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TECHNOLOGICAL PROGRESS, LABOUR PRODUCTIVITY AND ECONOMIC GROWTH: DISENTANGLING THE NEGATIVE AND POSITIVE EFFECTS

Abstract:

This study simply claims that technological progress has positive and negative effects on the labour productivity, so, on the economic growth. Technological progress may have a negative effect on economic growth because of skills obsolescence of labour. For this reason, if the nature of technological progress is assumed as Harrod-neutral for the steady-state analysis, then, the net effect of the technological progress on the economic growth can be examined. Using Hicks-neutrality, it cannot be possible to investigate positive and negative effects. The present study offers a simple calculation procedure in order to disentangle the positive and negative effects. Finally, the study tries to introduce capital-deepening-induced technological progress, if the growth rate and contribution of technological progress is found negative while there is positive economic growth and the steady state conditions are hold at the final state.

Keywords:

Economic growth, technological progress, skills obsolescence.

JEL Classification: O40, O39

Introduction

As Uzawa (1961) proved that the nature of technological progress in consistent with the steady state conditions is Harrod-neutral technological progress. Acikgoz and Mert (2014) also emphasize the importance of taking into account the contradiction between economic and econometric analysis.

Apart from the contradiction between economic and econometric analysis, there is another point on this subject we need to discuss: Does technological progress have always a positive effect on the labour productivity, so, on the economic growth?

It is known from the literature that technological progress may have a negative impact on economic growth via skills obsolescence of labour (de Grip and van Loo 2002). Therefore, if the nature of technological progress is assumed as Harrod-neutral, the net effect of the technological progress on the economic growth can be examined. As it will be discussed in the next section, there is a difference between the **growth rate of technological progress** and the **contribution of technological progress to the output growth**. This difference should stem from the negative growth effect of technological progress. This negative effect may be called skills obsolescence of labour. Thus, it can be noted that there is a negative effect of the technological progress on the economic growth. On the other hand, technological progress induces economic growth also positively via capital deepening, which is called total factor productivity induced growth by Madsen (2010).

Apart from the negative and positive effects, another issue is the negative value of growth rate and contribution of technological progress to the output growth. In the present paper this situation is also explained briefly. This explanation points out that there should be capital-deepening-induced technological progress if the nature of technological progress is Harrod-neutral.

This study is organized as follows: Next section explains the main problems. Final section is the conclusion.

The Main Problems

Assuming that there are constant returns to scale conditions and the nature of the technological progress is Harrod-neutral[1], production function can be written in the Cobb-Douglas form as follows:

[1] According to Hicks (1963: 121), technological progress occurs if the capital-labour ratio does not change while the ratio of factor prices is constant. According to Harrod (1948: 82), technological progress occurs if the capital-output ratio does not change while the marginal productivity of the capital-labour ratio is constant.

$$Y_t = K_t^{\alpha}\left(A_t L_t\right)^{1-\alpha} \tag{1}$$

Taking natural logarithm and derivative of the production function, output growth per labour can be written as follows:

$$\frac{dY}{dt}\frac{1}{Y_t} - \frac{dL}{dt}\frac{1}{L_t} = \left(\frac{dK}{dt}\frac{1}{K_t} - \frac{dL}{dt}\frac{1}{L_t}\right)\alpha + \frac{dA}{dt}\frac{1}{A_t}\left(1-\alpha\right) \tag{2}$$

Note that $\frac{dA}{dt}\frac{1}{A_t}\left(1-\alpha\right)$ is the **contribution of technological progress**.

