firm's input presented here differ from those in most standard economic theories; movements of TFP depend on investment and time and the dynamics of inputs rely on its internal system which can be express in a differential mode.

Model

Suppose a new economic policy is imposed in a country or in a firm. This effects productive system and simultaneously on the total factor productivity also.

Let A_t be the TFP of the new economic policy at time t and A_0 be the TFP of the old system when t equals zero that means from that time new economic system is implemented. Again, we take $\frac{A_t}{A_0}$ be the corresponding relative TFP of the economy at time t and denote it by A^* which is to be studied. Then it may be considered as a list of TFP of new economic system with respect to old economic TFP. Assumptions made a priori about A^* (i.e., continuity on the relative TFP functions) define the space of Economies to which the study is restricted. The authority receives a return of the relative total TFP by implementing the new economic policy as

$$\frac{d\,A^*}{A^*} \cdot (\alpha)$$

Model 1

This return (α) expresses the change in the relative TFP of the old system with the new one. TFP may be represented as the information necessary to achieve certain outcomes produced from a particular means of combining or processing selected inputs. This model has two components. The first one is comprised of $E\,\chi\,dt$ where E is embodied technology measured from the stock of new knowledge which is derived from economic transaction

and χ is investment of capital to implement new economic policy. The second one depends on F t *dt,* where F is other factors' cautioning the limitless growth of TFP that is F is an unenthusiastic factor affecting TFP.
Then,

$$\frac{d A^*}{A^*} = E\,\chi\,dt - \text{F t}\,dt. \ (1)$$

$$\text{Or, } \log A^* = -\frac{F\,t^2}{2} + E\,\chi\,\text{t} + \text{ Constant term.}$$

This constant term reduces to zero when t equals with zero and that time $A_t = A_0$ which gives $A^* = 1$.

Then,

$$A^* = \exp\,(\text{E}\,\chi\,\text{t} - \frac{F\,t^2}{2})\ (2)$$

This gives,

$$\frac{A_t}{A_0} = \exp\,(E\,\chi\,\text{t} - \frac{F\,t^2}{2}).\ (3)$$

This equation also gives,

$$A_t = A_0 \exp\,(E\,\chi\,\text{t} - \frac{F\,t^2}{2}).\ (4)$$

Claim 1: TFP at time t of new economy policy depends on the shares of old TFP as well as on the other factors negatively, embodied technology, time and the new investment exponentially.

Model 2

A change in new investment can cause output of per unit input TFP to increase, even if rate of the technologies remains unchanged. This reinforces the basic point that growth of new TFP depends on new investments, other factors and embodied technologies and it tries to free from the bondage of old TFP as time proceeds.

It is possible to assume relative A^* as a continuously differentiable function (It means there are negligible set of critical values in the set) which will be represented by a point at 't' = 0 and see what happens in the neighborhood of that point.

Now the economic policy is structured as follows.
Assumption 1: Relative A^* is continuously differentiable at t = 0.

Assumption 2: $A^* = [x_n]_{n=0}^{\infty}$ is the list of inputs used by a firm that generates TFP, there is some value B such that $x_n = 0$ for all $n \geq B$.

Now we define A^* by means of the relation

$$A^* = \sum_{n=0}^{\infty} x_n\,(\chi)\,t^n \text{, valid for all finite } \chi \text{ and t. (5)}$$

These equations show that TFP is highly specific and encompasses multiple definite sub-processes of inputs.

