Capital-Skill Complementarity, Wage Bargaining, and Inequalities †

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Abstract

The purpose of this paper is to analyze the effects of medium-run shocks, such as increased capital intensity and skill-biased technical change, on wage inequality and unemployment with capital-skill complementarity technology in a unionized economy, which implies that efficient bargaining determines wages and employment in the skilled labor market of advanced countries. We develop our analysis using the three-factor, two-level CES monopolistic competitive general equilibrium framework. We show the contrasting outcomes of wage inequality and unemployment. Increasing capital intensity can facilitate compression of wage inequality and unemployment only in unskilled labor with some relevant capital-skill complementarity. However, even with the same relevant capital-skill complementarity, skill-based technical change is likely to create not only increasing wage inequality but also unemployment of both skilled and especially unskilled labor. Furthermore, the implications of labor market deregulation reflecting globalization are investigated. In particular, we show that when the reservation wage in the skilled labor market is perfectly sensitive to the unskilled wage, the movements of wages and employment in both skilled and unskilled labors can synchronize. Thus, the effects of medium-shocks on wage inequality, income inequality, and unemployment of both skilled and unskilled labors are likely to be enhanced.

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1. Introduction

The purpose of this paper is to investigate the effects of medium-run shocks within a unionized economy on wage inequality and unemployment. As Blanchard and Giavazzi (2003) have clearly shown, combining the models of monopolistic competition and efficient bargaining provides a useful framework to analyze the effects of macroeconomic deregulation on goods and labor markets. As the monopolistic competitive goods market determines the size of rent and efficient bargaining determines the distribution of rent between firms and their employees, it is possible to examine the effects of market deregulation on income inequality that currently prevails in OECD countries.[1]

However, to analyze the issues surrounding contemporary income inequality, other factors influencing this inequality are needed. For instance, Autor (2014) suggests that the three forces of technological change, deunionization, and globalization, create income inequality. According his suggestion, we need to add elements of new technologies such as advanced information and communication technology (ICT), computerization and artificial intelligence in order to explain one of the main contributing factors to the recent rise in income inequalities to Blanchard and Giavazzi's (2003) framework.[2]

In this paper, we introduce capital-skill complementarity technology to develop the monopolistic competitive framework with efficient bargaining into a three-factor model and explore the effects of technological change, unionization, and globalization on income inequalities. In our model, which is based on a three-factor nested two-level CES production technology,[3] the capital-skill complementarity production technology and a skill-biased technical change capture the implications of new technology such as advanced ICT and computerization. In addition, the flexibility of reservation wage in the skilled labor market captures the implication of deunionization or the market deregulation. Furthermore, the increase in capital reflects the increase in the number of firms due to implications of globalization.

Using our framework, we explore the effects of medium-run shocks on inequalities and employment in the monopolistic competitive general equilibrium.[4] To analyze the implication of deuionization, we then compare the case where the reservation wage in the skilled labor market is constant with that in which the reservation wage is linked to the

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[1] See Atkinson et al. (2011) and Piketty (2014).

[2] See Acemoglu (2002), Saint-Paul (2008), and Acemoglu and Autor (2011).

[3] For a pioneering work, see Sato (1967). For the empirical evidence, see Griliches (1969) and Krusell et al. (2000).

[4] For a different context, see Nickell and Layard (1999), Blanchard and Wolfers (2000).

unskilled wages.

Our main findings are as follows. In some empirically relevant capita-skill complementarity, when the reservation wage in the skilled labor market is constant, the increase in demand countercyclically decreases income inequality and fluctuates more in unskilled employment. In contrast, the increase in capital compresses wage inequality and increasing unemployment in unskilled labor. Skill-biased technical change can increase wage inequality and has the possibility of increasing unemployment in both skilled and unskilled labor. Both cases can create income inequality. However, when the reservation wage dependent on the unskilled wage implies labor market deregulation, the movement of wages and employment in skilled labor can synchronize with the movement of these in unskilled labor. Thus, these medium-shocks can create wage inequality, income inequality, and moreover, unemployment in both skilled and unskilled labor, especially more unemployment in unskilled labor. Hence, our analysis confirms the conjecture of Autor (2014) that ongoing new technology, deunionization, and globalization can create inequalities[5], and furthermore we add that these three factors increase unemployment, particularly of unskilled labor and that our research can offer policy implications.

The structure of the paper is as follows. Section 2 presents the model. Section 3 analyzes the effects of medium-run shocks. Section 4 concludes.

2. Model: Monopolistic Competition, Efficient Bargaining with Capital-Skill Complementarity

2.1 Partial equilibrium

We develop a general equilibrium model by incorporating a three-factor nested two-level CES production technology[6] that reflects capital-skill complementarity in order to analyze the effect of shocks on wage inequalities and unemployment. First, we define our model and then present the short-run partial equilibrium. Finally, we describe the short-run general equilibrium in monopolistic competition.

Production function

We consider a three-factor weakly separable sub-aggregate production function where

[5] See Fitoussi, et al. (2000), Bliss (2007), Acemoglu and Autor (2011), and Bourguignon (2015). See also Acemoglu, et al. (2001).

[6] See Sato (1967).

