

*Full Length Research Paper*

# The effects of biased technological change on total factor productivity: Based on the new perspective of appropriate technology

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Received 15 January, 2014; Accepted 18 April, 2014

The paper explains the effect of biased technological change (BTC) on total factor productivity (TFP) from the new perspective of appropriate technology. We have certified that the assumption of neutral technology progress of Solow is ostensible and also to get the general technological progress which can be divided into three parts: effect of knowledge progress, effect of capital intensity improvement and scale effect. We selected the data of Chinese provinces to give an empirical test to the effect of BTC on TFP. When we have last-year based empirical analysis, it illustrates precisely that not all years' direction change between technical progress and factor endowments is consistent. But when we fix the capital and labor in 1997 as the base period, it seems that the eastern coast is still the main engine of China's economic growth in recent years. And in backward areas, upgrade of technological change and factor endowments need to be further improved. On the national level in terms of the effects of BTC on TFP, they all get still a steady growth process, which illustrate that the process of upgrading of China's factor endowments and technological change is relatively successful.

**Key words:** Total factor productivity; appropriate technology; biased technological change.

## INTRODUCTION

As we all know, technological progress is the driving force and source of economic growth. In the real economy, technological progress always shows non-neutral. After Hicks (1932) gave a emphasis on the issue of biased technical progress, Kennedy (1964), David and Klundert (1965), Ronald and Lawrence (1967), Sato (1970) and many researchers had done a lot of research, but they didn't give the rigorous microeconomic foundation of biased technical progress. Until recent years, Acemoglu (1998; 2000; 2002; 2007; 2009; 2011) takes biased technical progress into endogenous model.

Many economists have come to take a widespread consideration of it again. The issue of technological change direction is related to the future technology trends of a country or even the world. Countries with different factor endowments should take advantage of technological innovations that gives room for a more intensive use of locally abundant production factors. Countries introduced technologies that are able to match the local conditions of factor markets which can show better productivity performances. In other, for it to enhance the level welfare of the whole society to a certain extent. We

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should acknowledge the effects of BTC on productivity, so as to help to investigate the appropriateness and guide towards the best biased direction. Hence, finding a more closely method to the reality in which to measure the effect of biased technological change on TFP and guarantee the accuracy is the basis of following study.

Measuring the biased technical change is always the interest of academia. From the initially Hichs (1932) studied on the definition and measurement of biased technical change, in the following, many researchers (Binswanger, 1974a, 1974b; Stevenson, 1980) measured the BTC with elements share and the elasticity of substitution method, up to recently Acemoglu (2002; 2003) used normalized supply-side system. They all gave an effective measurement about the existence and direction of BTC, explained the phenomenon of capital accumulation and rapid development of large-scale machine capital equipment in US and other developed countries. Also, they solved the problem of decreasing labor remuneration share in developing countries to some extent. These studies always put emphasis on the direction of BTC to a whole economy which can get a result of capital biased or labor biased. These theoretical and empirical researches have made great contribution to relevant field. But they don't show the direct effect of BTC to economic development or TFP. Therefore, we should search for literatures of effect of BTC on TFP so as to react and give guidance to the reality effectively.

But, very few attempts can be found in the literature addressing the implications of BTC on the measurement of TFP. The neglect of the effects of BTC on TFP can date back from the original contribution of Solow (1957) who allows the change in the output elasticity of capital, as measuring by its share on income, and does not account for its effects. Ferguson and Fehsenfeld (1968); Ferguson et al (1969) and Nelson (1973) had already shown that conventional methodologies for the measurement of TFP hold only if technological change is Hicks-neutral and the elasticity of substitution is unitary. Hence, Antonelli and Quatraro (2010) proposed an original methodology which is used to identify the effect on productivity of such bias and disentangle from it the standard consequences of the shift of the production function. They investigated the direction of technological change for a sample of 12 organisation for economic cooperation and development (OECD) countries and explored its effects on TFP within a growth accounting framework over the period 1970 to 2003. Antonelli and Quatraro (2010) got three points from the empirical of 12 OECD countries based on their methodology. But, they ignored that the intrinsic consequence of Solow's calculating which called technical progress productivity is far from neutral. So they gave a wrong model framework and their conclusions were skeptical. Therefore, the literatures and achievements about this issue in academia are scarce. Not mention to the analysis of China and other developing countries. But there is no doubt about

the importance of effect of BTC on TFP, This also highlights the necessity and urgency of the research. Hence, the paper construct the measuring method effect of BTC on TFP from a new perspective of appropriate technology and gives an empirical research based on 30 provinces in China. Compared with the existed research, the main contribution of the paper are as follows:

Firstly, we explain the effect of BTC on TFP from the new perspective of appropriate technology. Through the issue has been researched by others from aspects of the elasticity of substitution, international trade, education and so on. For example, some theoretical and empirical analysis thought that the elasticity of substitution of elements affected the BTC and contributed most to the economy growth (La Grandville, 1989; Klump and Preissler, 2000; Irmen and Klump, 2009; Palivos and Karagiannis, 2010). But we actually give a new way to elaborate this issue.

Secondly, we have certified that the assumption of neutral technology progress of Solow is ostensible. We get the general technological progress which can be divided into three parts: effect of knowledge progress, effect of capital intensity improvement and scale effect. So we have combed the intrinsic meanings clearly.

Thirdly, we selected the data of Chinese provinces to give an empirical test to the effect of BTC on TFP. This is according to the practical needs and development confusion of developing countries. It can take reference for their further strategy of economic convergence to developed countries.

Specifically, we find that in the sample study period, the capital stock increases at nearly 18% per year while the amount of labor is only at the slow growth rate of 1.6% which means China's factor endowments is changing rapidly. When we have last-year based empirical analysis, it illustrates precisely that not all years' direction change between technical progress and factor endowments is consistent. But when we fixed capital and labor in 1997 as the base period, it seems that the eastern coast is still the main engine of China's economic growth in recent years. And in backward areas, upgrade of technological change and factor endowments need to be further improved. On the national level in terms of the effects of BTC on TFP, they all get still a steady growth process, it illustrates that the process of upgrading of China's factor endowments and technological change is relatively successful.

The remainder of the paper is organized as follows. In Sect. 2 we point out the relationship between appropriate technology and effect of BTC on TFP. That is to say the theoretical basis of our new measuring method. In Sect. 3 we would construct the model of method basing on Solow's frame. In Sec. 4 we show the essence of the results of the statistical calculating about Chinese provinces and analyze the formation reasons. The

concluding conclusions follow in Sect.5.

### **Appropriate technology, biased technological change and economy convergence**

Economic growth is the central issue of research and the theory of economic growth is of great importance in relevant study. From the perspective of global economic development, there is a general growth trend in national economies, but also it shows significant growth differences. The level of technology or knowledge accumulation and persistent creation are used to explain the gap of economic growth and income in different countries (Easterly and Levine, 2001; Kuznets, 1966; Prescott, 1998). Developed countries which are in the forefront of technology and knowledge can only maintain their advanced technology superiority through continuous invention and innovation. Developing countries with relatively backward technology may achieve technological innovation and technical level convergence through imitation and introduction from developed countries (Teece, 1977; Mansfield et al., 1981).

Therefore, developing countries have the advantage of technological progress which can learn from the developed countries to achieve their relatively sustained rapid technological upgrading and economic growth, and ultimately the convergence of income levels. But why the economic convergence of developing and developed countries in the process of economic development is not universal? In addition to a handful of countries and regions in East Asia, most developing countries are not able to narrow the income gap with the developed countries, why not? This question is related to technical knowledge absorptive capacity of a developing country, and technical knowledge absorptive capacity of a developing country is endogenous to the country's economic development strategy (Lin, 1994; Lin, 1996;).

Schumacher (1973) put forward the definition of appropriate technology and that the technology choice of developing countries is the key point whether their development strategy can succeed. Basu and Weil (1998) pointed out:

It is possible that developing can converge developed countries of technological theoretically. But, whether the technology from developed country is appropriate depends on the difference between the two countries of factor endowments.

The theory of appropriate technology shows that the technology of developed countries is resigned by endowments in their own countries. The introduction of technology is a black box. So the direction of technical change is important, but few had paid attention to it. Los and Timmer (2005) showed that there would be limited spillover effects only when technology introducers' capital

strength was similar. Lin (2003; 2004) pointed out that the technical level of a country is appropriate to the country's endowment structure. If the economy always enhances the structure of factor inputs which manufacturers faced in order to cater to the mature technology of the developed countries, it would make enterprises nonviable, and thus lead to a series of economic problems.

