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Technological progress and wage inequality in an economy with a segmented labor market

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Abstract

We examine the effect of technological progress on the wage gap between skilled and unskilled labor. Furthermore, we apply Beladi et al.'s (2012) analysis of technological progress and informal workers to the problem of wage inequality between skilled and unskilled labor. We conclude that technological progress in the organized sector will harm informal workers, while progress in the unorganized sector will benefit them. Additionally, we find that the effect of labor-saving technological progress on the wage gap depends on the industries' relative factor intensities.

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1. Introduction

Both trade and labor economists have extensively researched the effects of technological progress on factor prices. However, it should be noted that the two schools evaluate the effect of labor-saving technological progress on the wage rate in vastly different manners. In labor economics, labor-saving technological progress is thought to lower the demand for labor and thereby decreases the wage rate. Conversely, the standard 2x2 trade model, which is popular in trade economics, holds that labor-saving technological progress in labor intensive sectors should, in fact, raise the wage rate through the Stolper–Samuelson process; thus, the results of this model depend on the sectors' factor intensities. Recently, Beladi *et al.* (2012) examined the effect of labor-saving technological progress on informal wage rates in segmented labor markets. In order to do so, they utilized a 2x2 neoclassical trade model wherein the two factors were labor and capital and the two goods were agricultural and manufacturing products. Their model differed from the standard model in one regard; that is, the wage rate in the formal (manufacturing) sector was set at a higher level in order to account for the existence of trade unions. They assumed that "some workers are employed in a high-wage unionized sector and the rest exist in the competitive flexible wage segment" (Beladi *et al.*, 2012).

Additionally, a large number of studies have been conducted on the inequality between skilled and unskilled laborers' wages (see, for example, Davis, 1998; Feenstra and Hanson, 1997, 2003; Jones and Marjit, 2003; Kar and Beladi, 2004; Marjit and Kar, 2005; Chaudhuri and Yabuuchi, 2007; and Beladi *et al.*, 2008). Thus, it should be interesting to examine the effect of technological progress on the wage gap by extending Beladi *et al.*'s (2012) analysis to include skilled labor explicitly in the model. Following Beladi *et al.* (2012), let us suppose that the economy in question is that of a developing country and that unskilled labor is fully employed in the informal sector under a flexible, competitive wage. Policy makers in developing countries are greatly concerned with the impact of their legislation on wage rates, especially those in the informal sectors. Thus, our analysis will provide useful insights into the mechanics of wages that will aid in their efforts to create effective policies. As an alternative scenario, we can incorporate unemployment, which is characteristic of developing economies, in a manner similar to that of the Harris–Todaro model (Harris and Todaro, 1970). However, we shall concentrate on a full employment scenario because it allows us to compare our results with those of Beladi *et al.,* 2012, who did not account for skilled labor, and because we obtain the same qualitative results in both cases.

2. The model and assumptions

In the simple 2x3 neoclassical trade model, three factors, unskilled labor, skilled labor, and capital, are used to produce two goods, agricultural and manufacturing products. Unskilled labor and capital are used to produce agricultural goods in the informal (unorganized) sector, while unskilled labor, skilled labor, and capital are used to produce manufacturing goods in the formal (organized) sector.

Let a_{ij} be the amount of the *i*th factor used in the *j*th industry to produce one unit of output, w_j be the wage rate of unskilled labor in the *j*th sector, *s* be the wage rate of skilled labor, *r* be the rental of capital, and p_j be the price of the *j*th good (*j* = 1,2). Then, zero-profit conditions in the sectors imply that

$$p_1 = a_{L1}w_1 + a_{K1}r\,, \tag{1}$$

$$p_2 = a_{L2}w_2 + a_{K2}r + a_{H2}s\,. \tag{2}$$

We assume that all goods are traded and that their prices are given exogenously in this small country.

Taking endowments as exogenously given imposes the following resource constraints:

$$a_{L1}X_1 + a_{L2}X_2 = L\,, \tag{3}$$

$$a_{H2}X_2 = H\,, \tag{4}$$

and

$$a_{K1}X_1 + a_{K2}X_2 = K\,, \tag{5}$$

where X_j is the output of good *j*, and *L*, *H,* and *K* are the domestic endowments of unskilled labor, skilled labor, and capital, respectively. The model has five unknown variables, w_1, *s, r,* X_1, and X_2, which are solved for with five equations, (1) - (5), for given parameters, w_2, p_1, p_2, *L, H,* and *K.*[1]

[1] Yabuuchi (2009) used a similar model to examine the effect of emigration on wage inequality.