Leaving alone **the growth rate of the technology**:

$$\frac{dA}{dt}\frac{1}{A_t} = \frac{\frac{dY}{dt}\frac{1}{Y_t} - \frac{dK}{dt}\frac{1}{K_t}\alpha - \frac{dL}{dt}\frac{1}{L_t}(1-\alpha)}{1-\alpha} \tag{3}$$

If the nature of the technology was Hicks-neutral rather than Harrod-neutral, then the residual would be calculated as (3):

$$\frac{dA}{dt}\frac{1}{A_t} = \frac{dY}{dt}\frac{1}{Y_t} - \frac{dK}{dt}\frac{1}{K_t}\alpha - \frac{dL}{dt}\frac{1}{L_t}(1-\alpha) \tag{4}$$

Note that, contribution of technological progress and growth rate of the technology is equal to each other under Hicks-neutrality**. Thus, if the identifying assumption is assumed to be Hicks-neutral, contribution of technological progress and growth rate of the technology cannot be disentangled.**

However, the estimation equation used in estimating parameters should be same as if the nature of the technological progress is Hicks-neutral due to the fact that there are no technology data representing the level of technology series. In the traditional growth accounting studies, the residual is calculated assuming that the nature of technology is Hicks-neutral and the constant term is equal to the level of the technology in natural logarithmic form. On the other hand, as it is emphasized above, if it is assumed that the nature of the technological progress is Harrod-neutral, the constant term is equal to $\left(1-\alpha\right)\ln A$.

Thus, the critical point here is that if the nature of the technological progress is Harrod-neutral, there should be a difference between the **growth rate of the technological progress** $\left(\frac{dA}{dt}\frac{1}{A_t}\right)$ and the **contribution of the technological progress to the output growth** $\left(\frac{dA}{dt}\frac{1}{A_t}(1-\alpha)\right)$. In other words, if the nature of the technological progress is Harrod-neutral, the growth rate of the technological progress should be greater than the contribution of the technological progress to the output growth. Hence, the reasons for that difference should be analyzed.

The major reason for the difference may be the skills obsolescence of the labour. de Grip and van Loo (2002) point out that; there are two types of skills obsolescence: i) technological obsolescence and ii) economic obsolescence. Technological obsolescence contains the obsolescence due to the wear and atrophy of workers' skills. Economic obsolescence includes three types obsolescence; i.e. job specific skills obsolescence, skills obsolescence by sectoral shifts, firm-specific skills obsolescence.

In the present study, the debate mainly depends on the concept of economic obsolescence. Because of rapid technological progress, the workers' skills may obsolete. There are some major studies on this subject. For example, according to Allaart et al. (2002: 121) economic obsolescence occurs "when the skills of a worker are no longer in demand on the labor market." In other words, if there is mismatch between a worker's skills and the job's requirements due to using new technologies, some certain skills may obsolete. Allaart et al. (2002) test the hypothesis that whether or not skills obsolescence occurs when new products or technologies are introduced using the U.S. data covering the years 1997 and 1999. They find evidence that supports this hypothesis. Another study, Fernández (2002), indicates that technological change creates new jobs and provides productivity gains. Therefore according to the Fernández (2002: 176) "the new jobs or tasks represent shifts in the demand for skills." Fernández (2002, 187) proved mathematically that "any degree of skills obsolescence as captured by skills mismatches is harmful for growth."

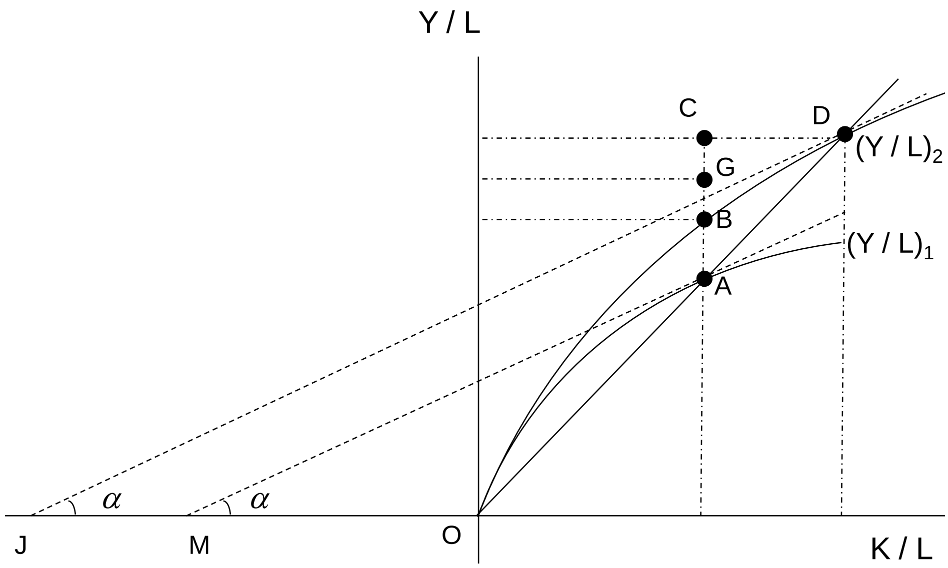
Madsen (2010) explains total factor productivity induced growth. Madsen (2010: 756) shows that because of capital deepening is endogenous, total factor productivity magnifies by a factor $\frac{1}{1-\alpha}$.[2] Because Madsen (2010) expresses that capital deepening has two impacts: To him, capital deepening has a direct impact including essentially an advance in methods of production. The other impact reveals indirectly. Indirect impact

