STUDYING TECHNOLOGICAL PROGRESS AND ITS IMPACT ON ECONOMIC GROWTH IN CHINA

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ABSTRACT

In this article, we analyze the tendency of technological development and the possibility to catch up with the advanced level in China. The technology progress has been playing an important part in the future, in turn, the economic growth has significant influence on technology level. According to the policy test results, we give the proposal and get the conclusions about developing technology in China.

1. INTRODUCTION

Economic theory in 30s paid much attention to the unemployment problem and concentrated on the function of labor in production. Just after World War II, on the contrary, economists went to the other extreme, attaching more importance to the influence of capital in the growth process. Recently, with a comprehensive study in economic growth, economists have tried to combine the influences of the growth in labor, capital and technology. The effect of technological progress on economy is playing more and more important role both at present and in the future. Economists have been much concerned with how to describe the effect of technological progress on the growth in economy. The paper, therefore, sheds light on the alternative policy choices with respect to how technology can be developed in China.

1.1 BACKGROUND

Since this century, the development of science and technology has played a great part in economic growth. In some advanced countries, the impact of technological progress on economic growth has reached 60%-70% measured in percentage in comparation with other factors. Technology has become major power in promoting economic growth. Now in China, the low technology level causes only 20%-30% impact on economic growth. It will not be the main factor in stimulating the growth of the economy unless it improves its historically progress rate. Firstly, we will briefly review the history of the past 30 years.

The history of technological development in China can be divided into four stages:

The first stage is from 1953 to 1962. Through the so called "three-year adjustment" after the war, basic industry and agriculture and systems of science and education were built up by means of the transfer and import from the Soviet Union. As a result, a conventional industry at the level of advanced countries before World War II was formed, and the primary systems of education and scientific research were established.

In the second stage (1963-1966), technological advancement was consolidated and promoted further. The economic system and the systems of education and scientific research introduced from the Soviet Union were being transfered and nationalized gradually.

The third stage (1966-1978) was a period of stagnation and hesitation especially for science and technology. The Cultural Revolution made the economic system and cultural and educational undertakings fall into disorder. The national economy was on the verge of collapse. The gap in technology between China and the advanced countries became even greater.

In the fourth stage (1978-1984), the central task of the country was being transfered from political campaigns to the construction of the national economy. Work was resumed after a period of disorder. The importance of science and technology has been gradully realized by the people. Furthermore, policies favourable to science and technological progress, such as greater investment in the development of science, technology and education, have accelerated the progress of technological advancement.

1.2 PROBLEMS TO BE CONSIDERED

We will use the NMC (national model of China) to answer the following questions:

. How will the technology of China progress under various condition? How and when will China's technology catch up with that of advanced countries?
. What is the major factors promoting technological progress?
. How does technological progress influence economic growth and vice versa?

2. MODEL OVERVIEW

The technology sector, as a part of the NMC, has a close connection with other sectors, such as the education sector, allocation of national income sector, production capacity sector and others. The primary part of the technology sector is a level variable implying the level of technological progress named TEI, or T for short in the production function. There are also three auxiliary variables considered as the major factors affecting technological progress, which will be described in detail later.

2.1 THE EXOGENOUS VARIABLE

It is supposed that technological progress in advanced countries (named TEIADV in the model) grows in the exponential form.

A TEIADV.K = TEIADI x EXP (M x (TIME.K-1965))

Where

TEIADI -- Initial Value

M -- The Rate of Technological Progress in Advanced Countries

Another exogenous variable is the foreign trade ratio (named FORTR in the model), which equals the ratio of total volume of import to total volume of national income.

2.2 THE LEVEL OF TECHNOLOGICAL PROGRESS

There is only one level variable in the technology sector i.e. variable TEI. The following are level equation and rate equation of technological progress:

L TEI.K = TEI.J + DT x RATTEI.JK

R RATTEI.KL = EITEI.K x (WTEI x FTTEI.K + (1-WTEI) x

X FTTFT.K)

Where

TEI--Technology in Industry

RATTEI--Rate of Transfer of Technology in Industry

EITEI--Effect of Investment of Technology

FTTEI--Factor for Technology Transfer from Education

WTEI--Weight of Technology in Industry

FTTFT--Factor for Technology Transfer from Foreign Trade

We can see from the formula above that technological progress depends on EITEI, FTTEI and FTTFT which represent the investment factor, education factor and introduction factor respectively. The weighted sum of FTTEI and FTTFT has an overall effect of increasing technology level. Nevertheless, the variable EITEI acts on both variable FTTEI and FTTFT and appears as a multiplier, which means that the transfef of technology from both education and science or foreign trade will need investment. In fact, education and science only provide skilled workers with certain special knowledge and capacities of invention and innovation. If they are to be transfered into productivity, they will need the support from the whole economy. On the other hand, the introduction of technology also needs investment to import equipment and technology and transfer them into domestic technology which will become one of the forces to develop national economy.