3. Technological progress and wage rates

Let us now explore the effects of labor-saving technological progress on the unskilled wage rate and compare the results with those obtained by Beladi *et al.*, 2012. Let us consider labor-saving technological progress, wherein the amount of unskilled labor decreases for a given set of factor prices. This implies that

$$\hat{a}_{L1} < 0 \quad \text{or} \quad \hat{a}_{L2} < 0 \tag{6}$$

while $\hat{a}_{K1} = \hat{a}_{K2} = 0$.

Differentiating (1) - (5) and rearranging the terms yield

$$\begin{bmatrix} 0 & \theta_{H2} & \theta_{K2} & 0 & 0 \\ \theta_{L1} & 0 & \theta_{K1} & 0 & 0 \\ \lambda_{L1}S_{LL}^1 & \lambda_{L2}S_{LH}^2 & A & \lambda_{L2} & \lambda_{L1} \\ 0 & S_{HH}^2 & S_{HK}^2 & 1 & 0 \\ \lambda_{K1}S_{KL}^1 & 0 & B & \lambda_{K2} & \lambda_{K1} \end{bmatrix} \begin{bmatrix} \hat{w}_1 \\ \hat{s} \\ \hat{r} \\ \hat{X}_2 \\ \hat{X}_1 \end{bmatrix} = \begin{bmatrix} -\theta_{L2}\hat{a}_{L2} \\ -\theta_{L1}\hat{a}_{L1} \\ -(\lambda_{L1}\hat{a}_{L1} + \lambda_{L2}\hat{a}_{L2}) \\ 0 \\ 0 \end{bmatrix}. \tag{7}$$

where θ_{ij} is the distributive share of factor i in the jth sector (e.g., $\theta_{H2} = sa_{H2} / p_2$), and $A = \lambda_{L2}S_{LK}^2 + \lambda_{L1}S_{LK}^1 > 0$, $B \equiv \lambda_{K2}S_{KK}^2 + \lambda_{K1}S_{KK}^1 < 0$, $S_{KL}^1 = (r / a_{K1})(\partial a_{K1} / \partial r)$, and so on.

First, let us examine the effects of labor-saving technological progress in sector 1. By solving (7) for $\hat{w}_1$ and $\hat{s}$ with respect to $\hat{a}_{L1}$, we obtain

$$\begin{aligned} \hat{w}_1 / \hat{a}_{L1} = \theta_{L1}[\theta_{H2}\{(\lambda_{K1}\lambda_{L2}S_{LK}^2 - \lambda_{L1}B) + \lambda_{L1}\lambda_{K1}\theta_{K1}(\sigma_{LK}^1 - 1/\theta_{L1})\} \\ + (\theta_{H2}S_{HK}^2 - \theta_{K2}S_{HH}^2)\Lambda + \theta_{K2}\Pi] / \Delta \end{aligned}, \tag{8}$$

$$\hat{s} / \hat{a}_{L1} = \lambda_{L1}\lambda_{K1}\theta_{L1}\theta_{K2}\{(S_{LL}^1 - S_{LK}^1) - 1\} / \Delta > 0, \tag{9}$$

where $\Lambda = \lambda_{L1}\lambda_{K2} - \lambda_{K1}\lambda_{L2}$, $\Pi = (\lambda_{L1}\lambda_{K2}S_{KH}^2 - \lambda_{K1}\lambda_{L2}S_{LH}^2)$, and $\sigma_{LK}^j = S_{LK}^j / \theta_{Kj}$ is the Allen–Uzawa partial elasticity of substitution in sector j and Δ is the value of the coefficient matrix's determinant,

$$\begin{aligned}\Delta = &\lambda_{L1}\lambda_{K1}\theta_{K1}\theta_{H2}(S_{LL}^{1} - S_{KL}^{1}) + \theta_{L1}\theta_{H2}(\lambda_{L1}B - \lambda_{K1}A) \\ &+ \theta_{L1}(\theta_{K2}S_{HH}^{2} - \theta_{H2}S_{HK}^{2}) - \theta_{L1}\theta_{K2}\Pi\end{aligned}.$$

It can be seen that $\Delta < 0$ under the following assumption.