There is theoretical possibility for the developing countries to achieve technological convergence to the developed ones, but whether the technology of the developed countries is applicable to developing countries depends on factor endowments differences between the two countries. The technology of developed countries is researched according to its own factor endowments and appropriate to its endowments. In the premise of different endowments between developed and developing countries, the introduction of the technology from developed countries does not match with the factor endowments for developing countries which resulted in the huge difference of economic performance (Acemoglu and Zilibotti, 2001).

As we know, developing countries may achieve the economic convergence only when they choose the appropriate technology strategy. But how can we judge the appropriate technology or how the direction of technical change should be in order to achieve economic convergence. That is to say in which situation the biased technological progress would do positive effect of TFP.

In general, developing countries are aimed to achieve technological catch-up, government decision-makers have introduced a large number of advanced Western technology to encourage the development of capital and technology-intensive industries. Such a leap of capital deepening has deviated from the factor endowments, and failed to take absolute advantages effectively. It resulted in the loss of economic development follow-up forces. The international academic community has argued for the mode of economic development in developing countries: like the developing countries such as China should be careful to choose the appropriate technology to avoid prematurely capital deepening appearing before factor endowments changed. Developing countries should develop labor-intensive industries based on factor endowments advantage. It is not only effectively to absorb surplus labor, avoid inhibition of the income distribution gap, but also still to enhance the industrial output, wages and profit levels on the whole (Pack, 1986). For developing countries, this model of development based on comparative advantage in reality encountered the challenge of balanced growth model based on the theory of economic growth (Chenery, 1961).

Economic decision-makers thought that capital deepening and heavy industrialization is an inevitable stage of economic development in general. In order to balance economic growth and improve the speed of economic development, they developed the introduction of capital and technology-intensive industries firstly, which

can produce more profits for recycling investment and the expansion of the capital stock would help absorb more labor (Galenson and Leibenstein, 1955). However, many issues like the low level of technical knowledge absorptive capacity of developing countries, the gap between industrial technology and the current level, difficult of grasping the technological complexity and characteristics and so on, have resulted in distortions of industrial development and endowment structure.

Lin (2004) pointed out that the government giving priority to the development of capital-intensive industries is not in line with the economy's comparative advantage in an open competitive market. If so, enterprises in these industries are nonviable. To support nonviable enterprises, government takes a series of distortions in international trade, the financial sector and the labor market. In this way, they may establish capital-intensive industries in developing economies, but it would lead to misallocation of resources, rampant rent-seeking activities, instability of macroeconomic, inefficiency of economy, lack of competitiveness of the national economy, and the country would fail to achieve income convergence to developed countries. With respect to such introduction of technology which is violation of a country's factor endowments, the development of comparative advantage in technology may help to raise the level of the domestic and long-term economic development (Antonelli and Quatraro, 2010).

The existed technology in developed countries is a beam of set which consists of different technologies and has an evolving process. When a country has chosen the strategy which is in line with their factor endowments growing, acquisition costs of technology are lower than that situation which is against with their factor endowments (Lin, 1999; 2004). The knowledge absorptive capacity in developing countries is not an exogenous variable, but instead, it is born in the development strategies of developing countries. A country's optimal industrial and technical arrangement is endogenous to its endowment structure (Lin, 1994; 2003; 2004). Endowment structure is upgraded to provide a basis for industrial and technological structure growing (Lin, 1994; Basu and Weil, 1998).

Governments of developing countries should promote the upgrading of factor endowments structure, rather than upgrading of technology and industrial structure as the goal. Because once the endowment structure upgraded completely, the profit motivation and competitive pressures would drive spontaneously technology and industrial structure upgrading. Developing countries adjust the path of technological progress and also select the appropriate factor endowments technology according to their stage of development constantly. Then it can play the advantage to accelerate the pace of technical progress and achieve high-speed growth. With the enhancement of factor endowments, ultimately it would achieve convergence to developed countries economic. Conversely, if the technology of choice is on a wrong direction, it would affect the speed of scientific and

technological progress, and the income gap may be widened with the developed countries.

