

Analysis on the Relationship between Skill Biased Technological Progress and Human Capital Investment

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Keywords: Skill Biased Technological Progress, Wage Disparity, Human Capital Investment, CES Production Function.

Abstract: In the current turbulent trend of social innovation and rapid technological progress, the research on human capital investment is becoming more and more important. This paper attempts to answer these questions by analyzing the relationship between skill biased technological progress and human capital investment, that is, why do high skilled workers get higher wages? How does skill biased technological progress affect wage disparity, and how does it affect human capital investment through wage disparity? Will human capital investment affect the wage disparity? How does human capital investment affect skill biased technological progress?

1. Introduction

The theory of economic growth points out that technological progress is the driving force to promote the sustainable development of the world economy, but technological progress does not play an independent role. It is often coupled with other production factors, such as capital and labor, which gives new connotation to traditional production factors and produces differentiated marginal output to different types of production factors, which leads to biased technological progress [1]. Entering the post-industrial society, the distribution of occupation has changed greatly [2] At this time, there are two obvious trends in western developed countries: on the one hand, highly educated high-quality personnel become beneficiaries of technological progress and obtain good job opportunities and social status; On the other hand, the blue collar workers who have not received good education have become the victims of technological progress. They have lost the opportunity to move upward. Due to the application of automation technology, many high-wage jobs have been lost, and they have lost a lot of employment opportunities and gradually become the middle and lower classes of society [3]. This also shows that the bias of technological progress has led to social career differentiation, the wage disparity is widening, and the social structure has changed accordingly.

Human capital, as the stock of knowledge, is the source of innovation [4]. In the 21st century, human capital as an indispensable factor of production has been paid more and more attention by all production organizations, which leads to the increasing of labor remuneration of workers, and the production organization also attaches more and more importance to the corresponding human capital investment. According to the theory of supply and demand, when the supply of a production factor increases, the income reward will decrease correspondingly, but the skilled workers have a reverse result, that is, economic growth does not benefit all the workers, but there is a "skill premium" and the unequal labor remuneration. In other words, the wage of high skilled workers is higher [5].

Why is there a phenomenon that the wages of highly skilled workers are higher? How does the technology progress of skill bias affect the wage disparity and how to influence the investment of human capital through the wage disparity? Will human capital investment affect wage disparity? It is worth further discussion. This paper intends to explore the relationship between skill biased technological progress, wage disparity and human capital investment (Figure 1) theoretically to explore the principle of their role.

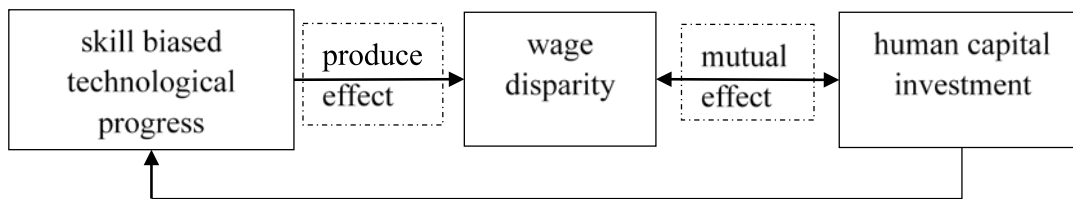


Figure 1. the relationship between skill biased technological progress and human capital investment

2. Literature Review

2.1 Skill biased technological progress

The theory of biased technical progress was first proposed by Hicks (1932). He pointed out that, with the capital and labor factors input unchanged, technological progress will affect their relative marginal output, and the technological progress can be divided into neutral and biased technological progress [1]. Subsequently, Kennedy (1964) thought that the direction of technological progress was determined by the innovation possibilities frontier, that is, the boundary of innovation possibility determines the distribution of elements [6]. However, due to the lack of rigorous theoretical deduction and micro basis, the theory of biased technology progress has not been paid enough attention. To solve the problem of the lack of biased technology progress theory, Acemoglu (2002) uses endogenous growth theory to biochemical skills biased technology and take mathematical model of capital and other production factors as the micro mechanism of technology progress direction [7].