As we observe the previous relation (2),

$A^* = \exp\,(E\,\chi\,\text{t} - \frac{F\,t^2}{2})$ in which A^* has a series expansion.
Then,

$$\frac{\partial A^*}{\partial t} = A^*\,(\text{E}\,\chi - \text{F t})\ (6)$$

and

$$\frac{\partial A^*}{\partial \chi} = \text{E t}\,A^*.\ (7)$$

From equations (6) and (7), we find the equation,

$$(\chi - \frac{F\,\text{t}}{E})\frac{\partial A^*}{\partial \chi} - \text{t}\frac{\partial A^*}{\partial t} = 0, \text{ provided E} \neq 0.$$

It can be written as

$$(\chi - \frac{F\,\text{t}}{E})\,A_\chi^* - \text{t}\,A_t^* = 0, \text{ where } A_\chi^* = \frac{\partial A^*}{\partial \chi} \text{ and } A_t^* = \frac{\partial A^*}{\partial t}.\ (8)$$

Claim 2: Total factor productivity at time t follows a partial differential equation with respect to investment and time.
The equation (8) can be written as,

$$\frac{A_t^*}{A_\chi^*} = \frac{\chi}{t} - \frac{F}{E},$$

$$\frac{d\chi}{dt} = \frac{\chi}{t} - \frac{F}{E}, \quad \text{which establishes the relation}$$

$$\text{E} = \frac{F\,\text{t}\log\frac{1}{\text{t}}}{\chi}. \quad (9)$$

Claim 3: Effective embodied technology depends on other factors, investment and time.
Since

$$A^* = \sum_{n=0}^{\infty} x_n\,(\chi)\,t^n,$$

it follows from (8) that

$$\chi \sum_{n=0}^{\infty} x_n'\,(\chi)\,t^n - \frac{F}{E}\sum_{n=0}^{\infty} x_n'\,(\chi)\,t^{n+1} - \sum_{n=0}^{\infty} n\,x_n\,(\chi)\,t^n = 0.\ (10)$$

In the second term, replace n by n - 1 and get,

$$\chi \sum_{n=0}^{\infty} x_n'\,(\chi)\,t^n - \sum_{n=0}^{\infty} n\,x_n\,(\chi)\,t^n - \frac{F}{E}\sum_{n=1}^{\infty} x_{n-1}'\,(\chi)\,t^n = 0.\ (11)$$

Since $x_{n-1}'(\chi) = 0$, for n = 0, 1 we get,

$$\chi \sum_{n=0}^{\infty} x_n'\,(\chi)\,t^n - \sum_{n=0}^{\infty} n\,x_n\,(\chi)\,t^n - \frac{F}{E}\sum_{n=0}^{\infty} x_{n-1}'\,(\chi)\,t^n = 0.\ (12)$$

By equating co-efficient of t^n we obtain,

$$\text{E}\,\chi\,x_n'(\chi) = n\,E\,x_n(\chi) + \text{F}\,x_{n-1}'(\chi). \quad (13)$$

Claim 4: The growth rate of inputs in its n-th subdivision multiplied by embodied technology and investment is equal to the sum of product of old input with other factors and also product of embodied technology with the number n and current input.
Also, the relation,

$$\exp\,(\frac{F\,t^2}{2} + E\,\chi\,\text{t}) = \sum_{n=0}^{\infty} x_n\,(\chi)\,t^n$$

yields at once by differentiating with respect to χ and get,

$$\text{E t}\sum_{n=0}^{\infty} x_n\,(\chi)\,t^n = \sum_{n=0}^{\infty} x_n'\,(\chi)\,t^n.\ (14)$$

Or, $E \sum_{n=0}^{\infty} x_n (\chi) t^n = \sum_{n=0}^{\infty} x_n^{'} (\chi) t^n$. (15)

$\sum_{n=0}^{\infty} x_{n-1} (\chi) t^{n-1} = x_0^{'} (\chi) t^0 + \sum_{n=1}^{\infty} x_n^{'} (\chi) t^n$.

[Here, $x_0^{'} (\chi) = 0$]

This gives the equation,

$$x_n^{'}(\chi) = \mathrm{E}\, x_{n-1} (\chi) \text{ . (16)}$$

Claim 5: Rate of change of inputs equals with the product of embodied technology and old inputs.