[2] Note that (2) is also compatible with this phrase. However, when the nature of technological progress is not Hicks-neutral it will be wrong to say that total factor productivity induced growth. Since the nature of technological progress is Harrod-neutral (labour-augmenting), true statement will be labour-productivity-induced growth.

explains a relationship from higher total factor productivity to rise in expected earnings through a mechanism from the share market. Madsen (2010) supports the following proposition: “In contrast to most growth accounting exercises, capital deepening was found to be an unimportant source of growth after taking into account that most capital deepening over the past 137 years has been TFP-induced” (Madsen 2010: 765).

In Figure 1, $(Y/L)_1$ and $(Y/L)_2$ represent the production functions before and after technological progress, respectively. The tangent of the line starting from the origin is the inverse of capital-output ratio, so this line represents the steady state growth path. The tangents JD and MA display the marginal productivity of capital per labour. In the Figure 1, points A and D represent the initial and final states, respectively.

Figure 1: The Production Functions before and after Technological Progress



Source: Author’s own.

It is known that the growth rate of output per labour from the initial state to the final state can be shown as (2):

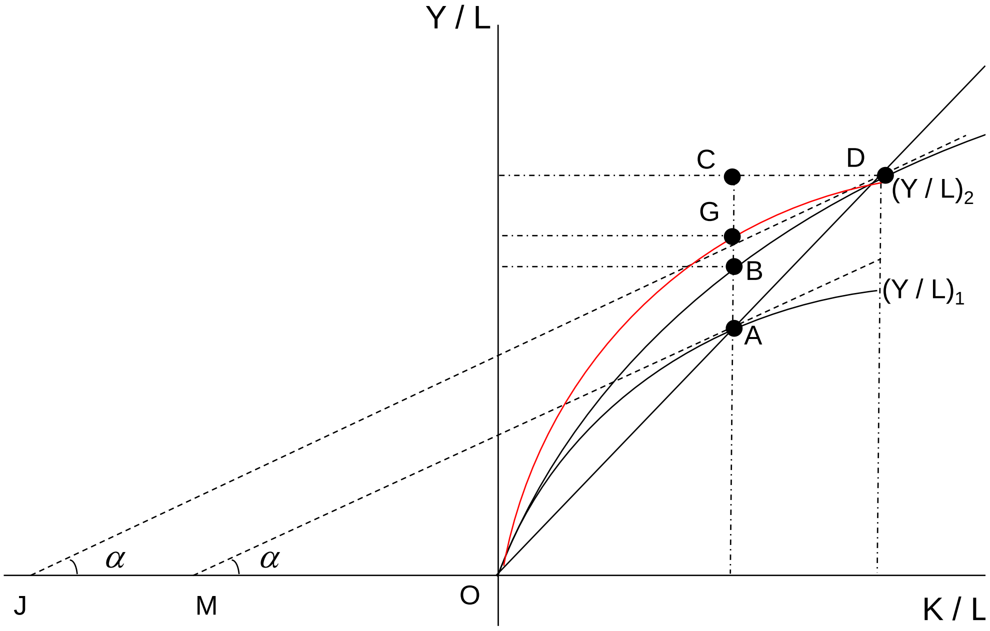
$$\frac{dY}{dt}\frac{1}{Y_t}-\frac{dL}{dt}\frac{1}{L_t}=\left(\frac{dK}{dt}\frac{1}{K_t}-\frac{dL}{dt}\frac{1}{L_t}\right)\alpha+\frac{dA}{dt}\frac{1}{A_t}(1-\alpha) \tag{2}$$