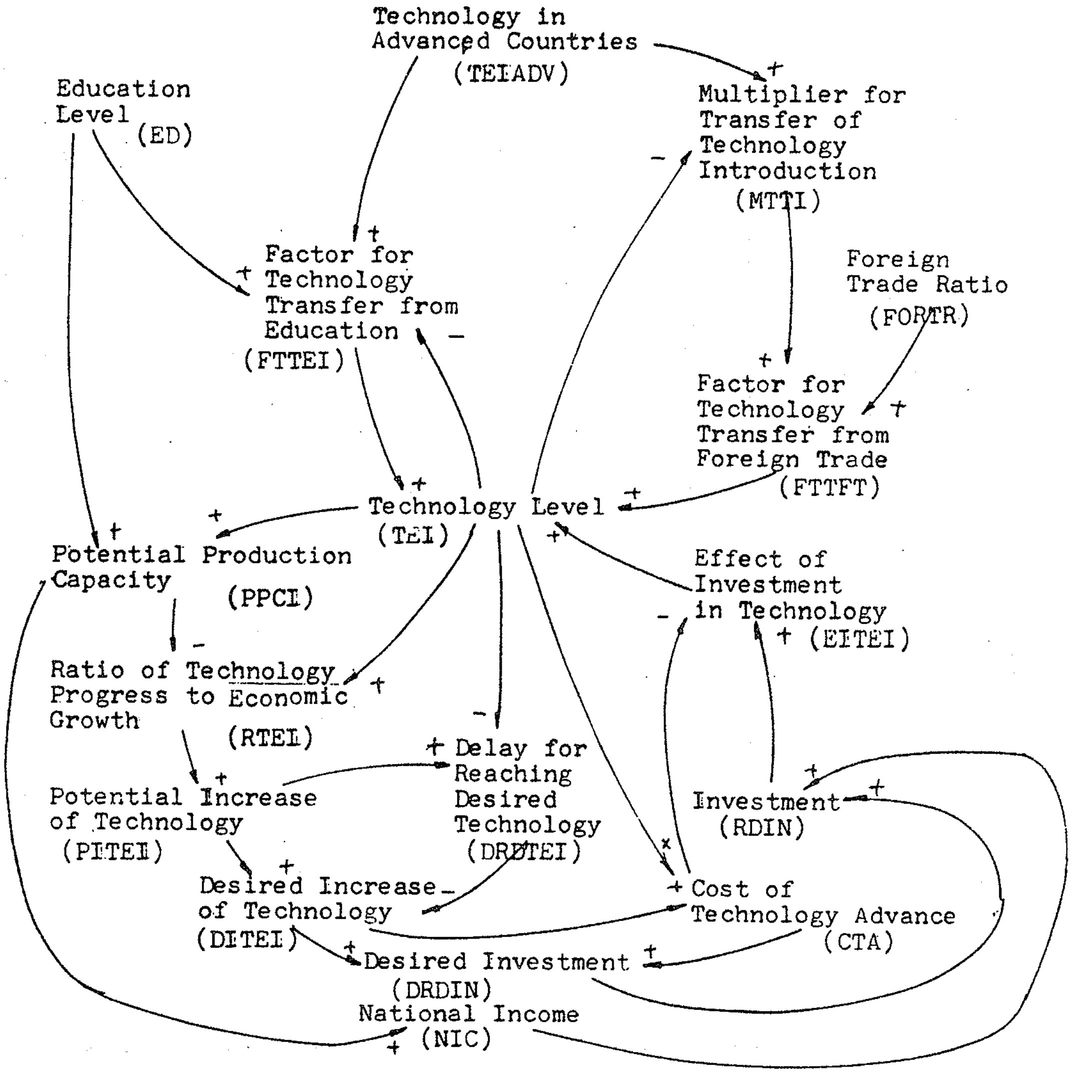


Fig.1 Causal Loop

2.3 THE ANALYSIS OF MECHANISM AND CAUSAL LOOPS

We will analyze the mechanism of the technology sector by means of the causal loops draft shown as Fig.1. As stated above, the core of the modal is a level variable TEI and the other parts of the model are developed from it. Three factors are now considered in the model i.e. the domestic education factor, the technology introduction factor and the investment factor as well. Education factor is determined by the technology of advanced countries and the education level (which comes from the education sector). They have a positive influence on technological growth.

Also, technology level returns back to the education factor to form a negative loop.

The technology introduction factor has a similar causal relationship to the education factor. The variable MTTI (multiplier of transfer of technology introduction) is a function of difference between TEIADV and TEI. The bigger the difference, the greater the variable MTTI.

The investment factor, one of the important parts in the technology sector, represents the effect of promotion of economic growth on the progress of technology.

Making a comprehensive survey of the causal loop draft, we can get several feedback loops which will allow us to understand the mechanism better and will be helpful in the analysis of dynamic behaviors and developing trends of technology.

The first feedback loop includes the following variables:

$$\begin{tikzcd}
\mathrm{TEI} \arrow[r, "+"] & \mathrm{RTEI} \arrow[r, "+"] & \mathrm{PITEI} \arrow[r, "+"] & \mathrm{DITEI} \arrow[r, "+"] & \mathrm{DRDIN} \arrow[r, "+"] & \mathrm{RDIN} \arrow[r, "+"] & \mathrm{EITEI} \arrow[llllll, bend left, "+"']
\end{tikzcd}$$

It is a positive feedback loop which means the continuous and unlimited development of technology.

There are two negative feedback loops in the technology sector. One of them is as follows:

$$\begin{tikzcd}
\mathrm{TEI} \arrow[r, "+"] & \mathrm{RTEI} \arrow[r, "+"] & \mathrm{PITEI} \arrow[r, "+"] & \mathrm{DRDTEI} \arrow[r, "-"] & \mathrm{DITEI} \arrow[r, "+"] & \mathrm{DRDIN} \arrow[r, "+"] & \mathrm{RDIN} \arrow[r, "+"] & \mathrm{EITEI} \arrow[lllllll, bend left, "+"']
\end{tikzcd}$$

Another one is:

$$\begin{tikzcd}
\mathrm{TEI} \arrow[r, "+"] & \mathrm{RTEI} \arrow[r, "+"] & \mathrm{PITEI} \arrow[r, "+"] & \mathrm{DITEI} \arrow[r, "+"] & \mathrm{CTA} \arrow[r, "-"] & \mathrm{EITEI} \arrow[lllll, bend left, "+"']
\end{tikzcd}$$

The former loop contains time delay or inertia of technological progress, which limits the developing speed of technology. The latter loop shows the limitation of technological progress due to the cost of technological progress. Time delay and cost are two factors limiting the development of technology. The former loop is an intrinsic attribute of technological progress. The latter one, on the other hand, can be modified by increasing investment.