Y is the output, L_1 is skilled labor, L_2 is unskilled labor, K is the capital stock, and A is skill augmenting technology that represents a skill-biased technical progress.

$$y = f(AL_1, L_2, K) \tag{1}$$
$$= \left[\{\delta_2\{\delta_1(AL_1)^{(1-\sigma_1)/\sigma_1} + (1-\delta_1)K^{(1-\sigma_1)/\sigma_1}\}\right]^{(1-\sigma_2)\sigma_1/(1-\sigma_1)\sigma_2} + (1-\delta_2)L_2^{(1-\sigma_2)/\sigma_2}\Big]^{\sigma_2/(1-\sigma_2)}.$$

We assume that each production function is twice differentiable and homogenous of degree one and specify, for convenience, a nested two-level CES production function having two elasticity parameters, the elasticity of substitution between capital and skilled labor σ_1 and the elasticity of substitution between capital and unskilled labor σ_2. In this specification, $\sigma_2 > \sigma_1$ gives a capital-skill complementarity technology[7] that has been widely estimated (Krusell, et al. 2000, Hornstein, et al. 2005) and we deal with this ongoing new technical progress. In particular, we mainly deal with $\sigma_2 > 1 > \sigma_1$ an empirically relevant capital-skill complementarity. [8]

Goods market

In a monopolistic competitive goods market, each firm behaves as a price setter and determines its own price of goods, output and unskilled employment to maximize current profit subject to the following expected demand for the goods produced by each firm

$$y_i = \eta(p_i / P)^{-\varepsilon}, \tag{2}$$

where η is the average demand for each firm, p_i is price set by firm *i*, P is the aggregate price level, and ε is the elasticity of demand of each firm with respect to relative prices and $\varepsilon > 1$ is assumed.[9]

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[7] Capital-skill complementarity is indicated as an inequality that the elasticity of complementarity between capital and skilled labor is larger than that between capital and unskilled labor $c_{1K}(= f_{1K} f / f_1 f_K) > c_{2K}(= f_{2K} f / f_2 f_K)$. Here, $c_{ij} \equiv f_{ij} f / f_i f_j$ is defined as a partial elasticity of complementarity between *i* and *j*. Our two-level CES production technology specifies $c_{1K} - c_{2K} = (\sigma_1^{-1} - \sigma_2^{-1})(1 - f_2 L_2 / f)$ since $c_{1K} = (\sigma_1^{-1} - \sigma_2^{-1})(1 - f_2 L_2 / f) + \sigma_2^{-1}$, $c_{2K} = \sigma_2^{-1}$. Thus, $\sigma_2 > \sigma_1$ implies $c_{1K} > c_{2K}$. We later refer $\sigma_2 > \sigma_1$ as capital-skill complementarity.

[8] See Duffy, et al. (2004) and Hornstein, et al. (2005).

[9] Blanchard and Giavazzi (2003) specify each firm's elasticity of demand with respect to relative prices as $\varepsilon \equiv \bar{\varepsilon} h(m)$, an increasing function of the number of firms m. This specification enables us to analyze the effect of globalization because a larger number of

Labor market

In the labor market, there is skilled labor and unskilled labor. We assume that skill differences and implicit institutional factors create labor market segmentation. In the skilled labor market, we assume that a Nash bargaining between each firm and its skilled workers within firm determines wages W_{1i} and employment L_{1i} .[10] This efficient bargaining is to maximize the weighted value of product of their surpluses.

$$[(\eta^{1/\varepsilon} f(AL_{1i}, L_{2i}, K)^{1-1/\varepsilon} P - W_{1i}L_{1i} - W_2 L_{2i}]^{1-\rho}[L_{1i}(W_{1i} - Pg(w_2))]^{\rho}. \quad (3)$$

Here, since $\eta^{1/\varepsilon} f(AL_{1i}, L_{2i}, K)^{1-1/\varepsilon} P$ is the revenue of each firm, $\eta^{1/\varepsilon} f(AL_{1i}, L_{2i}, K)^{1-1/\varepsilon} P - W_{1i}L_{1i} - W_2 L_{2i}$ expresses the profit of each firm. $L_{1i}(W_{1i} - Pg(w_2))$ represents the surplus received by skilled workers. $g(w_2)$ is the reservation wage of the skilled worker that is assumed to be an increasing function of real wage of unskilled labor $g' > 0$. w_2 is the real wage of unskilled labor evaluated by the price level. ρ expresses the strength of relative bargaining power of skilled workers. The reason why we assume this type of wage bargaining is that the outcome of efficient bargaining can easily indicate the implications of distributable rent going to workers and firms. The decline of relative bargaining power of skilled labor implies deregulation of the labor market. Alternatively, as previously mentioned, unskilled employment is determined by the profit maximization of each firm. However, the solution of Nash maximization with respect to L_2 and that of profit maximization is the same. We simply assume that unskilled wages are given in the short-run partial equilibrium.