To sum up, the direction of technological progress is the root issue of appropriate technology. When the direction of technological progress is consistent with the local factor endowments' change direction, it may have a positive effect on economic growth in order to complement each other. Otherwise, it would produce the reverse adverse effects. Therefore, from the perspective of factor endowments upgrading, or from the angle whether the direction of technological progress and the factor endowments upgrading is consistent with examining the effect of technical change on TFP. If the direction of technological progress and factor endowments change is in the same direction, we can know effect of the direction of technological progress on TFP is positive, and vice versa.

### Methodological implementation

Based on the above analysis, we imagine whether the biased direction of technology and factor endowments direction of change is consistent with the measure effect of economic convergence or economic growth. But before that, we first look at what is technological progress? What is the so-called A in the end? First, we should know the defects of Solow-effect which is the basis of the original. Solow (1957) built his theoretical framework according to the following steps. Set the production function as a non-specific general form:

$$Q = F(K_t, L_t, t) \quad (1)$$

Assume that technological progress is Hicks neutral, then the production function turns into:

$$Q = A_t \cdot f(K_t, L_t) \quad (2)$$

$A_t$  is the total factor productivity (TFP). Then we can derive the following function:

$$\ln A_t = \ln Q_t - (w_{kt} \ln K_t + w_{lt} \ln L_t) \quad (3)$$

Among them,  $\ln Q_t$  is percent change of output,  $\ln K_t$  is of capital and  $\ln L_t$  is of labor; And  $w_{kt}$  is the output partial elasticity coefficient of capital, which equals to the revenue share of capital under the assumption of perfect competition. Also,  $w_{lt}$  is the output partial elasticity coefficient of labor, which equals to the revenue share of labor under the assumption of perfect competition. Suppose further that the constant returns to scale, that is to say  $w_{kt} + w_{lt} = 1$ . So, we can get the following from (3):

$$\ln A_t = \ln Q_t - w_{kt} \ln K_t - (1 - w_{kt}) \ln L_t = \ln q_t - w_{kt} \ln k_t \quad (3a)$$

Thus,  $q_t = Q_t / L_t$  is average output of labor which called labor productivity and  $k_t = K_t / L_t$  is average capital of labor which called capital-labor ratio. Then they can get the rate of technology progress  $\ln A_t$  basing on the data of  $q_t$ ,  $k_t$  and  $w_{kt}$ . That is what Solow's model. But, if we abandon the assumption of Hicks neutral technology progress, we try to derive another result. The labor as a piece of factors is special. We can take it represent a variety of factors' matching. So, we give the definition:

$$Q_t = L_t \cdot \frac{Q_t}{L_t} = L_t \cdot q_t \tag{4}$$

$Q_t$  is the output and  $L_t$  is the labor which represents other factors be matched with. And the formula  $q_t = Q_t / L_t$  is the labor productivity. Then we can get:

$$\ln Q_t = \ln L_t + \ln q_t \tag{5}$$

$\ln Q_t$  is the percent growth of output;  $\ln L_t$  is percent growth of the labor force;  $\ln q_t$  is the percent of labor productivity growth which also called the rate of generalized technical progress.  $\ln L_t$  represents the epitaxial growth of output growth and  $\ln q_t$  represents the connotation growth of output growth. The technical input-output relations in the process of production can be described:

$$Q = F(K_t, L_t, t)$$

To arrive at the output growth equation:

$$\begin{aligned} \ln Q_t &= \frac{1}{F} \frac{dF}{dt} = \frac{1}{F} \left( \frac{\partial F}{\partial t} + \frac{\partial F}{\partial K_t} \cdot \frac{dK_t}{dt} + \frac{\partial F}{\partial L_t} \cdot \frac{dL_t}{dt} \right) \\ &= \left( \frac{1}{F} \frac{\partial F}{\partial t} \right) + w_{kt} \ln K_t + w_{lt} \ln L_t \end{aligned} \tag{6}$$