If $\frac{dK}{dt}\frac{1}{K_t}-\frac{dL}{dt}\frac{1}{L_t}=0$, then growth rate of output per labour is equal to $\frac{dA}{dt}\frac{1}{A_t}(1-\alpha)$. According to the Figure 2, the AB distance represents the upward shift is equal to $\frac{dA}{dt}\frac{1}{A_t}(1-\alpha)$. The AC distance is the final change in Y/L when the nature of technological progress is assumed to be Harrod-neutral. Assume that there are steady state conditions both at initial and final states. Here, the contribution of the technological progress to the per labour output growth is related with the AB distance. On the other hand, the growth rate of the technological progress is related with a distance between A and a point above B since the growth rate of technology is greater than the contribution of the technological progress to the per labour output growth $\left[\frac{dA}{dt}\frac{1}{A_t}>\frac{dA}{dt}\frac{1}{A_t}(1-\alpha)\right]$. Besides, while the BC distance is the change in the level of output per labour due to the capital deepening as Madsen (2010) pointed out. $\mathrm{AC}\,(=\mathrm{AB}+\mathrm{BC})$ distance is the *total* change in the level of output per labour. Hence, for example, if the economy is at B while it should be at G, there should be a decrease in the level of output per labour equals to BG because of skill obsolescence. Thus, according to Figure 2, there is a downward shift of production function because of skill obsolescence. However, due to the effect of labour-productivity-induced growth[3], the economy moves to the point D at the steady state. So, it should be noted that there is a positive effect of labour-productivity-induced growth on the level of output per labour represented by the distance BC and a negative effect of the skill obsolescence on the level of output per labour represented by the distance BG.

Thus, if the identifying assumption is assumed to be Hicks-neutral, contribution of technological progress and growth rate of the technology cannot be disentangled, so, positive and negative effects of technological progress cannot be disentangled.

[3] See, footnote 2.

Figure 2: The Production Functions Including Negative and Positive Effects of Technological Progress



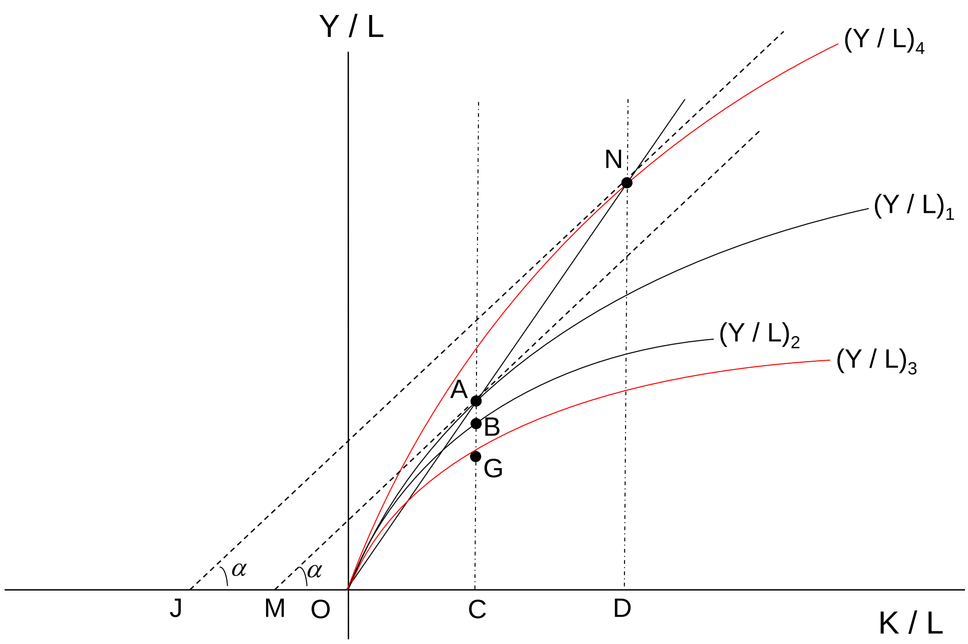
Source: Author's own.