The solutions of Nash bargaining and of profit maximization provide the short-run partial equilibrium. This is demonstrated by the following three equations:

$$(1-\frac{1}{\varepsilon})\eta^{1/\varepsilon} f(AL_{1i}, L_{2i}, K)^{-1/\varepsilon} A f_1(AL_{1i}, L_{2i}, K) = g(w_2), \quad (4)$$

$$w_{1i} = (1-\rho)g(w_2) + \rho[\eta^{1/\varepsilon} f(AL_{1i}, L_{2i}, K)^{1-1/\varepsilon} - w_2 L_{2i}]/L_{1i}, \quad (5)$$

$$(1-\frac{1}{\varepsilon})\eta^{1/\varepsilon} f(AL_{1i}, L_{2i}, K)^{-1/\varepsilon} f_2(AL_{1i}, L_{2i}, K) = w_2, \quad (6)$$

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firms, which reflects more competitiveness, increases the elasticity of substitution between commodity goods. In this respect, it seems difficult to analyze the effect of globalization because our model assumes ε is constant. However, we can analyze the implication of globalization if the increase in capital K is interpreted as the increase in the number of firms.

[10] For efficient bargaining, see McDonald and Solow (1981), Cahuc and Zylberberg (2004), and Layard et al. (2005). See also Spector (2004).

where $(1-\frac{1}{\varepsilon})\eta^{1/\varepsilon} f(AL_{1i}, L_{2i}, K)^{-1/\varepsilon} Af_1(AL_{1i}, L_{2i}, K)P$ is the marginal revenue of skilled labor and $(1-\frac{1}{\varepsilon})\eta^{1/\varepsilon} f(AL_{1i}, L_{2i}, K)^{-1/\varepsilon} f_2(AL_{1i}, L_{2i}, K)P$ is the marginal revenue of unskilled labor, respectively. As is known, equation (4) represents the vertical contract curve and equation (5) represents the equity locus, and both determine the efficient employment and wages of skilled labor. Equation (6) simply indicates that the marginal revenue of unskilled labor equal to unskilled labor wage determines the employment of unskilled labor. We have two remarks on equations (4) and (5). The first is that the vertical contract line is derived from the risk neutral preference of both parties and implies that employment is determined in such a way that the marginal product of skilled labor is equal to the reservation wage. Thus, the bargaining power of skilled workers has no allocative effect on employment. The second is that the skilled labor wages set by bargaining have the distributable rent going proportionally to the skilled workers and that the firm exhibits labor hoarding implying that skilled labor employment is larger than skilled labor demand at the bargained wages.

2.2 General equilibrium

Next, we develop the short-run general equilibrium in the monopolistic competition. The short run means K is constant. The general equilibrium in monopolistic competition requires that the price set by each firm is equal to the aggregate price $p_i = P$, and each firm is identical so that $y_i = \eta$, $L_{1i} = L_1$, $L_{2i} = L_2$, $K_i = K$, $w_{1i} = w_1$. It implies that the equilibrium revenue becomes ηP, thus the equilibrium marginal revenue of each labor is reduced to $(1-\frac{1}{\varepsilon})Af_1(AL_1, L_2, K)P$ and $(1-\frac{1}{\varepsilon}) f_2(AL_1, L_2, K)P$. From equations (4), (5) and (6), the short-run general equilibrium is given by as follows:

$$(1-\frac{1}{\varepsilon})Af_1(AL_1, L_2, K) = g(w_2), \tag{7a}$$

$$w_1 = (1-\rho)g(w_2) + \rho[(Y/m) - w_2 L_2]/L_1, \tag{7b}$$

$$(1-\frac{1}{\varepsilon}) f_2(AL_1, L_2, K) = w_2, \tag{7c}$$

$$f(AL_1, L_2, K) = \eta. \tag{7d}$$

The four equations provide four endogenous variables L_1, L_2, w_1, w_2.[11]

[11] Note that in general equilibrium, the reservation wage of skilled labor is endogenously determined. This determination differs from that in Blanchard and Giavazzi (2003).

3. Effects of the Medium-Run Shocks

3.1 Case where the reservation wage is constant ($\nu = 0$)

We first examine the case where the reservation wage in skilled labor is constant ($g'w_2 / g \equiv \nu = 0$). Then we examine the case where the reservation wage is perfectly dependent on the secondary wage ($g'w_2 / g \equiv \nu = 1$). Comparing these results, there is an implication of deunionization of the skilled labor market. In other words, we can see the implication of labor market deregulation. In the case where the reservation wage is constant, the general equilibrium is given by as follows:

$$(1-\frac{1}{\varepsilon})Af_1(AL_1, L_2, K) = \overline{w}\,, \tag{8a}$$

$$w_1 = (1-\rho)\overline{w} + \rho(\eta - w_2 L_2)/L_1\,, \tag{8b}$$

$$(1-\frac{1}{\varepsilon})\, f_2(AL_1, L_2, K) = w_2\,, \tag{8c}$$

$$f(AL_1, L_2, K) = \eta\,. \tag{8d}$$

Here, $\overline{w}$ is the constant reservation wage in skilled labor. Specifying $f_{ij}L_j / f_i$ in our weak separable two-level CES production technology[12], total differentiation in (8a) and (8b) gives the following matrix.