From equations (12) and (15), we obtain the recurrence relation $x_n (\chi)$,

$$\mathrm{n}\, x_n (\chi) - \chi\, \mathrm{E}\, x_{n-1} (\chi) + F\, x_{n-2} (\chi) = 0. \text{ (17)}$$

Claim 6: A recurrence relation for inputs $x_n(\chi)$ is established when n > 0.

It also gives the differential equation of $x_n(\chi)$,

$$\mathrm{F}\, x_n^{''} (\chi) - E^2 \chi\, x_n^{'} (\chi) - E^2\, \mathrm{n}\, x_n (\chi) = 0. \text{ (18)}$$

Claim 7: A second order derivatives of inputs $x_n(\chi)$ is formed when n > 0.

Discussion

In claim 1, we find out that TFP depends on five basic parameters such as old TFP, other factors, embodied technology, time and new investment. Since TFP function in our model is a convex function for large dataset then it offers a consistent approximation. It is known that new investment is an important source of TFP growth which can be assessed in components of consumption [22, 23]. Our findings also suggest that embodied technology is also an important driver of TFP as developed by many researchers recently by contradicting the claim that embodied technology is important in the short run only [24-27]. Many economists have focused on the improvement of other factors and time as a source of increased TFP [28-30]. This interpretation is incorporated in our model in claim 1 by assuming all the above parameters that affect the growth of TFP qualitatively as well as quantitatively.

The novel equation of claim 2 proposes a relation between the marginal TFP function with respect to investment and the marginal TFP function with respect to time also. It indicates a specific use of TFP to which an agent will invest money to enjoy a definite increase within a certain period of time or the specific use of TFP that will be abandoned in response to a given decrease. This also gives in our claim 2; the marginal TFP with investment detects the best position and time that it can avail optimality and the precise application of TFP experienced a rapid immense development of the economy of backward countries [31].

A reasonable behavior of the embodied technology is observed by establishing the relation in claim 3, in which the product of effective embodied technology and investment solely depends on other factors and time endogenously. Claim 3 ascertains that when the other factors are active in dragging the economy behind and time is not favorable, the huge amount of investment in economy and the application of sophisticated technology will not be effective to increase the growth of economy as observed in US and Europe by Comin et al. [32].

The growth rate of inputs in claim 4 follows a recurrence relation depending on embodied technology, investment, other factors and growth rate of old inputs. From the equation (13) investment is measured in ratio of inputs and growth rate of inputs when n equals with one. Growth rates of inputs in different stages can be calculated by recurrence relation by taking n equals with one, two etc. Other factors are negative factors that dragging the economy behind can also be calculated from the equation (13) by putting different values of n. The concept of growth rate of inputs is basically firm specific that is close to sustainability which is included in our model as other factors. The analysis of TFP of the China's economy is structured around the conceptual framework of Chen et al. and Feng et al. with the question of sustainable economic growth which can be explored in claim 4 by estimating other factors [33, 34].

Economic growth comes from technological progress, which in turn consequences from embodied technological performance among different research firms that produce improved ideas. Embodiment means because of technological advance; the new inputs are more efficient than old the old ones. The growth rate of new inputs is dependable on embodied technology and old inputs as established in claim 5 which is alluded to by Hesmati & Kumbhakar; Mastromarco & Zago; Gordon and many others [35-37]. This also indicates that research firms are stimulated by the prospect of embodied technology that can be incarcerated when a successful technology is patented.

The features of embodied technology are extremely inter-reliant and cannot easily be distinguished from the movement of inputs. The characteristics of the inputs that are considered in our model include other factors, new investment, embodied technology and the movement of old inputs also. Assuming that TFP is properly specified and that other factors and investment are evaluated from previous claims then the movement of inputs is explained in our claim 6 by considering a recurrence relation of inputs in its different sub-divisions.

From the result of claim 7 and also from the discussions of TFP, so far, has been the understanding that the inputs are combined in such a way as to produce the optimal potentiality of the growth of economics. By deriving the differential equation of inputs in its subdivisions, we can predict the dynamics of different stages of inputs with the other factors, investment and embodied technology. Our results, so far discussed here, show that feedback effects from the micro level of inputs and different economic factors to macro level variables are important in determining inputs impact on TFP and economic policy of a firm in a comparative framework.