In the equation,  $w_{kt} = \frac{\partial F}{\partial K_t} \cdot \frac{K_t}{F}$  is output partial elasticity coefficient of capital and  $w_{lt} = \frac{\partial F}{\partial L_t} \cdot \frac{L_t}{F}$  is output partial elasticity coefficient of labor. Take (6) into formula (5), we can get:

$$\begin{aligned} \ln q_t &= \left( \frac{1}{F} \cdot \frac{\partial F}{\partial t} \right) + w_{kt} \ln K_t + w_{lt} \ln L_t - \ln L_t \\ &= \left( \frac{1}{F} \cdot \frac{\partial F}{\partial t} \right) + w_{kt} (\ln K_t - \ln L_t) + (w_{lt} + w_{kt} - 1) \ln L_t \\ &= \left( \frac{1}{F} \cdot \frac{\partial F}{\partial t} \right) + w_{kt} \ln k_t + (w_{lt} + w_{kt} - 1) \ln L_t \end{aligned} \tag{7}$$

As shown above, labor productivity growth can be divided into three parts:  $\left( \frac{1}{F} \cdot \frac{\partial F}{\partial t} \right)$  is the part Solow wanted to calculate the so-called technical progress;  $w_{kt} \ln k_t$  is capital-labor ratio, which means the effect of capital intensity improvement;  $(w_{lt} + w_{kt} - 1) \ln L_t$  represents the rate of labor productivity change resulted from scale effect. When we take constant returns to scale, we can get:

$$\frac{1}{F} \frac{\partial F}{\partial t} = \ln q_t - w_{kt} \ln k_t \tag{3b}$$

In the left of the above equation, it represents that the isoquants of production function  $F$  autonomously changes with time  $t$ . This change involves sheer position move of isoquants and changes in the slope. So the technology progress calculated is not neutral.

In the assumption of neutral technology progress of Solow, we can calculate the rate in equation (3a). While we abandon the assumption, we can calculate the technology progress rate in equation (3b). But, the result is the same no matter the situation, through equation (3a) or (3b). So, the assumption of neutral technology progress of Solow is ostensible. The one in the left and the two in the right are all biased generally. As we can know labor productivity growth can be divided into three parts:  $\left( \frac{1}{F} \cdot \frac{\partial F}{\partial t} \right)$  is the knowledge progress;  $w_{kt} \ln k_t$  is capital-labor ratio;  $(w_{lt} + w_{kt} - 1) \ln L_t$  represents the rate of labor productivity change resulted from scale effect. Hence, we know that A which is  $\frac{1}{F} \frac{\partial F}{\partial t}$  in the above equation is general technical progress. It may be capital biased or labor biased, and neutral in special situation.

According to the analysis of the above part of the article, we set the technological advancement direction and change direction of factor endowments. That is the relationship of biased technological progress on economic growth. The main idea is to give a description of technological progress affecting the economic growth in the direction changing both of technology and factor endowments so as to control factor endowments change, and finally to seek the effect of direction of technological progress on TFP.

If the technology matches with the factor endowments of a country, the technology would do positive effect on TFP and be appropriate technology. Further, it is well known that the technologies are little neutral. That's why we can get the effect of biased technology on TFP. The factor endowment of a country is changing over time. Then the standard of appropriate technology turns to be whether the technology progress is in accordance with the changing endowments. On the basis of this, we can construct that:

$$A_{it}' = \frac{Y_{it}}{K_{it=0}^{\alpha_{it}} \cdot L_{it=0}^{\beta_{it}}} \quad (8)$$

The factor endowments of both labor and capital are frozen at time  $t=0$ , so that at each moment in time  $A_{it}'$  is equal to the ratio between the actual output and the output that would have been obtained by technology progress, had the factor endowments been fixed over time. Next we got the bias effect (BIAS) as the difference between  $A_{it}'$  and  $A_{it}$ :

$$\lambda = A_{it}' - A_{it} \quad (9)$$

The index  $\lambda$  obtained from above equation is easy to interpret. When  $\lambda$  is zero, that's to say the biased technology progress has little effect of TFP. When  $\lambda$  in one country is above zero, then its technological activity is characterized by the right directionality, and vice versa.

## Empirical analysis

### *The method and data*

Following Euler's theorem, as in Solow (1957), they assumed that output elasticities equal the factors' shares in total income, as the assumption of perfect competition in both factor and product markets. According to income approach components of gross regional product, gross regional product can be divided into compensation of employees, net taxes on production, depreciation of fixed assets and operating surplus. So, we only need to make the compensation of employees divided by gross regional product if only judge from the surface level. Though this method is easy to calculate, it still has some problems to be solved.