What happens, on the other hand, if the growth rate and contribution of technological progress is found negative likewise in the Crafts (2000) and Maddison (1970)? If the growth rate of technological progress is negative, this means that production function shifts to the downwards.[4] So, technological progress leads to lower the average productivity of the labour while production technique (capital labour ratio) is constant. This situation may occur due to the fact that labour cannot adapt to the new technology **initially**. Note that this inconsistency does not mean skills obsolescence. Skills obsolescence may happen **after** technological progress due to, for example, when the demand for skills of some workers cease. However, falling in the average labour productivity happens because of technological progress in itself. In other words, technological progress, initially, causes a productivity loss rather than productivity gain. It is represented by AB distance in the Figure 3. The negative effect of technological progress due to the skills obsolescence is shown as the BG distance in the Figure 3. If there is positive economic growth and if the steady state conditions are hold at the final state, then, after technological progress capital deepening should occur. If there is

[4] Note that Solow (1957: 312) uses the phrase *technical change* for *any kind of shift* in the production function and show that positive *technical change* causes an upward shift.

positive economic growth and if the steady state conditions are hold at the final state, there should be a shift to the upwards during the capital deepening process, so that the economy moves to the steady state equilibrium. Therefore, after technological progress, capital accumulation occurs which is represented by CD distance and the economy moves to the point N which is the steady state point. The major theoretical conclusion from this explanation that we need to emphasize is as follows: The shift of the production function to the upwards during the capital deepening indicate that, besides the labour-productivity-induced growth[5] there exists also capital-deepening-induced technological progress.

Figure 3: The Production Functions including Negative and Positive Effects of Technological Progress when Growth Rate of Technological Progress is Negative but Growth Rate of Y/L positive



Source: Author's own.

Although capital-deepening-induced technological progress contradicts with the proposition in the neoclassical model that technological progress is exogenous, it may occur because at least some of the labour tries to adapt to and learn the new technology

[5] See, footnote 2.

after the initial effect that causes a decrease in average labour productivity. Hence, this learning process may cause an effect that shifts to the economy upwards. In sum, if the growth rate and contribution of technological progress is found negative likewise in the Crafts (2000) and Maddison (1970), it seems to stimulate a process which is described by;

i) inconsistency between the labour and new technology (a shift to the downwards) (moving from A to B in the Figure 3),

ii) skills obsolescence after technological progress (a shift to the downwards) (moving from B to G in the Figure 3),

ii) capital deepening, so, an increase in the average labour productivity in correspondence with the increase in the capital labour ratio (moving from C to D in the Figure 3),

iii) a learning process, so, compensating and exceeding the initial fall in the average labour productivity (a shift to the upwards) (moving to N in the Figure 3).

Conclusion

As a consequence, there are three important theoretical conclusions on the subject: i) There is a growth process due to labour productivity-induced capital deepening, i.e. the positive effect of the technological progress, while ii) there is a non-utilized or obsoleted labour productivity due to the skills obsolescence, i.e. the negative effect of the technological progress. iii) If the growth rate and contribution of technological progress is found negative, then there exists capital-deepening-induced technological progress.

Note that, if the nature of technological progress is assumed to be Hicks-neutral, contribution of technological progress and growth rate of the technology cannot be disentangled, thus, positive and negative effects of technological progress cannot be disentangled.

In order to analyze positive and negative effects of technological progress, one first can estimate the elasticity of the output per labour with respect to the capital per labour for the selected countries. Then the contribution of the technological progress to the per labour output growth based on (3) is calculated. Meanwhile, the contribution of the per labour capital stock to the per labour output growth, so, the positive effect of the technological progress is calculated. Moreover, the growth rate of technological progress according to (2) is calculated. Finally, the difference between the growth rate of technological progress and the contribution of the technological progress to the output growth, i.e. the negative effect of the technological progress is calculated. This is the offer of the present study.

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