Conclusion

This paper has tried to derive the result that new TFP depends positively on different economic parameters which contributes the economic performance in a certain period of time. For variety movements of TFP, the best optimization position and time of TFP is determined in our model also. Application of huge amount of investment with misled technology provides a little less effect on the economic performance than one firm owner might wish but the preponderance of investment specific technology with a specific position and time certainly favors the economic growth. The depending factors of inputs have an effect on economic policies being encouraging but it would be more helpful when inputs will be calculated in its subdivisions. This promotes that a successful application of embodied technology with new investment will be effective to the growth of TFP. One might observe also that it is interesting and suggestive that the dynamics of inputs of a firm would be easy to analyze in light of a recurrence relation of inputs in its least possible subdivisions. In fact, such recurrence relations frame a new second order derivative relation of inputs and are helpful aids in finding out the characteristics of inputs in its micro-level.

Limitations and Study Forward

In sum, the features of TFP and inputs of a firm appear in our model to have some predictive power and will be tested when dataset is available. Any attempt to comprehensively measure the inputs needs time and energy to collect the required dataset; the results of these efforts may be available long after policy-makers will collect all the stagnant and limp economic parameters which are not considered here. Because informational needs are important, the study of the dynamical behavior of TFP and inputs presented here would prove functional. Exactly how these studies predict the outcomes of the nature of TFP and inputs of a firm by considering all the economic parameters remains a topic of ongoing research.

Acknowledgement

The author receives no financial and non-financial support from any institutions and organizations.

The author has no conflict of interest.

References

1. Abramovitz, M. (1956). Resource and output trends in the United States since 1870. In Resource and output trends in the United States since 1870 (pp. 1-23). NBER.
2. Solow, R. M. (1960). Investment and technical progress. Mathematical methods in the social sciences, 1(10), 48-93.
3. Jorgenson, D. W. (1966). The embodiment hypothesis. Journal of Political Economy, 74(1), 1-17.
4. Solow, R. M. (1956). A contribution to the theory of economic growth. The quarterly journal of economics, 70(1), 65-94.
5. Cass, D. (1965). Optimum growth in an aggregative model of capital accumulation. The Review of economic studies, 32(3), 233-240.
6. Srinivasan, T. N. (1989). The Theory of International Trade, Steady-state Analysis and Economics of Development. Joan Robinson and Modern Economic Theory, 687-701.
7. Miller, S. M., & Upadhyay, M. P. (2002). Total Factor Productivity, Human Capital and Outward Orientation: Differences by Stage of Ddevelopment and Geographic Regions.
8. Jeong, H., & Townsend, R. M. (2007). Sources of TFP growth: occupational choice and financial deepening. Economic Theory, 32, 179-221.
9. Restuccia, D., & Rogerson, R. (2013). Misallocation and productivity. Review of Economic dynamics, 16(1), 1-10.
10. David, J. M., & Venkateswaran, V. (2019). The sources of capital misallocation. American Economic Review, 109(7), 2531-2567.
11. Banerjee, A. V., & Duflo, E. (2005). Growth theory through the lens of development economics. Handbook of economic growth, 1, 473-552.
12. Midrigan, V., & Xu, D. Y. (2014). Finance and misallocation: Evidence from plant-level data. American economic review, 104(2), 422-458.
13. Hombert, J., & Matray, A. (2017). The real effects of lending relationships on innovative firms and inventor mobility. The Review of Financial Studies, 30(7), 2413-2445.
14. Bai, J., Carvalho, D., & Phillips, G. M. (2018). The impact of bank credit on labor reallocation and aggregate industry productivity. The Journal of Finance, 73(6), 2787-2836.
15. Collard-Wexler, A., Asker, J., & De Loecker, J. (2011). Productivity volatility and the misallocation of resources in developing economies (No. w17175). National Bureau of Economic Research.
16. Kalemli-Ozcan, S., Luttini, E., & Sørensen, B. (2014). Debt crises and risk-sharing: The role of markets versus sovereigns. The Scandinavian Journal of Economics, 116(1), 253-276.
17. Miao, J., & Wang, P. (2012). Bubbles and total factor productivity. American Economic Review, 102(3), 82-87.
18. Ding, S., Sun, P., & Jiang, W. (2016). The effect of import competition on firm productivity and innovation: does the distance to technology frontier matter? Oxford Bulletin of Economics and Statistics, 78(2), 197-227.
19. Bloom, N., Draca, M., & Van Reenen, J. (2016). Trade induced technical change? The impact of Chinese imports on innovation, IT and productivity. The review of economic studies, 83(1), 87-117.
20. Boucekkine, R., Del Rio, F., & Licandro, O. (2003). Embodied Technological Change, Learning-by-doing and the Productivity Slowdown. Scandinavian Journal of Economics, 105(1), 87-98.
21. Dube, P. P. (2021). Some Comments on TFP and its Growth in India. Bulgarian Economic Papers, (5), 2-13.
22. Venturini, F. (2015). The modern drivers of productivity. Research Policy, 44(2), 357-369.
23. Cardona, M., Kretschmer, T., & Strobel, T. (2013). ICT and productivity: conclusions from the empirical literature. Information Economics and policy, 25(3), 109-125.
24. Barsky, R. B., & Sims, E. R. (2011). News shocks and business cycles. Journal of monetary Economics, 58(3), 273-289.
25. Beaudry, P., Green, D. A., & Sand, B. (2012). Does industrial composition matter for wages? A test of search and bargaining theory. Econometrica, 80(3), 1063-1104.
26. Ben Zeev, N., & Khan, H. (2015). Investment-specific news