If the variable PPCI and NIC which come from the economic sector are added into the draft, another feedback loop can be obtained i.e.:

$$\begin{tikzcd}
\mathrm{TEI} \arrow[r, "+"] & \mathrm{PPCI} \arrow[r, "+"] & \mathrm{NIC} \arrow[r, "+"] & \mathrm{RDIN} \arrow[r, "+"] & \mathrm{EITEI} \arrow[llll, bend left, "+"']
\end{tikzcd}$$

This is a positive feedback loop, which means that economic development is another important force promoting technological progress. But in return, technology progress also accelerates economic growth. Therefore, an economic growth and technological progress are mutually promoting.

2.4 THE COBB-DOUGLAS FORMULA

The Cobb-Douglas formula using labor, capital, education and technology as the factor of input in production is used in the equation for potential production capacity. It emerges as the following form in the model:

$$P = C \times T \times (L)^{\alpha} \times (K)^{\beta} \times (E)^{\gamma}$$

Where

P--Output of Potential Production Capacity

C--Constant

T--Technology Progress Level

K--Capital

L--Labor Force

E--Education

β--Exponent of Capital in Output

α--Exponent of Labor in Output

γ--Exponent of Education in Output

The equation shown above portrays the combination of labor, capital education and scale factor (C x T) to produce the potential production capacity. The scale factor is a variable of time in the model. Variable T, defined as technological progress level in a broad sense (called technological progress for short) is considered to be "neutral", which means that technological progress will cause the other three factors (K,L and E) to increase in same proportion.

2.5 THE RELATIVE ROLE OF EACH FACTOR IN ECONOMIC GROWTH

The Cobb-Douglas formula representing potential production capacity in the NMC plays the key role in the economic sector. Four factors are considered in the equation which all affect economic growth. But the effect of each one is different.

In order to define the role of each factor in economic growth, we will rewrite the Cobb-Douglas equation as follows and assume each variable to be continuous:

$$P = C \times T \times (L)^{\alpha} \times (K)^{\beta} \times (E)^{\gamma}$$

Differentiating the two sides of the equation, we have:

$$\begin{aligned} dP/dt = {} & C \times (dT/dt) \times L^{\alpha} \times K^{\beta} \times E^{\gamma} + C \times T \times \alpha \times (dL/dt) \times \\ & \times L^{\alpha-1} \times K^{\beta} \times E^{\gamma} + C \times T \times L^{\alpha} \times \beta \times (dK/dt) \times K^{\beta-1} \times E^{\gamma} + \\ & + C \times T \times L^{\alpha} \times K^{\beta} \times \gamma \times (dE/dt) \times E^{\gamma-1} \end{aligned}$$

The two sides are then divided by P:

$$(1/P) \times (dP/dt) = (1/A) \times (dA/dt) + \alpha \times (1/L) \times (dL/dt) + \beta \times$$
$$\times (1/K) \times (dK/dt) + \gamma \times (1/E) \times (dE/dt)$$

If the right side of the equation is divided by the left, we have:

$$1 = (dT/T) / (dP/P) + \alpha \times (dL/L) / (dP/P) + \beta \times$$
$$\times (dK/K) / (dP/P) + \gamma \times (dE/E) / (dP/P)$$

From the equation above, we can see that the denominator dP/P is the growth rate of the output variable P, and the numerator dT/T is the growth rate of the variable T. We define (dT/T)/(dP/P) as the effect of technological progress on economic growth, named RIEI. The other three items in the equation are defined in a similar way and named RLI, RKI and REDIN respectively. Therefore, we can obtain the equation as follows:

$$1 = RTEI + RLI + PKI + REDIN$$

3. BASIC ASSUMPTIONS AND ANALYSIS OF BASE RUN

3.1 BASIC ASSUMPTIONS AND CONDITIONS OF OPERATION

The operation starts from 1965 so as to calibrate the historical data. The initial values and the parameters are determined by analysing the related materials and articles, and calculating or dealing with the data published in the statistical yearbook (almanac). The initial values of domestic technology level and technology level of advanced countries are supposed as 1.21 and 3 (dimensionless) respectively. And the rate of technological progress in advanced countries is assumed to be about 0.01-0.02. Foreign trade ratio is limited to within 10%. Fig.2 shows the approximate tendency of variable FORTR.

The elasticity of labor, capital and education in the Cobb-Douglass formula are 0.5, 0.4 and 0.1 respectively.

3.2 THE ANALYSIS OF BASE RUN

Fig.3 shows the result of technological progress under the basic assumptions and initial values presented in last section. The initial difference ratio (technology in advanced countries/domestic technology level) is 2.47. As the results show, during the period between 1965 and 1980 the increase in technology is very slow due to low education level and little investment availability (investment available / desired investment) which is below 40% on the average. Technology level in 1980 is only 1.443. The difference ratio is 2.55, which is greater than that in 1965. That means the difference has become greater. The impact of technological progress on economic growth is only 3%-24%, which may be the main factor hindering the development of the economy.