$$\begin{bmatrix} -(c\sigma_1^{-1} + ab\sigma_2^{-1})/(1-b) & b\sigma_2^{-1} \\ a & b \end{bmatrix} \begin{bmatrix} \hat{L}_1 \\ \hat{L}_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 1 \end{bmatrix} \hat{\eta} + \begin{bmatrix} -c(\sigma_1^{-1} - b\sigma_2^{-1})/(1-b) \\ -c \end{bmatrix} \hat{K} \tag{9}$$

$$+ \begin{bmatrix} -(c\sigma_1^{-1} + ab\sigma_2^{-1})/(1-b) - 1 \\ -a \end{bmatrix} \hat{A}$$

where $a(\equiv f_1 L_1 / f)$ is the elasticity of output with respect to skilled labor, $b(\equiv f_2 L_2 / f)$ is the elasticity of output with respect to unskilled labor, $c(\equiv f_K K / f)$ is the elasticity of output with respect to capital, $a + b + c = 1$, and $\hat{x}(\equiv dx / x)$ is the percentage change in x. Combining total differentiation in (8b) and (8c) and the outcomes of the matrix, and by rearranging the matrix, we have the effects of three medium-run parameters on employment, wages and wage inequality, and labor shares. We first analyze the effect of the demand for goods

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[12] Our two-level CES production function specifies $f_{ij}L_j / f_i$ as follows:

$$f_{11}L_1 / f_1 = -(c\sigma_1^{-1} + ab\sigma_2^{-1})/(1-b) < 0\,, \quad f_{12}L_2 / f_1 = b\sigma_2^{-1} > 0\,,$$
$$f_{21}L_1 / f_2 = a\sigma_2^{-1} > 0\,, \qquad f_{22}L_2 / f_2 = -(1-b)\sigma_2^{-1} < 0\,.$$

whose fluctuation reflects the business cycle[13], and then subsequently investigate the effects of capital intensity and skill-biased technical change.

(i) Demand shock:

We first derive the effects of increasing demand for goods on employment in both skilled and unskilled labor as follows:

$$\hat{L}_1 / \hat{\eta} = \frac{-1}{\Delta} b\sigma_2^{-1} > 0 \tag{10a}$$

$$\hat{L}_2 / \hat{\eta} = \frac{-1}{\Delta} \frac{1}{1-b}(c\sigma_1^{-1} + ab\sigma_2^{-1}) > 0 \tag{10b}$$

$$\hat{L}_2 / \hat{\eta} - \hat{L}_1 / \hat{\eta} = \frac{-1}{\Delta} \frac{c}{1-b}(\sigma_1^{-1} - b\sigma_2^{-1}) \tag{10c}$$

where Δ is the determinant of the matrix and its value is negative.

$$\Delta = \frac{-b}{1-b}(c\sigma_1^{-1} + a\sigma_2^{-1}) < 0 . \tag{11}$$

The effects on wages and wage inequality are given as:

$$\hat{w}_1 / \hat{\eta} = \frac{-1}{\Delta} \frac{bc}{1-b} \frac{\rho R}{w_1 L_1} \left[\frac{1}{\varepsilon}\sigma_1^{-1} - \{1 - b(1 - \frac{1}{\varepsilon})\}\sigma_2^{-1} + (1-b)(1 - \frac{1}{\varepsilon})\sigma_1^{-1}\sigma_2^{-1} \right] \tag{12a}$$

$$\hat{w}_2 / \hat{\eta} = \frac{1}{\Delta} c\sigma_1^{-1}\sigma_2^{-1} < 0 \tag{12b}$$

$$\hat{w}_1 / \hat{\eta} - \hat{w}_2 / \hat{\eta} = \frac{-1}{\Delta} \frac{c}{1-b} \left[\frac{b}{\varepsilon} \frac{\rho R}{w_1 L_1}\sigma_1^{-1} - b\{1 - b(1 - \frac{1}{\varepsilon})\} \frac{\rho R}{w_1 L_1}\sigma_2^{-1} \right.$$

$$\left. + (1-b)\{1 + b(1 - \frac{1}{\varepsilon}) \frac{\rho R}{w_1 L_1}\}\sigma_1^{-1}\sigma_2^{-1} \right] \tag{12c}$$

Furthermore, we obtain the effects on each labor share $s_{L_1} (\equiv w_1 L_1 / Y)$, $s_{L_2} (\equiv w_2 L_2 / Y)$ and income inequality s_{L_1} / s_{L_2} as follows:

$$\hat{s}_{L_1} / \hat{\eta} = \hat{w}_1 / \hat{\eta} + \hat{L}_1 / \hat{\eta} - 1 \tag{13a}$$

$$= \frac{-1}{\Delta} \frac{bc}{1-b} \left[(\frac{\rho R}{w_1 L_1} \frac{1}{\varepsilon} - 1)\sigma_1^{-1} + [1 - \{1 - b(1 - \frac{1}{\varepsilon})\} \frac{\rho R}{w_1 L_1}]\sigma_2^{-1} + (1-b)(1 - \frac{1}{\varepsilon}) \frac{\rho R}{w_1 L_1}\sigma_1^{-1}\sigma_2^{-1} \right]$$

$$\hat{s}_{L_2} / \hat{\eta} = \hat{w}_2 / \hat{\eta} + \hat{L}_2 / \hat{\eta} - 1 = \frac{-1}{\Delta} c\sigma_1^{-1}(1 - \sigma_2^{-1}) \tag{13b}$$

[13] See Teulings and Baldwin (2014).

$$\hat{s}_{L_1}/\hat{\eta} - \hat{s}_{L_2}/\hat{\eta} = \frac{-1}{\Delta}\frac{c}{1-b}\Big[(\frac{\rho R}{w_1 L_1}\frac{b}{\varepsilon} - 1)\sigma_1^{-1} + [1-\{1-b(1-\frac{1}{\varepsilon})\}\frac{\rho R}{w_1 L_1}]\sigma_2^{-1} + (1-b)\{1+b(1-\frac{1}{\varepsilon})\frac{\rho R}{w_1 L_1}\}\sigma_1^{-1}\sigma_2^{-1}\Big] \quad (13c)$$

Summarizing the outcomes yields the following proposition.