shocks and US business cycles. Journal of Money, Credit and Banking, 47(7), 1443-1464.

27. Phelps, E. S. (1962). The new view of investment: a neoclassical analysis. The Quarterly Journal of Economics, 76(4), 548-567.
28. Haider, F., Kunst, R., & Wirl, F. (2021). Total factor productivity, its components and drivers. Empirica, 48, 283-327.
29. De Loecker, J., & Van Biesebroeck, J. (2016). Effect of international competition on firm productivity and market power (No. w21994). National Bureau of Economic Research.
30. Acemoglu, D., Robinson, J. A., & Verdier, T. (2017). Asymmetric growth and institutions in an interdependent world. Journal of Political Economy, 125(5), 1245-1305.
31. Özak, Ö. (2018). Distance to the pre-industrial technological frontier and economic development. Journal of Economic Growth, 23(2), 175-221.
32. Comin, D. A., Gonzalez, J. Q., Schmitz, T. G., & Trigari, A. (2020). Measuring TFP: The role of profits, adjustment costs, and capacity utilization (No. w28008). National Bureau of Economic Research.
33. Chen, L., Wang, Y., Lai, F., & Feng, F. (2017). An investment analysis for China's sustainable development based on inverse data envelopment analysis. Journal of cleaner production, 142, 1638-1649.
34. Feng, C., Wang, M., Liu, G. C., & Huang, J. B. (2017). Sources of economic growth in China from 2000–2013 and its further sustainable growth path: A three-hierarchy meta-frontier data envelopment analysis. Economic Modelling, 64, 334-348.
35. Heshmati, A., & Kumbhakar, S. C. (2011). Technical change and total factor productivity growth: The case of Chinese provinces. Technological Forecasting and Social Change, 78(4), 575-590.
36. Mastromarco, C., & Zago, A. (2012). On modeling the determinants of TFP growth. Structural Change and Economic Dynamics, 23(4), 373-382.
37. Gordon, R. J. (2016). The rise and fall of American growth. In The Rise and Fall of American Growth. Princeton University Press.