With the in-depth study of technological progress, scholars have found that technological progress can be combined with labor force to form skill biased technological progress. Acemoglu (2009) proposed that technology monopolists carry out technology innovation activities and technology production, and take profit maximization as the goal. The change of labor relative supply will bring scale effect and price effect to technology market. When the substitution elasticity of high skilled labor and low skilled labor is greater than 1, the scale effect of high skilled labor supply will be greater than price effect, Technology monopoly will employ more high skilled workers, which will promote the biased technological progress of high skilled workers, and the relative wages of high skilled workers will also increase; On the contrary, when the substitution elasticity is less than 1, the price effect of high skilled labor supply is greater than the scale effect, and the technology monopoly chamber will employ more low skilled workers, which will promote the biased technological progress of low skilled technology, and then the relative wages of high skilled workers will also be reduced [8]. Bratti and Matteucci (2004) used company level data to verify whether there is skill biased technological progress in Italian manufacturing industry. The results show that R & D has an impact on the ratio of skilled labor and unskilled labor, which also confirms the existence of skill biased technological progress in Italy [9]. Song Donglin (2010) used 1978-2007 time series data to verify the dual characteristics of materialization and skill bias in China's technological progress [10]. Xu Zhicheng and Yan Jia (2011) verified that skill biased technological progress will aggravate wage inequality in the short term, but it will alleviate wage inequality in the long term [11]. Based on the national data from 1997 to 2017, Guan Aiping and Xie Jing (2020) verified skill biased technological progress and relative supply effect of skilled labor are negatively correlated with skill premium [12].

In terms of the definition of skill biased technological progress, most literatures define it by the change of factor marginal output ratio during technological progress. It is assumed that there are two production factors S and U in production. If technological progress improves the marginal output of S relative to U , it is said that technological progress tends to S . Specifically, assuming that the total production function is Y , there are two kinds of labor inputs of high skilled workers S and low skilled workers U in production, A_1 and A_2 represent the technological progress that can promote labor inputs s and u respectively, and MP represents the marginal output, then the conditions to meet the bias of technological progress are as follows:

$$\frac{\frac{\partial Y/\partial S}{\partial Y/\partial U}}{\frac{\partial(A1/A2)}} = \frac{\partial(MP_S/MP_U)}{\partial(A1/A2)} > 0 \quad (1)$$

When the above conditions are met, it can be considered that technological progress is biased towards highly skilled workers, and skill biased technological progress is biased towards highly skilled labor.

2.2 Human capital investment

Human capital is a concept corresponding to material capital. Schultz (1961) believes that human capital refers to the knowledge, skills, experience and health condensed in people [13]. Becker (1964) defined human capital investment as "all the activities that affect future monetary and psychological income by increasing human resources", and "enterprise human capital investment" refers to the activities that an enterprise invests in the owner of enterprise human capital through a certain amount of investment in order to obtain the expected income [14]. Li Jiaming (2004) pointed out that human capital investment refers to the activities of units or individuals to increase the profit output of human capital through the capital input of human capital for a certain purpose [15]. Zhang Shanhu (2018) defined human capital investment as: through education, training, medical care, learning by doing and labor migration and other activities, the integration of knowledge, skills and health condensed on people can not only increase people's resources, but also affect their future monetary income and consumption [16].

The main body of human capital investment generally involves three categories, namely government or country, unit or enterprise, family or individual [17]. As shown in Table 1, individuals are the main investors and owners of human capital. The purpose of individual human capital investment is to improve the quality of life of themselves and their families. Considering the limitation of individual investment resources and the existing supply conditions of the market, individual human capital investment generally adheres to the maximization of utility or income. Compared with individuals, the scope of investment of units or enterprises will be much smaller. Most of them train their employees through on-the-job training, learning by doing, medical care and other forms. However, enterprises also face the risk of brain drain when they invest in human capital. The leading role of the government or the state in human capital investment can't be replaced. The human capital investment of government investors is an important prerequisite for the formation of human capital in enterprises.

Table.1. Comparison of human capital investment subjects

Comparative project	Government or country	Unit or enterprise	Family or individual
Purpose of investment	Improve national quality and promote economic development	Profit	Improve the quality of life for yourself and your family
Principles of investment	Serving the people	Profit maximization	Maximizing revenue
Limitations of investment	Lack of pertinence	Investment scope; Employee turnover risk	The restriction of the individual investment resources; The restriction of market supply
Term of investment	Time other than employment	Employment period	Lifetime

Data source: the author collated the relevant literature

Human capital investment is closely related to wages. Mincer (1989) pointed out that the increase of human capital supply limits the wage disparity to an equilibrium level. At this level, this kind of investment has marginal profit as other types of investment [4]. Munch (2008) provides micro evidence of the relationship between the factor intensity of human capital and wage disparity [18]. Li Chengyou et al. (2018) pointed out that wage gap significantly promotes the incentive effect of capital stock on human capital formation, and "high income expectation" brought by wage disparity is an important reason for human capital formation [19].