Proposition 1

In the framework of monopolistic competitive general equilibrium and efficient bargaining, with some empirically relevant capital-skill complementary production technology $\sigma_2 > 1 > \sigma_1$ *and the reservation wage of skilled labor being constant, the following statements hold.*

During a boom in the business cycle, wage inequality can procyclically increase but income inequality can countercyclically decrease. That is, in the case of former, skilled wage increases but unskilled wage decreases, thus wage inequality can increase. In the latter, however, skilled labor share decreases but unskilled labor share increases, and thereby income inequality can decrease. Furthermore, unskilled employment fluctuates more in the business cycle.

[Insert Figures 1a and 1b]

Figures 1a and 1b show the proposition. Note that capital-skill complementarity technology plays a significant role in the movement of employment and wage inequality because it produces relatively skilled labor as a quasi-fixed factor and unskilled labor as a flexible factor. Therefore, employment of unskilled labor becomes a buffer variable in the business cycle and wage inequality also occurs. This implies that other production technology does not provide the same property. For instance, if we have Cobb-Douglas technology, skilled wages, and labor shares do not change, and thereby, in this case, neither does income inequality. Next, we analyze the effects of medium-run shocks.

(ii) Capital increase:

We derive the effects of an increase in capital on both employment in skilled and unskilled labor as follows:

$$\hat{L}_1/\hat{K} = \frac{-1}{\Delta}\frac{bc}{1-b}(\sigma_1^{-1} - \sigma_2^{-1}) \quad (14a)$$

$$\hat{L}_2/\hat{K} = \frac{1}{\Delta}c\sigma_1^{-1} < 0 \quad (14b)$$

$$\hat{L}_1/\hat{K}-\hat{L}_2/\hat{K}=\frac{-1}{\Delta}\frac{c}{1-b}(\sigma_1^{-1}-b\sigma_2^{-1})=\hat{L}_2/\hat{\eta}-\hat{L}_1/\hat{\eta} \quad (14c)$$

The effects of the capital increase on wages, wage inequality, besides labor shares and income inequality are expressed by the following equation. These effects are all equal to those of the demand increase in absolute value.

$$\hat{w}_1/\hat{K}=-\hat{w}_1/\hat{\eta} \quad (15a)$$

$$\hat{w}_2/\hat{K}=-\hat{w}_2/\hat{\eta}>0 \quad (15b)$$

$$\hat{w}_1/\hat{K}-\hat{w}_2/\hat{K}=-\hat{w}_1/\hat{\eta}+\hat{w}_2/\hat{\eta} \quad (15c)$$

$$\hat{s}_{L_1}/\hat{K}=\hat{w}_1/\hat{K}+\hat{L}_1/\hat{K}=-\hat{s}_{L_1}/\hat{\eta} \quad (16a)$$

$$\hat{s}_{L_2}/\hat{K}=\hat{w}_2/\hat{K}+\hat{L}_2/\hat{K}=-\hat{s}_{L_2}/\hat{\eta} \quad (16b)$$

$$\hat{s}_{L_1}/\hat{K}-\hat{s}_{L_2}/\hat{K}=-\hat{s}_{L_1}/\hat{\eta}+\hat{s}_{L_2}/\hat{\eta} \quad (16c)$$

(iii) Skill-biased technical change:

We finally derive the effects of skill-biased technical change on employment in both skilled and unskilled labor, wages, wage inequality, labor shares, and income inequality as follows:

$$\hat{L}_1/\hat{A}=\frac{-1}{\Delta}\frac{b}{1-b}(a+c-c\sigma_1^{-1}-a\sigma_2^{-1}) \quad (17a)$$

$$\hat{L}_2/\hat{A}=\frac{1}{\Delta}a<0 \quad (17b)$$

$$\hat{L}_1/\hat{A}-\hat{L}_2/\hat{A}=\frac{-1}{\Delta}\frac{1}{1-b}\{a+bc-b(c\sigma_1^{-1}+a\sigma_2^{-1})\} \quad (17c)$$

$$\hat{w}_1/\hat{A}=\frac{-1}{\Delta}\frac{b}{1-b}\frac{\rho R}{w_1L_1}\left[c\{1-b(1-\frac{1}{\varepsilon})\}\sigma_1^{-1}+\frac{a}{\varepsilon}\sigma_2^{-1}-(1-b)\{c+(1-c)\frac{1}{\varepsilon}\}\right] \quad (18a)$$