Assumption 1. $\Pi = (\lambda_{L1}\lambda_{K2}S_{KH}^{2} - \lambda_{K1}\lambda_{L2}S_{LH}^{2}) > 0$.

We suppose that sector 1 produces agricultural goods while sector 2 produces manufacturing goods. Thus, it is natural to assume $\Lambda = (\lambda_{L1}\lambda_{K2} - \lambda_{K1}\lambda_{L2}) > 0$. On the other hand, skilled labor is indispensable to produce manufacturing goods, and then it may be difficult to replace it with unskilled labor. Thus, assumption 1 is satisfied if the substitutability between skilled labor and unskilled labor is relatively small.

As such, we may calculate the impact of labor-saving technological change on sector 2 as follows:

$$\hat{w}_1 / \hat{a}_{L2} = -\theta_{K1}\{\lambda_{K1}\lambda_{L2}\theta_{H2} + \theta_{L2}(\Pi - S_{HH}^{2}\Lambda)\} / \Delta, \tag{10}$$

$$\begin{aligned}\hat{s} / \hat{a}_{L2} = \theta_{L2}[&\lambda_{L1}\{\lambda_{K1}(\theta_{L1}S_{LK}^{1} + \theta_{K1}S_{KL}^{1} - \theta_{K1}S_{LL}^{1}) - \theta_{L1}B\} \\ &+ \theta_{L1}\{\lambda_{K1}\lambda_{L2}\theta_{K2}(\sigma_{LK}^{2} - 1/\theta_{L2}) + S_{HK}^{2}\Lambda\}] / \Delta\end{aligned}. \tag{11}$$

The changes in the skilled and unskilled wage rates are summarized in the following proposition.

Proposition 1. ***Labor-saving technological progress in the informal sector increases the unskilled wage rate if*** $\sigma_{LK}^{1} > 1/\theta_{L1}$ ***, whereas it decreases the skilled wage rate unconditionally.***

Labor-saving technological progress affects the unskilled wage rate in two ways: First, as sector 1 can produce the same amount of X_1 by using more capital-intensive technology and less unskilled labor, an excess supply of said labor and demand for capital arises. Thus, due to the resulting resource allocation, the unskilled wage rate must fall and the rental of capital must rise in order to reach the full-employment equilibrium.

Second, the technological progress in sector 1 will also serve to reduce the cost of production; this tends to increase both the unskilled wage rate and the capital rent. Thus, it is clear that rental of capital will inevitably increases due to both the resource allocation effect and the cost-saving effect. It should be noted that the increase in rental should lower the skilled wage rate in order to maintain the zero profit condition in sector 2, as the unskilled wage rate and commodity price remain constant.

However, the ultimate change in the unskilled wage rate is rather complex as the aforementioned effects work in opposite directions. Our results indicate that if the cost-saving effect is greater than the resource allocation effect (i.e., $\sigma_{LK}^1 > 1/\theta_{L1}$), then the unskilled wage rate will eventually increase due to labor-saving technological progress in sector 1.

A similar analysis on the effects of unskilled labor-saving technological progress on sector 2 leads to the following proposition.

Proposition 2. ***Unskilled labor-saving technological progress in the organized sector decreases the unskilled wage rate unconditionally, while it increases the skilled wage rate if*** $\sigma_{LK}^2 > 1/\theta_{L2}$.

Therefore, our results support Beladi *et al.*'s (2012) conclusion that "sector-specific technological progress in the organized (unorganized) sector will hurt (help) informal workers" only in the case of unskilled labor-saving technological progress in the organized sector. In the case of such technological progress in the unorganized sector, however, the result depends on the factor substitutability and cost share of unskilled labor in sector 1. Suppose that the elasticity of substitution in sector 1 (σ_{LK}^1) is 1, and the cost share of unskilled labor (θ_{L1}) is 0.5, then the condition in proposition 1 is not satisfied. Thus, unskilled labor cannot gain if other positive terms in equation (8) are not large enough. The condition in proposition 1 is satisfied if the substitutability between capital and unskilled labor and the cost share of unskilled labor are large in sector 1.