2.3 Skill biased technological progress and human capital investment

John and Skinner (1985) pointed out that the technological progress in the 19th century resulted in the manual workshop being replaced by the production line, and the complexity of the original work in the factory was greatly reduced, which led to the reduction of the demand for skilled workers, the substitution of unskilled workers for skilled workers, and the corresponding willingness to invest in human capital [20]. Under the hypothesis of labor heterogeneity, Yang Xinming and Luo Rundong (2007) verified that different types of technological progress in urban and rural areas have different effects on wage disparity, and this difference will affect human capital investment accordingly [21]. Xu Xuejun (2008) pointed out that when technological progress is biased towards human capital, manufacturers will employ more high skilled labor and less low skilled labor, which will lead to an increasing wage disparity between high and low skilled workers [22].

There are many studies on the separation of skill biased technological progress and human capital investment, and the impact of the two on the wage disparity, but there are relatively few studies on the interaction between the two. How will human capital investment change under the condition of skill biased technological progress? Will the increase in the supply of high skilled human capital limit the wage disparity to a balanced level, or will it narrow the wage disparity and even expand it? These problems are worthy of further discussion.

3. Skill biased technological progress affects human capital investment

Due to the existence of skill biased technological progress, there will be an increase in the demand for high skilled labor and a decrease in the demand for low skilled labor in the labor market until a new labor market equilibrium is achieved. In the end, the new equilibrium result will inevitably lead to the increase of employment share and wage level of high skilled workers, while the corresponding decrease of low skilled workers, which leads to the so-called "human capital upsurge" phenomenon. The higher rate of return of human capital forms a strong incentive for human capital investment, and the corresponding increase of human capital investment in the labor market.

This paper first constructs a model to explain the influence of skill biased technological progress on wage disparity, and then points out the process of wage gap on human capital investment.

In view of the fact that CES production function (i.e. constant substitution elastic production function) is better than CD production function in theory, this paper uses CES production function to construct the theoretical model. Before constructing the theoretical model, we first make the following four basic assumptions: (1) labor is the only factor in the production process; (2) Labor factors are divided into high skilled workers and low skilled workers; (3) The labor market is completely competitive; (4) Technological progress has different effects on the work efficiency of high skilled workers and low skilled workers.

Firstly, the production function is established:

$$Y = [\gamma(A^\xi S)^{-\sigma} + (1 - \gamma)(A^\varepsilon U)^{-\sigma}]^{-\frac{1}{\sigma}} \quad (2)$$

Where Y is the total output, γ is the intensive parameter of high skilled workers, which represents the contribution share of labor input to output of high skilled workers, obviously, $\gamma \in (0,1)$, A is technical level, S is high skilled labor force, U is low skilled labor force, ξ and ε It represents the efficiency index of two groups of labor force under the influence of technological progress, $\sigma \in (-1,$

+ ∞) is the substitution elasticity parameter between high skilled workers and low skilled workers. The function has a fixed substitution elasticity, that is, $e = \frac{1}{1+\sigma}$.

According to the theory of perfect competition market, the enterprise will pursue profit maximization until the equilibrium price of factor market equals to its marginal output. By using partial derivatives of S and U in formula (1), we can get the wage W_S of highly skilled workers and wage W_U of low skilled workers. Then W_S and W_U by dividing, we can get the wage disparity W_{gap} between high skilled workers and low skilled workers.

$$W_{gap} = \frac{W_S}{W_U} = \frac{\gamma}{1-\gamma} A^{\frac{e-1}{e}(\xi-\varepsilon)} \left(\frac{S}{U}\right)^{-\frac{1}{e}} \quad (3)$$

By taking logarithm on both sides of formula (3) and further simplifying it, we can get that:

$$\ln \frac{W_S}{W_U} = \ln \frac{\gamma}{1-\gamma} + \frac{e-1}{e}(\xi-\varepsilon)\ln A - \frac{1}{e}\ln \frac{S}{U} \quad (4)$$

Next, (4) the partial derivative of $\ln A$ and the derivative of time are obtained:

$$\frac{G_W}{G_A} = \frac{\frac{\partial \ln(W_S/W_U)}{\partial t}}{\frac{\partial \ln A}{\partial t}} = \frac{e-1}{e}(\xi-\varepsilon) \quad (5)$$

Among them, G_W is the rate of change of wage gap, G_A is the rate of technological progress, t is the time.