$$\hat{w}_2/\hat{A}=\frac{-1}{\Delta}a\sigma_2^{-1}>0 \quad (18b)$$

$$\hat{w}_1/\hat{A}-\hat{w}_2/\hat{A}=\frac{-1}{\Delta}\frac{1}{1-b}\left[bc\{1-b(1-\frac{1}{\varepsilon})\}\frac{\rho R}{w_1L_1}\sigma_1^{-1}+a(\frac{b}{\varepsilon}\frac{\rho R}{w_1L_1}-1+b)\sigma_2^{-1}\right.$$
$$\left.-b(1-b)\{c+(1-c)\frac{1}{\varepsilon}\}\frac{\rho R}{w_1L_1}\right] \quad (18c)$$

$$\hat{s}_{L_1}/\hat{A}=\frac{-1}{\Delta}\frac{b}{1-b}\left[c[\{1-b(1-\frac{1}{\varepsilon})\}\frac{\rho R}{w_1L_1}-1]\sigma_1^{-1}+a(\frac{\rho R}{w_1L_1}\frac{1}{\varepsilon}-1)\sigma_2^{-1}+(1-b)[1-\{c+(1-c)\frac{1}{\varepsilon}\}\frac{\rho R}{w_1L_1}]\right] \quad (19a)$$

$$\hat{s}_{L_2} / \hat{A} = \frac{1}{\Delta} a \sigma_1^{-1} (1 - \sigma_2^{-1}) \tag{19b}$$

$$\hat{s}_{L_1} / \hat{A} - \hat{s}_{L_2} / \hat{A} = \frac{-1}{\Delta} \frac{1}{1-b} \Bigg[bc[\{1 - b(1 - \frac{1}{\varepsilon})\} \frac{\rho R}{w_1 L_1} - 1] \sigma_1^{-1} + a(\frac{b}{\varepsilon} \frac{\rho R}{w_1 L_1} - 1) \sigma_2^{-1}$$

$$+ (1-b)[a + b - b\{c + (1-c)\frac{1}{\varepsilon}\} \frac{\rho R}{w_1 L_1}] \Bigg] \tag{19c}$$

Summarizing these outcomes, we have the following proposition.

Proposition 2

In the framework of monopolistic competitive general equilibrium and efficient bargaining, with some empirically relevant capital-skill complementary production technology and the reservation wage of skilled labor being constant, the following statements hold.

(1) Contrary to the case of business cycle boom, the increase in capital intensity has a compressive effect on wage inequality but an unfavorable effect on income inequality. That is, in the case of the former, the increase in capital intensity decreases skilled wage but unskilled wage increases, thereby decreasing wage inequality. In the case of the latter, however, this increase in capital increases skilled labor share but decreases unskilled labor share, and thus increases income inequality. Although the increase in capital can increase skilled employment, it decreases unskilled employment and consequently increases unskilled unemployment.

(2) Although the mechanism differs, skill-biased technical change is likely to increase both wage and income inequality. In the case of the former, it increases skilled wage more than unskilled wage, thereby increasing wage inequality. However, in the case of the latter, it increases skilled labor share but decreases that of unskilled labor, and thereby increasing income inequality. However, this biased technical progress has the possibility of decreasing both skilled and unskilled labor, in particular increasing unskilled unemployment.

[Insert Figures 2a, 2b, 3a and 3b]

Figures 2a, 2b, 3a, and 3b show the proposition. We make two remarks. First, there is symmetry between the effects of increasing demand and those of increasing capital. This is because the

relationship between output and capital is only statically dependent on the production technology. Thus, the symmetry of these results may change in the dynamic process where capital accumulation occurs. Second, in the empirically relevant capital-skill complementarity, among the medium-run shocks, the skill-biased technical change tends to make unskilled labor more of a buffer variable with regards to wages and unemployment. This is due not only to the nature of biased technology that increases skilled wages, but also the asymmetric structure of production technology that allows unskilled labor to be a more flexible factor and the bargaining structure that stabilizes skilled wages and protects skilled workers. Therefore, the results change if we have another production technology and/or bargaining structure. For example, if we have a Cobb-Douglas technology, wages and employment in skilled labor, and labor shares in both sectors do not change. As shown in the next section, if some deregulation occurs in skilled labor, results can also change.

3.2 Case where the reservation wage is perfectly dependent on the unskilled wage (ν =1)

Finally, we investigate the case where the reservation wage in skilled labor is no longer constant but depends on the unskilled wage. This analysis explores the effect of deregulation on the skilled labor market. We find in some conditions, wages and employment in skilled labor are likely to synchronize with those in unskilled labor. In this case, we have the following general equilibrium:

$$(1-\frac{1}{\varepsilon})Af_1(AL_1, L_2, K) = g(w_2), \tag{7a}$$

$$w_1 = (1-\rho)g(w_2) + \rho(\eta - w_2 L_2)/L_1, \tag{7b}$$

$$(1-\frac{1}{\varepsilon})f_2(AL_1, L_2, K) = w_2, \tag{7c}$$

$$f(AL_1, L_2, K) = \eta. \tag{7d}$$

Total differentiation in (7a), (7c), and (7d) produces the following matrix:

$$\begin{bmatrix} -(c\sigma_1^{-1} + a\sigma_2^{-1})/(1-b) & \sigma_2^{-1} \\ a & b \end{bmatrix} \begin{bmatrix} \hat{L}_1 \\ \hat{L}_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 1 \end{bmatrix} \hat{\eta} + \begin{bmatrix} -c(\sigma_1^{-1} - \sigma_2^{-1})/(1-b) \\ -c \end{bmatrix} \hat{K}$$

$$+ \begin{bmatrix} (c\sigma_1^{-1} + a\sigma_2^{-1})/(1-b) - 1 \\ -a \end{bmatrix} \hat{A} \tag{20}$$

Combining the total differentiation in (7b) and the matrix outcomes, and by rearranging it, we have the effects of the three parameters on employment, wages and wage inequality, and labor shares. The analyses provide the outcomes as follows.