### *The process of net taxes on production*

Gomme and Rupert (2004) pointed out that national accounts are not strictly divided in accordance with the factor income attribution. The case of net taxes on production is just in point. It is neither labor income nor the income of capital, but a wedge outside labor and capital. When the tax is increasing, the labor income share calculated in accordance with the above method will decline, and this decline is not the result of capital strength enhanced, which would tend to overestimate the decline of the labor income share. Therefore, to accurately estimate the labor income share, we should get net taxes on production deducted from gross regional product. Specifically,  $Y_L$  is labor income,  $Y_K$  capital income,  $Y_T$  net taxes on production,  $Y$  is Gross Regional

Product, then the labor income share compared:

$$\beta_{it} = \frac{Y_L}{Y - Y_T}$$

### *The classify of individual income*

Another challenge in estimating the labor share of income is to classify the individual income (Krueger, 1999). In the income of self-employed individual industrial and commercial households, one part is the income as workers, while the other part is the economic returns generated as investors. However, this is difficult to be clearly distinguished in practice. With historical data in the United States of the year 1850 to 1952, Johnson (1954) and Kravis (1959) found that the individual labor income share is stable at about 65%. Due to the overall labor income share in the United States has been stable at 65 to 70%, Gomme and Rupert (2004) even equaled labor income share of the individual and non-individual economy. However, this method actually has the possibility to underestimate the share of labor income. At the same time, this method is only applicable to stable labor income share countries such as the U.S., while it does not apply to countries whose labor income share is decline and instability like China.

We use the employment data to process the part of individual income which is in compensation of employees (Gollin, 2002). Specifically: suppose the same labor compensation of individual economy employees and other employees. We use the income which clearly attributed to workers divided by employees of the non-individual economy to get average labor remuneration. The average labor compensation is then multiplied by the total employees, and this would get total labor remuneration which is included the individual economy.  $Y_{ul}$  is a compensation of non-individual economy workers, employees of the individual economy is  $L_A$ ,  $L$  represents total employees. Then the labor income share is:

$$\beta_{it} = \frac{Y_{ul} \cdot L / (L - L_A)}{Y - Y_T}$$

They also assumed constant return to scale, the output elasticity of capital is obtained as follows:  $\alpha_{it} = 1 - \beta_{it}$ .

The measure of  $A$  obtained in this way, accounts for "any kind of shift in the production function" (Solow, 1957), and it might be considered a rough proxy of technological change (Link, 1987).

The data of gross regional product, fixed capital stock and the employment used for the analysis are mainly drawn from China's national bureau of statistics and people's bank of China. They are related to 30 provinces

in China except for Tai Wan, Tibet, Hong Kong and Macao. The gross regional product has been deflated by using the CPI index and the gross fixed capital formation which is applied to calculate fixed capital stock using the price deflator of fixed assets. These data are all based on 1997=100.

These data allow us to derive the effect of biased technology change on TFP measuring whether the technology progress is appropriate to the changing factor endowments. In what follows we first provide evidence concerning the dynamics of the amount of labor and capital, stressing its variation over time and across different provinces. Then we will provide the results of the calculations conducted following the methodology presented in Sect.3, showing the empirical effect of BTC on TFP.]

### The changing amount of labor and capital

As showed in Table 1, the capital stock of China's 30 provinces has undergone tremendous changes in the sample period. Among which Shandong, Jiangsu and Guangdong were the top three in terms of the absolute amount of the capital stock. Without exception, the three provinces are all in the east of the coastal zone, relying on the geographical advantages of resources and the environment, getting a rapid development. Most of the coastal provinces' capital stocks are ranked relative to the front, so it seems that the eastern coast is still the main engine of China's economic growth in recent years.

When it comes to Shanxi, Inner Mongolia, Jilin, Guangxi, Shaanxi and Ningxia, the six provinces' 14-year average annual growth rate of capital stock are all more than 20%, appropriately equaling the doubled GDP growth rate of China. For this, there are two comments of analysis. First, although the six provinces' growth rate remains high, they are all located in the middle of China and have less dominant. So the capital stocks are of smaller base, but if there are the same growth around the capital stock, their growth rates are naturally higher than elsewhere. Second, the six provinces are basically in the central region, rather than we have imagined in the eastern coastal areas, which illustrated that firms tend to give investment in the more profitable central region, combined with the ensuing kinds of labor and other production costs rise in recent years, due to the eastern coastal development reaches a certain level.