According to the definition of skill bias, when $\frac{e-1}{e}(\xi-\varepsilon) > 0$, which means that technological progress tends to high skilled workers, that is, there is a skill biased technological progress. When $e > 1$, the two kinds of skilled labor force replace each other, and technological progress and high skilled labor force complement each other ($\xi > \varepsilon$), When $e < 1$, the two kinds of labor are complementary, and technological progress and low skilled labor complement each other ($\xi < \varepsilon$).

Finally, the derivation of time from formula (4) is obtained:

$$G_W = \frac{e-1}{e}(\xi-\varepsilon) G_A - \frac{1}{e}(G_S - G_U) \quad (6)$$

Among them, G_S stands for the change rate of the supply of highly skilled workers, G_U represents the change rate of the supply of low skilled workers.

Obviously, as can be seen from formula (6), wage disparity is affected by technological progress, skill bias, supply of high skilled workers and low skilled workers, and substitution elasticity between high skilled workers and low skilled workers. When skill biased technological progress appears, technological progress is biased towards highly skilled workers, then the wage disparity will become larger, and the higher the rate of technological progress is, the larger the wage disparity will be.

After the technology progress has an impact on the wage disparity, it will affect the investment of human capital. Tinberg (1975) proposed that when the supply of human capital caused by technological progress is less than the demand of human capital, the relative wage disparity will expand, on the contrary, the relative wage disparity will be narrowed, that is, there is a "competition" between technological progress and human capital supply [23]. Tinbergen's analysis of this problem provides us with a suitable framework to study the technology progress of skill bias and human capital investment.

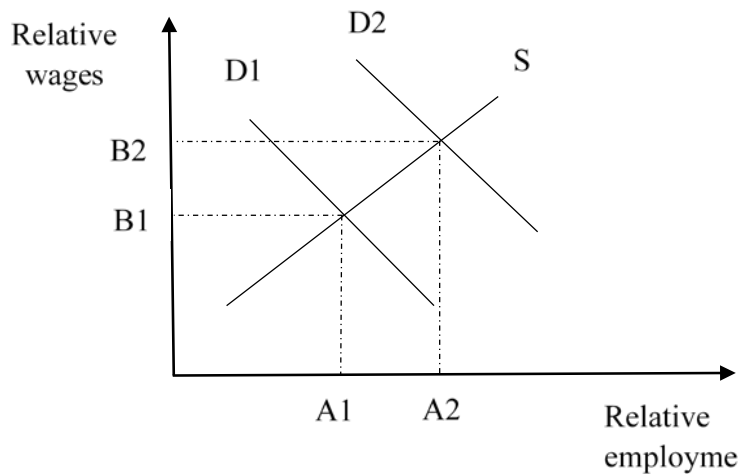


Figure 2. The process of skill biased technological progress inducing human capital investment

As shown in Figure 2, the coordinate of A1 is $(N_h, N_l)_0$; The coordinate of A2 is $(N_h, N_l)_1$; The coordinate of B1 is $(W_h, W_l)_0$; The coordinate of B2 is $(W_h, W_l)_1$. H is high skilled human capital, 1 is the low skilled human capital.

Suppose that there are two different types of labor in the labor market, namely, high skilled workers and low skilled workers. Manufacturers have a certain demand for labor force D1, and the market equilibrium point appears at the intersection of D1 curve and S curve. At this time, the relative wage of human capital is B1, and the relative supply of human capital is A1.

When the skill biased technological progress comes, the demand for high skilled labor increases, while the demand for low skilled labor decreases. The demand curve moves from D1 to D2. At this time, the relative wage also rises from B1 to B2, which indicates that the skill biased technological progress aggravates the wage gap between high skilled workers and low skilled workers. In order not to be eliminated and get more paid job opportunities, low skilled workers will increase human capital investment and promote the supply of human capital from A1 to A2. This process shows that the increase of human capital supply is induced by skill biased technological progress.

4. Human capital investment reverses wage gap and skill biased technological progress

The mechanism of skill biased technological progress on human capital investment has been discussed in the front. This paper will sort out how human capital investment reversely affects wage disparity and skill biased technological progress.

From the perspective of labor supply, with the continuous increase of human capital investment, the supply of high skilled labor is also increasing by a large margin. Because high skilled labor can achieve the specialization required by modern economic development by creating new products or adopting new behavior, a higher level of human capital investment will further promote social material accumulation, At the same time, it also promotes the technological progress of skill bias.