(i) Demand shock:

We derive the effects of increasing demand for goods on both employment in skilled and unskilled labor as follows:

$$\hat{L}_1 / \hat{\eta} = \frac{-1}{\Delta'}\sigma_2^{-1} > 0 \qquad (21a)$$

$$\hat{L}_2 / \hat{\eta} = \frac{-1}{\Delta'}\frac{1}{1-b}(c\sigma_1^{-1} + a\sigma_2^{-1}) > 0 \qquad (21b)$$

$$\hat{L}_2 / \hat{\eta} - \hat{L}_1 / \hat{\eta} = \frac{-1}{\Delta'}\frac{c}{1-b}(\sigma_1^{-1} - \sigma_2^{-1}) \qquad (21c)$$

where Δ' is the determinant of the matrix and its value is negative:

$$\Delta' = \frac{-1}{1-b}(bc\sigma_1^{-1} + a\sigma_2^{-1}) < 0. \qquad (22)$$

The effects on wages, wage inequality, labor shares and income inequality are as follows[14]:

$$\hat{w}_1 / \hat{\eta} = \frac{-1}{\Delta'}\frac{c}{1-b}\left[\frac{\rho R}{w_1 L_1}\frac{b}{\varepsilon}\sigma_1^{-1} - \{1-b(1-\frac{1}{\varepsilon})\}\frac{\rho R}{w_1 L_1}\sigma_2^{-1} - (1-b)(1-\frac{\rho R}{w_1 L_1})\sigma_1^{-1}\sigma_2^{-1}\right] \qquad (23a)$$

$$\hat{w}_2 / \hat{\eta} = \frac{1}{\Delta'}c\sigma_1^{-1}\sigma_2^{-1} < 0 \qquad (23b)$$

$$\hat{w}_1 / \hat{\eta} - \hat{w}_2 / \hat{\eta} = \frac{-1}{\Delta'}\frac{c}{1-b}\frac{\rho R}{w_1 L_1}\left[\frac{b}{\varepsilon}\sigma_1^{-1} - \{1-b(1-\frac{1}{\varepsilon})\}\sigma_2^{-1} + (1-b)\sigma_1^{-1}\sigma_2^{-1}\right] \qquad (23c)$$

$$\hat{s}_{L_1} / \hat{\eta} = \frac{-1}{\Delta'}\frac{c}{1-b}\left[b(\frac{1}{\varepsilon}\frac{\rho R}{w_1 L_1} - 1)\sigma_1^{-1} + [1 - \{1-b(1-\frac{1}{\varepsilon})\}\frac{\rho R}{w_1 L_1}]\sigma_2^{-1} - (1-b)(1-\frac{\rho R}{w_1 L_1})\sigma_1^{-1}\sigma_2^{-1}\right] \qquad (24a)$$

$$\hat{s}_{L_2} / \hat{\eta} = \frac{-1}{\Delta'}c\sigma_1^{-1}(1-\sigma_2^{-1}) \qquad (24b)$$

$$\hat{s}_{L_1} / \hat{\eta} - \hat{s}_{L_2} / \hat{\eta} = \frac{-1}{\Delta'}\frac{c}{1-b}\left[(\frac{\rho R}{w_1 L_1}\frac{b}{\varepsilon} - 1)\sigma_1^{-1} + [1 - \frac{\rho R}{w_1 L_1}\{1-b(1-\frac{1}{\varepsilon})\}]\sigma_2^{-1} + \frac{\rho R}{w_1 L_1}(1-b)\sigma_1^{-1}\sigma_2^{-1}\right] \qquad (24c)$$

---

[14] From $1 - \frac{\rho R}{w_1 L_1} = \frac{\rho}{(1-\rho)a(1-\frac{1}{\varepsilon}) + \rho\{1-b(1-\frac{1}{\varepsilon})\}}(a+b)(1-\frac{1}{\varepsilon})(\frac{a}{a+b} - \rho)$,

we have $1 - \frac{\rho R}{w_1 L_1} > 0$ if $\rho < \frac{a}{a+b}$.

(ii) Capital increase:

The effects of the increase in capital on both employment in skilled and unskilled labor are as follows:

$$\hat{L}_1 / \hat{K} = \frac{-1}{\Delta'} \frac{c}{1-b} (b\sigma_1^{-1} - \sigma_2^{-1}) \quad (25a)$$

$$\hat{L}_2 / \hat{K} = \frac{1}{\Delta'} c\sigma_1^{-1} < 0 \quad (25b)$$

$$\hat{L}_1 / \hat{K} - \hat{L}_2 / \hat{K} = \frac{-1}{\Delta'} \frac{c}{1-b} (\sigma_1^{-1} - \sigma_2^{-1}) = \hat{L}_2 / \hat{\eta} - \hat{L}_1 / \hat{\eta} \quad (25c)$$