4. Technological progress and wage inequality

Now, let us examine the impact of labor-saving technological progress on wage inequality. Following our discussion of the effects of labor-saving technological progress in the unorganized sector on skilled and unskilled wage rates, Proposition 1 implies that the inequality between skilled and unskilled wages improves if $\sigma_{LK}^{1} > 1/\theta_{L1}$. On the other hand, by subtracting (12) from (11), we obtain

$$\begin{aligned}(\hat{s}-\hat{w}_1)/\hat{a}_{L1} = [&\lambda_{L1}\lambda_{K1}\{\theta_{L1}\theta_{K2}(S_{LL}^{1}-S_{KL}^{1})-\Theta\}-\theta_{L1}\{\theta_{H2}(\lambda_{K1}A-\lambda_{L1}B) \\ &+(\theta_{H2}S_{HK}^{2}-\theta_{K2}S_{HH}^{2})\Lambda+\theta_{K2}\Pi\}]/\Delta\end{aligned}, \quad (12)$$

where $\Theta = (\theta_{L1}\theta_{K2}-\theta_{K1}\theta_{H2})$. Thus, it can be seen that $(\hat{s}-\hat{w}_1)/\hat{a}_{L1} > 0$ if $\Theta = (\theta_{L1}\theta_{K2}-\theta_{K1}\theta_{H2}) > 0$. Thus, the wage inequality improves if sector 2 is more capital intensive in the sense that $\theta_{K2}/\theta_{H2} > \theta_{K1}/\theta_{L1}$. The cost-saving effect increases the unskilled wage rate and the rental of capital. The increase in rental, in turn, decreases the skilled wage rate in order to maintain the zero profit condition in sector 2. Thus, wage inequality is certain to improve because of the cost-saving effect. On the other hand, the resource-allocation effect decreases the unskilled wage rate and increases rent, which then changes the wage rate of skilled labor. In order to examine the effect on skilled wages and wage inequality, we first differentiate (1) and (2), and thereby obtain

$$\theta_{L1}\hat{w}_1+\theta_{K1}\hat{r} = -\theta_{L1}\hat{a}_{L1} \quad (13)$$

$$\theta_{K2}\hat{r}+\theta_{H2}\hat{s} = 0. \quad (14)$$

In order to focus on the resource-allocation effect, we set $\hat{a}_{L1} = 0$, which yields

$$(\hat{s}-\hat{w}_1) = (\Theta/\theta_{H2}\theta_{K1})\hat{w}_1. \quad (15)$$

This implies that the skilled wage rate decreases more than the unskilled wage rate if $\Theta > 0$, and thus, wage inequality improves due to the resource-allocation effect.

Our results are summarized in the following proposition.

Proposition 3. ***Labor-saving technological progress in the informal sector improves wage inequality if either*** $\sigma_{LK}^{1} > 1/\theta_{L1}$ ***or*** $\Theta > 0$.

Additionally, we can analyze the impact of such technological progress in the unionized sector. Based on (13) and (14), the effect of unskilled labor-saving technological progress in sector 2 on wage inequality can be expressed as

$$(\hat{s}-\hat{w}_1)/\hat{a}_{L2} = [\theta_{L2}\{\theta_{L1}(\lambda_{K1}A-\lambda_{L1}B)+\lambda_{L1}\lambda_{K1}\theta_{K1}(S^1_{KL}-S^1_{LL}) \\ +(\theta_{L1}S^2_{HK}-\theta_{K1}S^2_{HH})\Lambda+\theta_{K1}\Pi\}-\lambda_{K1}\lambda_{L2}\Theta]/\Delta . \tag{16}$$

A similar investigation into the technological progress yields the following proposition.

Proposition 4. ***Unskilled labor-saving technological progress in the formal sector worsens wage inequality if either*** $\sigma^2_{LK} > 1/\theta_{L2}$ ***or*** $\Theta < 0$.

A study of *capital*-saving technological progress yields similar results, though the detailed conditions must be replaced.

5. Concluding remarks

In this paper, we extended the Beladi *et al*.'s (2012) model to include skilled labor in order to examine the effects of labor-saving technological progress on the inequality between skilled and unskilled wages. Our analysis confirms the robustness of some of Beladi *et al*.'s (2012) results with regard to developing countries. More importantly, though, our analysis sheds light on the factors that impact wage inequality, which has been a subject of great concern for developing countries. Our results should be of great use to policy makers in developing countries who seek to improve wage inequality.

We have assumed that the agricultural industry constitutes the informal sector; however, services such as shoe shining and housekeeping feature more of the typical characteristics of this sector. Thus, it would be more realistic to introduce a third sector into the model. In the future, it will also be important to explore the effects of capital-savings and uniform technological progress as well as to extend our analysis to developed countries.

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