Similarly, under the condition of skill biased technological progress, human capital investment will reverse the wage disparity.

With the development of skill biased technological progress, the unemployment rate of low skilled workers is rising, and the wage level is declining, which leads to the low ability of human capital investment of low skilled workers. On the contrary, high skilled workers get more employment opportunities and higher wages, which leads to their ability to invest in human capital. With the development of skill biased technological progress, the surplus of highly skilled workers is increasing. When the labor demand of manufacturers is greater than the surplus of human capital, manufacturers have to further invest in highly skilled workers to meet the production requirements. This exacerbates the wage gap between high skilled workers and low skilled workers.

As the main form of human capital investment, education is difficult for low skilled workers to invest in human capital through education when skill biased technological progress comes.

This is because the low skilled workers have little income, so they can only invest in human capital by borrowing. However, the loan market of human capital investment is incomplete, which makes it difficult for low skilled workers to invest in human capital by borrowing. There are several reasons for the imperfection of the loan market of human capital investment. First of all, the return of human capital investment has monetary and non monetary returns, while lending institutions only focus on monetary returns; Second, due to the information asymmetry, in order to protect their own rights and interests, the loan interest rate often increases with the increase of the number of loans, which leads to the low skilled workers can't bear the loan interest; Third, the uncertainty of future income, the lending institutions can't determine the individual's human capital production capacity, and the production capacity determines the future loan income; Finally, there is a long time interval between human capital investment and human capital income, which will increase the risk of loans. Card (1995) pointed out that the existence of credit constraints limits the opportunities for young people to pursue high productivity jobs [24].

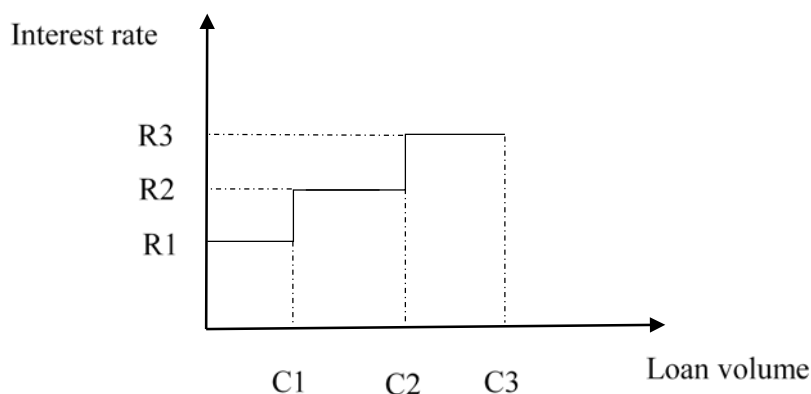


Figure 3. Relationship between lending volume and interest rate

In a word, under the condition of technology biased technological progress, due to the difference of human capital investment ability, the wage disparity between high skilled workers and low skilled workers will continue to expand.

5. Conclusion and Enlightenment

Through the above analysis, this paper finds that skill biased technological progress affects the wage disparity, and the higher the biased technological progress is, the larger the wage disparity is. Skill biased technological progress affects human capital investment by affecting the wage disparity. Similarly, due to the lack of human capital investment ability between high skilled workers and low skilled workers, the wage disparity will continue to expand. When the supply of highly skilled labor is increasing, it will further promote skill biased technological progress.

This paper also gives some enlightenment to human capital investment under the condition of skill biased technological progress.

First, we should pay attention to increasing the investment in human capital for low skilled workers from education and enterprise training. This is because the wage disparity caused by the technology progress of skill bias is objective. The high skilled workers get high wages is determined by the market mechanism, so we can only invest in human capital for the low skilled workers from other aspects.

Secondly, the social wage disparity is adjusted by the redistribution adjustment mechanism of tax and transfer payment. Because of the Matthew effect of wealth, if the state does not control it by means of macro-control, the disparity between the rich and the poor will be bigger and bigger. According to Keynes' theory, the consumption demand of the high-income class is lower than that of the low-income

class, but the wage disparity increases, while the poor are poorer, their purchasing power will be reduced, It will have negative impact on technological progress and economic development.

In this paper, there are some limitations in the analysis of the relationship between skill biased technological progress and human capital investment. The impact of wage disparity on skill biased technological progress has not been deeply analyzed. Similarly, the impact of human capital investment on wage disparity has only been theoretically analyzed, and no model has been built for further research, I hope it can make up for the limitations of this study in the future.

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