During the last twenty years of this century, the rapid introduction of technology and the continuous increase in investment (investment

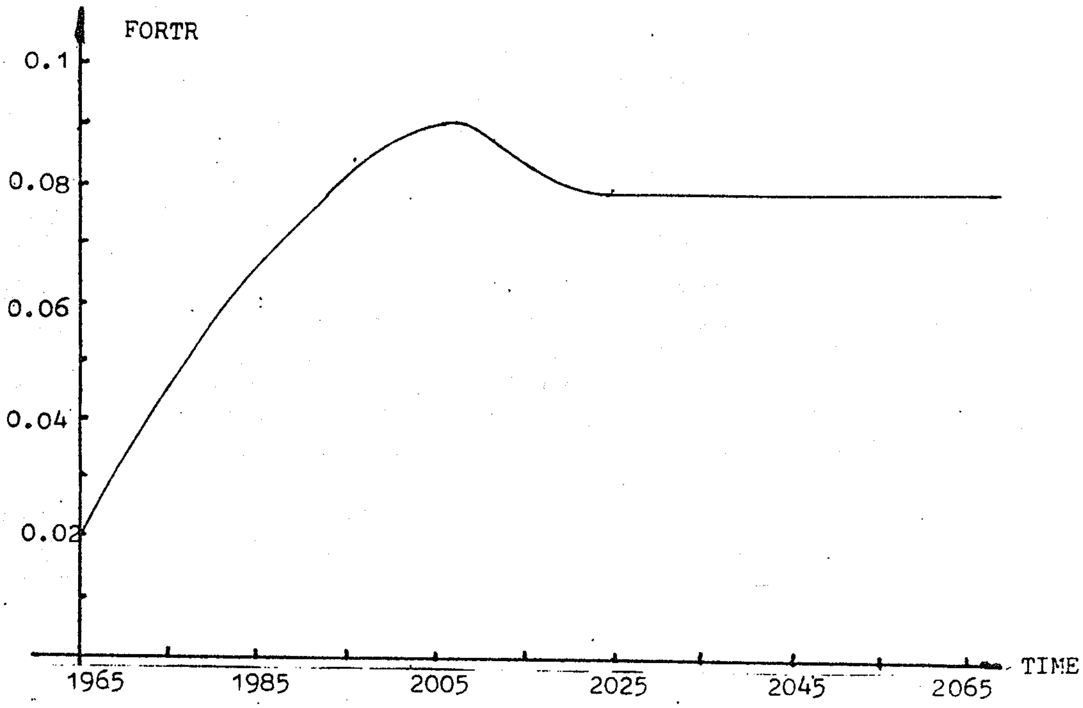
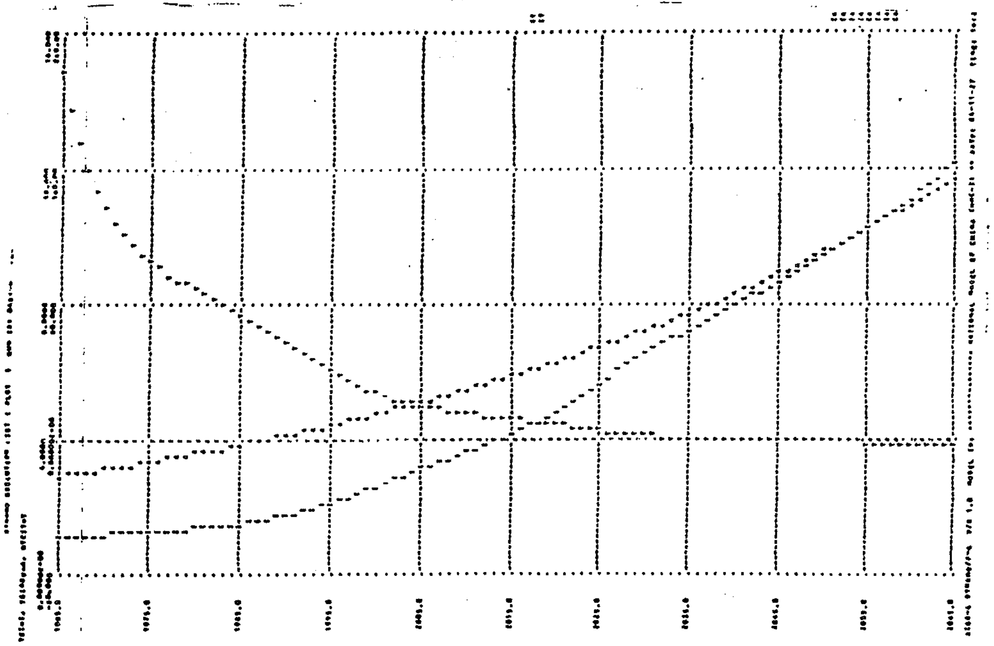


Fig. 2 Foreign Trade Ratio



I--Technology Level A--Technology in Advanced Countries

T--Normal Catching Time

Fig. 3 Developing Tendency of Technology availability keeps about 90% in average) will support the progress of technology. Technology level will increase at a speed of 3% per year on the average. As a result, technology level will reach about 2.7 by 2000 and the difference ratio will be 1.8, corresponding to the technology level of advanced countries in the 60s. The impact of technological progress on economic growth will rise to 40%-50%.

The increase rate of technology will reach a maximum in about 2000, then decline due to a decrease in technology introduction. After a low trough of twenty years, the increase rate begins to rise again. It should be noted that the cost of technological progress will rise rapidly as technology develops to the extent of relatively high level. Because of the rise in cost, investment availability will drop suddenly, leading to the increase rate to decline again in a forty-year cycle. The tendency of the increase rate is shown in Fig.4. According to the result of the base run, the technology level of China will catch up with that of advanced countries in about 2050.