In summary, the development of the six provinces is more rapidly, which reflects the shift of the industry to the central region to some extent. But the six provinces are basic in the middle level against the 30 provinces in view of the total amount of capital stock. There are only four provinces of which average annual growth rate is less than 15%, they are Beijing, Shanghai, Hainan and Xinjiang Province. For Beijing and Shanghai, their total ranking are both acceptable, which are in the middle

level. Xinjiang belongs to the western region of more remote areas, the transportation and geographical factors resulted in the slowly growth. Hainan's amount of total capital stock is resulted from its economic development mode, so it is necessary to further develop. Overall, except for the more remote areas of Qinghai, Gansu and Guizhou, other provinces' amount of total capital stock has been very high. In addition, in terms of the country's 30 provinces, the average annual growth rate of the capital stock is nearly 18%, much higher than the GDP growth rate in China, resulting from the rapid increase in the size of foreign direct investment in recent years. Similarly, a steady increase in the capital stock shows the changing of factor endowments from a certain extent.

Now, let us look at the changing labor amount. Of course, the overall trend of the absolute labor amount is increasing continually. Different from the increase of the capital stock, the amount of labor in the process of change, there are many negative rate of change Year, which means that the amount of labor is not always increasing. But the capital stock does always increase. In addition, as to the average annual growth rate of the labor amount, only five provinces exceed more than 2%, which are Beijing, Jiangsu, Zhejiang, Fujian and Hainan. The rest provinces' average annual growth rates are not prominent. Overall, the average annual growth rate of the labor force is just 1.6%, much lower than the growth rate of the capital stock, which certainly exists extrusion of capital for labor and precisely to show that the China's factor endowments changes is very obvious. In particular, in the sample study period, the capital stock increases at nearly 18% per year while the amount of labor is only at the slow growth rate of 1.6% which makes China's factor endowments change rapidly.

Therefore, in order to better adapt to the new changes in factor endowments to play their comparative advantages, it is inevitable for technical improvement. The changes of technology can response by the elasticity of output. The changes of labor output elasticity in China in recent years is as shown in the figure 1, which has been a downward trend from 61.2% in 1997, to 52.4% until 2007, for a decrease extent of 9%. This shows that China's technical structure has generated huge changes. It is puzzling that, from 2007 until 2011, the labor share of output is rising and has up to 61.3%, almost the same with the level of five years ago. This is a special phenomenon found in this paper, which is in stark contrast to the research of China's labor income share decline in recent years. How can this be explained? China's technological structure has returned to the 1997 level? Certainly it is not. Through inspection of whether technology bias is consistent with the direction of factor endowments change, in other words, the effect of biased technological progress on TFP is positive or not, we would give explanation for the phenomenon later. (Fig. 1 Evolution of labor output share, Table 1 The changing amount of capital, Table 2 The changing amount of labor)

### The changing effect of BTC on TFP

There are many literatures for appropriate technology and technology selection at home and abroad, mainstream is that a country's technology choice should match its own factor endowments. If developing countries can improve the factor endowments through all kinds of ways like increasing saving, it is possible to promote rapid economic growth and achieve economic convergence. Most studies suggest that developing countries' technology do not match with their endowment structure. Due to the mismatch between developing and developed countries, there is a huge total factor productivity and per capita output gap. Basu and Weil (1998), Lucas (1993), Acemoglu and Zilibotti (1999; 2001) assumed that developing countries always use the developed countries' frontier technologies, which is out of the reality too much.

Therefore, some scholars believe that the core factor of East Asian miracle is the government's development strategy giving full match to the advantage of its natural resources, to achieve the unity of efficiency and fairness in the process of economic development, rapid economic growth accompanied by a relatively equal distribution of income and economic structure optimization. Followed or contrary to the principle of comparative advantage determinants is the key point of a country's success in attaining convergence. Developing countries introduce and select the appropriate technology in accordance with the dynamic changes of their own endowment structure from developed countries to imitate, which can accelerate the speed of technological progress. The key of China's industrialization is the change on the development strategy of government which should make that the enterprise structure choice depends on the structure of factor inputs.