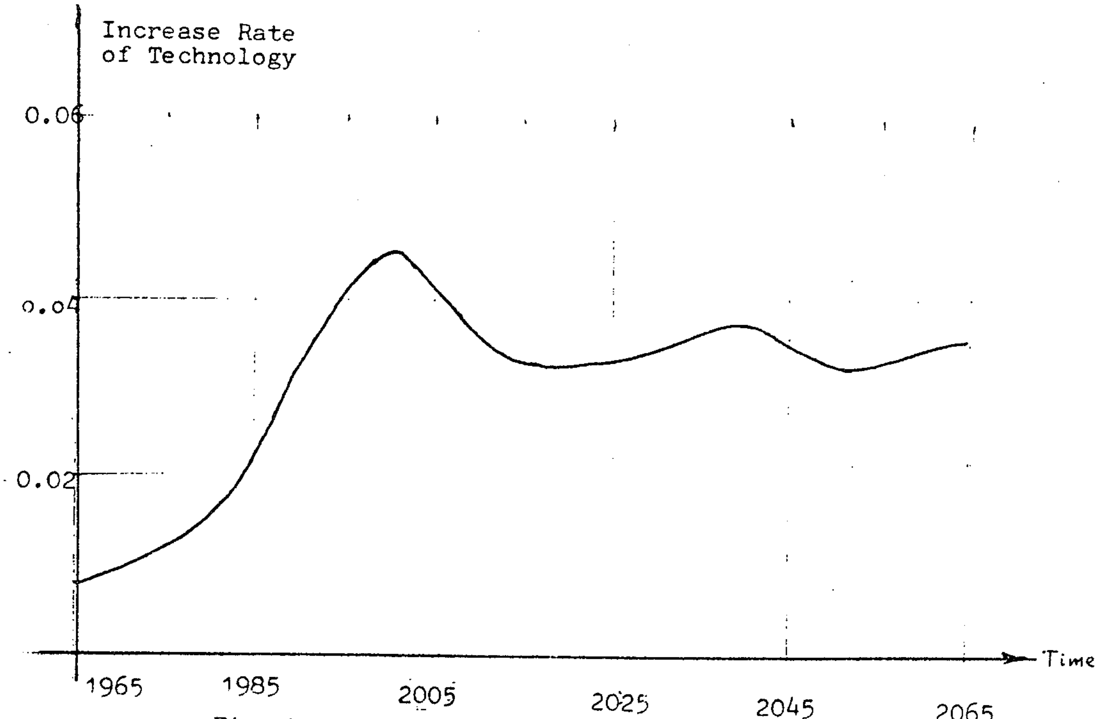


Fig. 4 Increase Rate of Technology

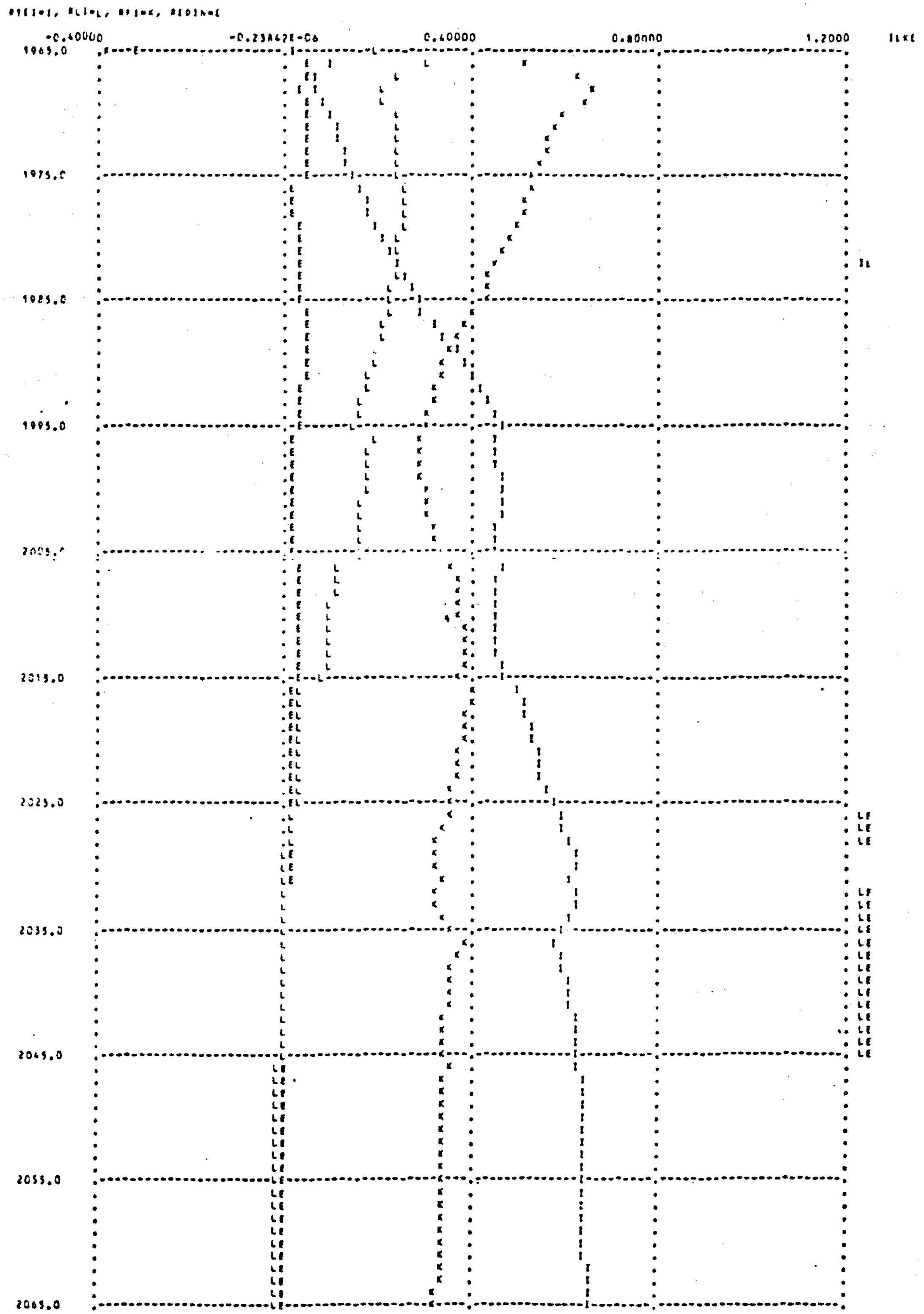


Fig. 5 The Impact on Economic Growth

4. THE TEST RESULTS CONCERNING TECHNOLOGICAL PROGRESS

4.1 THE ANALYSIS OF IMPACT OF TECHNOLOGICAL PROGRESS OF ECONOMIC GROWTH IN THE NEXT 100 YEARS

In this section, we will concentrate on the impact of technological progress and pay less attention to the impacts of other factors in the Cobb-Douglas equation. Fig.5 shows four curves representing the impact of four factors in the Cobb-Douglas equation. The total course can be divided into several stages.

. First Stage (1965-1982)

In this period, the impact of capital occupies the dominant position followed by labor, and then technology, which conforms to actual conditions at that time. The economy develops mainly by the increase in capital and labor force. Although the economy may develop temporarily, that will bring about many problems such as low efficiency, the drop of consumption level and over-investment etc. Finally, that may cause the economy to fall into disordered state.

. Second Stage (1983-1995)

The impact of technology rises to higher position than labor in 1983 and becomes dominant in 1990. In this period, technology level grows rapidly due to technology transfer and more investment.

. Third Stage (1995-2065)

At the beginning of this period, the impact of technology remains constant or even declines, but it maintains the dominant position, and will play an even greater role in the days to come.

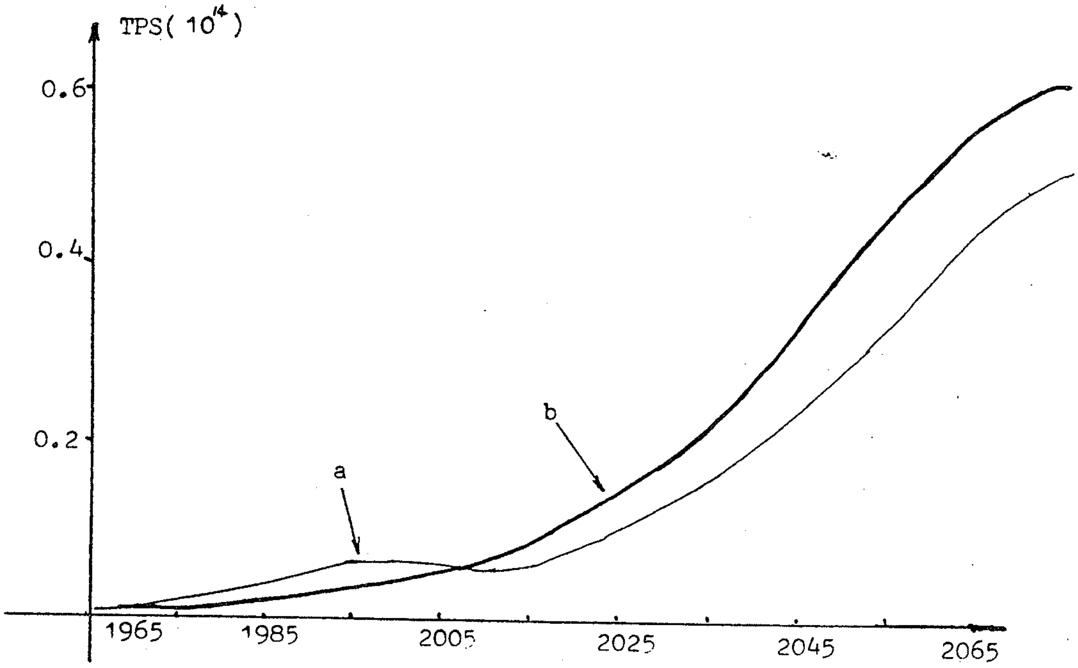


Fig. 6 The Impact of Technology and Capital on TPS

Another test result represented below will make clear the importance of technological progress. Curve (a) in Fig.6 indicates the developing trend of TPS under conditions of stagnating technological progress after 1980. Hence, capital will play the decisive role in the process of economic growth. Curve (b) in Fig.6 shows the developing trend of TPS assuming that capital input is kept at the 1980 level. In that case, technology becomes the major factor to promote the development of economy. Comparing these two curves, we can find that in the beginning period (1980-2005), curve (a) is higher than curve (b), but after 2005, curve (b) is consistently higher than curve (a). It is thus clear that it is technological progress which plays the major and persistent role in the development of the economy, and the role of capital is only temporary.