First, we make a last-year base period, in the case of fixed factor endowments constant, study the effect of biased technological progress on TFP. Table 2 shows that, in addition to a few provinces, the effects in most of the provinces in the years of inspection are significantly positive. In Beijing, for example, in terms of each year, the effect is more than 5%, which peaked at 18.7% in the study period and the average annual is of 8.7%. This shows that, only looking at the Beijing region, the technological progress and factor endowments change is in the same direction, the technology chosen by the enterprises is in terms of appropriate technology, and is conducive to economic development in general.

When it comes to Tianjin, the effect of BTC on TFP in 1998 is negative, indicating that the direction between technical change and factor endowments is inconsistent, the direction of technological progress is not well adapted to changes in factor endowments. In the short term, the phenomenon of inconsistency of technological progress direction and factor endowments change is normal. Similarly, we can see Tianjin in 2007, Shanghai in 2008, Hubei in 2007 and so on. This illustrates precisely that not all years' direction change between technical progress

and factor endowments is consistent. In terms of the 30 provinces in China, the overall average annual effect of biased technological progress on TFP has reached 7.7%. Both from the general, or from the provinces, as to the change from 2006 to 2007, the vast majority effects are still positive, but their number value over the previous year have dropped by a lot, which is the explanation of the recovery in the labor share of output in 2007 mentioned before. As we can know, in all provinces, almost most years the effects are positive. (Table 3 The changing effect of BTC on TFP basing on last year, Table 4 The changing effect of BTC on TFP basing on 1997)

Next, we fix the capital and labor in 1997 as the base period, to examine the cumulative effects of biased technological progress on TFP. After our study, we know that their effects are essentially a process of growth. This shows that, the direction of technological progress and changes in factor endowment is consistent which means the analysis of endowment structure upgrade above led to advances in technology, they both play a role on a higher level. Except for 1998 of Tianjin and Shanghai, the rest years, all provinces are not negative. Overall, the effects of BTC on TFP are positive which also illustrate the great growth rate of China in recent years.

Specifically, the accumulated effect of inner Mongolia in 2006, leading all provinces, firstly reached more than 100%. In the following 2007 is Shanxi, Jilin is in 2008, Tianjin and Zhejiang are in 2009. Until 2011, Beijing, Tianjin and other 14 provinces have the effects of more than 100%. While the majority of Heilongjiang, Jiangxi, Hunan and other provinces have got the effects close to or above 90%, the lowest value of the four provinces are Hubei, Hainan, Shaanxi, Xinjiang, less than 80%.

This also shows that in these relatively backward areas, upgrade of technological change and factor endowments need to be further improved. But on the national level in terms of the effects of BTC on TFP, they all get still a steady growth process, which illustrate that the process of upgrading of China's factor endowments and technological change is relatively successful. For further technical innovation, it has a certain promoting role.

### CONCLUSIONS

The paper explains the effect of BTC on TFP from the new perspective of appropriate technology. We actually give a new way to elaborate this issue. We have certified that the assumption of neutral technology progress of Solow is ostensible and get the general technological progress which can be divided into three parts: effect of knowledge progress, effect of capital intensity improvement and scale effect. So we have combed the intrinsic meanings clearly.

We selected the data of Chinese provinces to give an empirical test to the effect of BTC on TFP and find that in the sample study period, the capital stock increases at nearly 18% per year while the amount of labor is only at



the slow growth rate of 1.6% which means China's factor endowments changing rapidly. The output elasticity of labor changes in China in recent years has been a downward trend from 61.2% in 1997, to 52.4% until 2007, for a decrease extent of 9%. It is puzzling that, from 2007 until 2011, the labor share of output is rising and has up to 61.3%, almost the same with the level of five years ago. When we have last-year based empirical analysis, it illustrates precisely that not all years' direction change between technical progress and factor endowments is consistent. But when we fix the capital and labor in 1997 as the base period, it seems that the eastern coast is still the main engine of China's economic growth in recent years.

And in backward areas, upgrade of technological change and factor endowments need to be further improved. On the national level in terms of the effects of BTC on TFP, they all get still a steady growth process, which illustrate that the process of upgrading of China's factor endowments and technological change is relatively successful.

## Conflict of Interests

The author(s) have not declared any conflict of interests.

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