4.2 THE STUDY OF MAJOR FACTORS CAUSING TECHNOLOGY PROGRESS

There are three major factors causing technological progress in the model. They are:

a. The investment of development and research in technology

b. The increase in education and science

c. The introduction of technology

Although these are all important to the progress of technology, the degree of importance differs among them and with time. Fig.7 shows the curves of impact of three factors on the increase rate

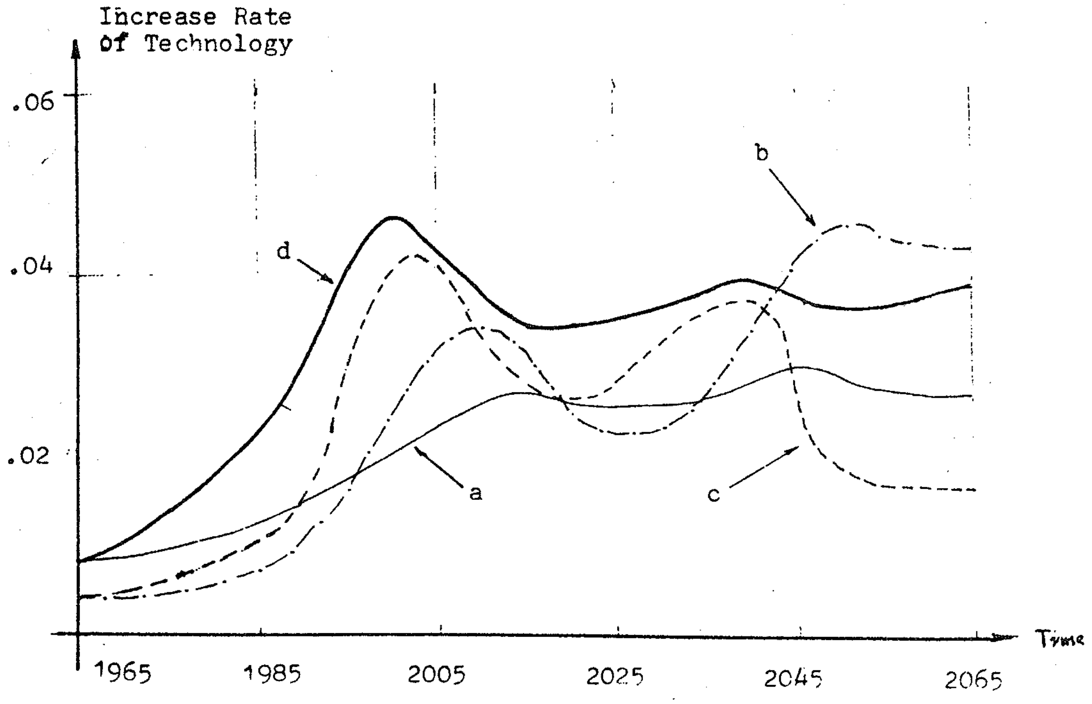


Fig. 7 Impact Factors Causing Technology Progress

of technology. Curve (a) expresses the increase rate assuming a reduction in investment by 35% from 1985 to 2000. Curve (c) shows the increase rate if the education factor is ignored (education level remains at its initial value). Curve (b) indicates the increase rate, if the technological introduction factor is not considered. Curve (d) shows the increase rate under the normal case.

The curves shown in Fig.7 express the impacts of different factors on the increase rate of technology, which give us a clear view of the intrinsic factors of technological progress.

From the curves, the following conclusions can be made:

- Investment plays decisive role in technological progress. If once it was insufficient, it would affect technological progress over a long period of time.
- The introduction of technology also plays an important role in technological progress, Especially during the period between 1985 and 2010, its role is much greater than the education factor due to the greater difference of technology between China and advanced countries.
- With the rapid progress of technology in China, the difference in technology between China and advanced countries is being reduced constantly, as is the role of technology introduction. The role of education continues to grow and becomes a major factor in the progress of technology.

4.3 SOME ILLUSTRATIONS ABOUT THE MODEL

a. The model was based on the Cobb-Douglass formula. We attached more importance to the impact of technological progress on economic growth.

b. Technology is considered in a broad sense. It includes management technique, innovation and production processes etc. They are combined into one in the model for the simplification of the model.

c. There is a variable in the model which has great influence upon the developing trend of technology. It is the cost of technological advance (CTA). Curve (a) in Fig.8 expresses the curve of variable CTA at base run. Curve (b) in Fig.8 shows another curve of variable CTA which brings about a developing trend in technology shown as Fig.9. From Fig.9, we can see that there is great change as compared with the result of base run. It is thus obvious that a little variation in parameters of variable CTA will cause great changes in the developing trend of technology. That means variable CTA is more sensitive than other factors. Hence we should pay greater attention to it.

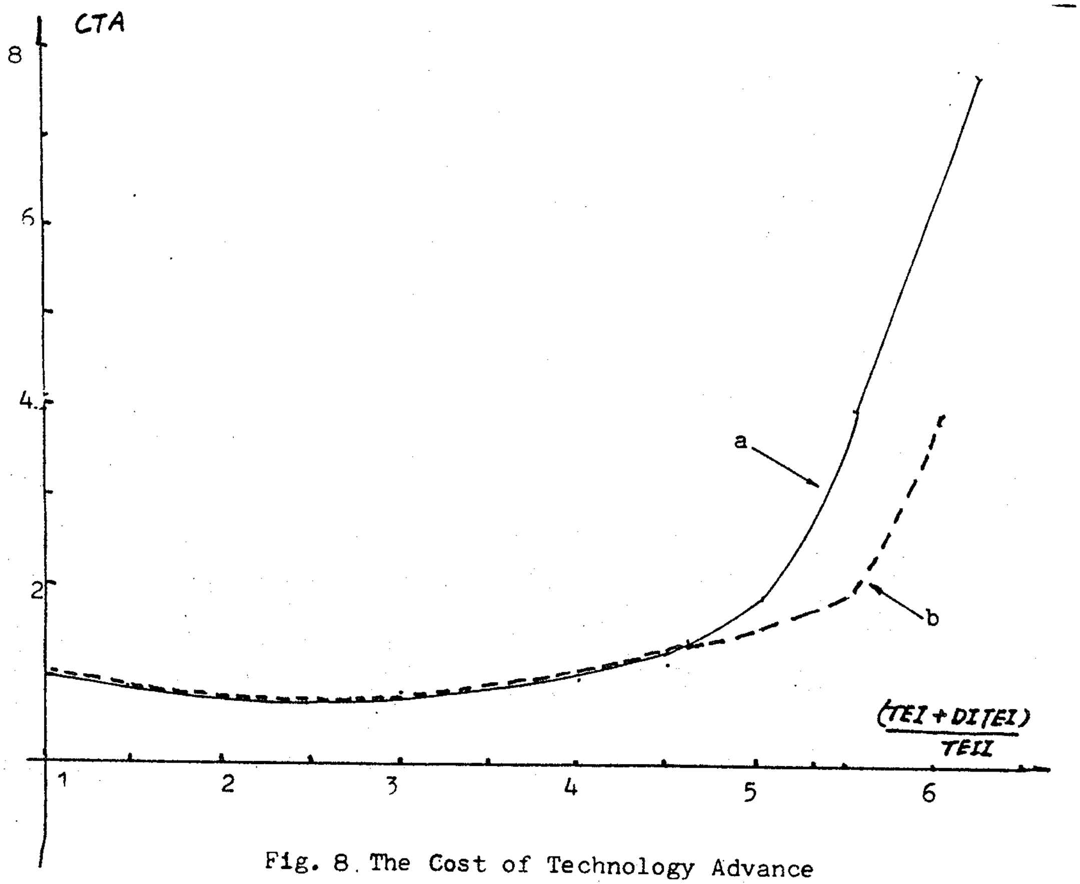


Fig. 8 The Cost of Technology Advance

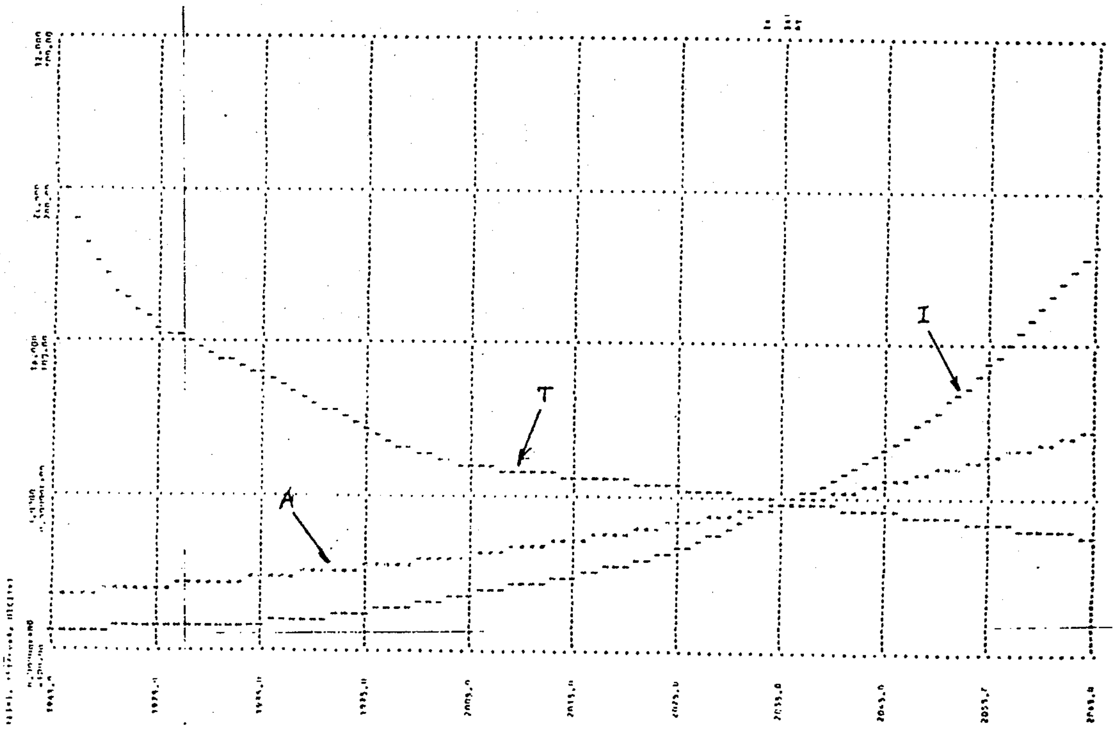


Fig. 9 The developing Tendency of Technology

I--TEI A--TEIADV T--NTCIT

4.4 CONCLUSION

It can be seen that the impact of technological progress will play the most important role in the process of economic growth. It would be reasonable to further study the specific situation of society and economy in China. For the Chinese population, the largest in the world, it will not be underemployment but overemployment which cause problems. Overemployment causes marginal output of labor to decline and makes efficiency drop. While also increasing the number of people who must share in the total output. Therefore, an increase in labor is not an effective way to promote the development of economy. An increase in capital, of course, can increase total output without an increase in population and ensures growth in GNP per capita. But an increase in capital is limited, hence technological progress -- an increase in the productivity -- is proven to be the most important factor of growth in the economy.

The way to develop the technological level of China should be as follows: Before about 2000, we should pay more attention to the introduction of technology, learning and introducing advanced technology from advanced countries as quickly and much as possible. On the other hand, we should devote major efforts to developing education and science. Especially in the days after 2000, more efforts should be directed towards developing technology and science of China's own for purpose of catching up with the advanced countries technology level.

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