Similar to the previous case of constant reservation wage, the effects of this capital increase on wages, wage inequality, labor shares, and also income inequality, which are equal to those of the demand increase in absolute value, are provided as follows:

$$\hat{w}_1 / \hat{K} = -\hat{w}_1 / \hat{\eta} \quad (26a)$$

$$\hat{w}_2 / \hat{K} = -\hat{w}_2 / \hat{\eta} > 0 \quad (26b)$$

$$\hat{w}_1 / \hat{K} - \hat{w}_2 / \hat{K} = -\hat{w}_1 / \hat{\eta} + \hat{w}_2 / \hat{\eta} \quad (26c)$$

$$\hat{s}_{L_1} / \hat{K} = -\hat{s}_{L_1} / \hat{\eta} \quad (27a)$$

$$\hat{s}_{L_2} / \hat{K} = -\hat{s}_{L_2} / \hat{\eta} \quad (27b)$$

$$\hat{s}_{L_1} / \hat{K} - \hat{s}_{L_2} / \hat{K} = -\hat{s}_{L_1} / \hat{\eta} + \hat{s}_{L_2} / \hat{\eta} \quad (27c)$$

(iii) Skill-biased technical change:

We derive the effects of the skill-biased technical change on these variables as a whole as follows:

$$\hat{L}_1 / \hat{A} = \frac{-1}{\Delta'} \frac{1}{1-b} \{b(1-b) - bc\sigma_1^{-1} - a\sigma_2^{-1}\} \quad (28a)$$

$$\hat{L}_2 / \hat{A} = \frac{1}{\Delta'} a < 0 \quad (28b)$$

$$\hat{L}_1 / \hat{A} - \hat{L}_2 / \hat{A} = \frac{-1}{\Delta'} \frac{1}{1-b} (a + bc - bc\sigma_1^{-1} - a\sigma_2^{-1}) \quad (28c)$$

$$\hat{w}_1 / \hat{A} = \frac{-1}{\Delta'} \frac{1}{1-b} \left[bc\{1 - b(1 - \frac{1}{\varepsilon})\} \frac{\rho R}{w_1 L_1} \sigma_1^{-1} + a(1 - b + \frac{b}{\varepsilon} \frac{\rho R}{w_1 L_1}) \sigma_2^{-1} \right.$$

$$\left. - b(1-b)\{c + (1-c)\frac{1}{\varepsilon}\} \frac{\rho R}{w_1 L_1} \right] \quad (29a)$$

$$\hat{w}_2 / \hat{A} = \frac{-1}{\Delta'} a\sigma_2^{-1} > 0 \tag{29b}$$

$$\hat{w}_1 / \hat{A} - \hat{w}_2 / \hat{A} = \frac{-1}{\Delta'} \frac{b}{1-b} \frac{\rho R}{w_1 L_1} \left[c\{1-b(1-\frac{1}{\varepsilon})\}\sigma_1^{-1} + \frac{a}{\varepsilon}\sigma_2^{-1} - (1-b)\{c+(1-c)\frac{1}{\varepsilon}\} \right] \tag{29c}$$

$$\hat{s}_{L_1} / \hat{A} = \frac{-1}{\Delta'} \frac{b}{1-b} \left[c[\{1-b(1-\frac{1}{\varepsilon})\}\frac{\rho R}{w_1 L_1} - 1]\sigma_1^{-1} + a(\frac{\rho R}{w_1 L_1}\frac{1}{\varepsilon} - 1)\sigma_2^{-1} + (1-b)[1-\{c+(1-c)\frac{1}{\varepsilon}\}\frac{\rho R}{w_1 L_1}] \right]$$

(30a)

$$\hat{s}_{L_2} / \hat{A} = \frac{1}{\Delta'} a\sigma_1^{-1}(1-\sigma_2^{-1}) \tag{30b}$$

$$\hat{s}_{L_1} / \hat{A} - \hat{s}_{L_2} / \hat{A} = \frac{-1}{\Delta'} \frac{b}{1-b} \left[bc[\{1-b(1-\frac{1}{\varepsilon})\}\frac{\rho R}{w_1 L_1} - 1]\sigma_1^{-1} + a(\frac{b}{\varepsilon}\frac{\rho R}{w_1 L_1} - 1)\sigma_2^{-1} \right.$$

$$\left. + (1-b)[a+b-b\{c+(1-c)\frac{1}{\varepsilon}\}\frac{\rho R}{w_1 L_1}] \right] \tag{30c}$$

Summarizing these outcomes yields the following proposition.

Proposition 3

In the framework of monopolistic competitive general equilibrium and efficient bargaining, with some empirically relevant capital-skill complementary production technology and the reservation wage of skilled labor being highly sensitive to the secondary wage, the following statements hold.

The movements of wages and employment in the skilled labor are likely to synchronize with the movements of those in unskilled labor. Although the consequences of the three shocks on wage inequality and income inequality almost hold, the consequences of such shocks on wages and employment in skilled labor differ from those in the case of a constant reservation wage. Namely:

(1) In the business cycle boom, although the mechanism differs, the consequences that wage inequality can procyclically increase, income inequality can countercyclically decrease and employment of unskilled labor increases more almost hold. However, when the bargaining power of skilled labor is relatively low, the movement of skilled wage can synchronize with that of unskilled wage. Thus, both wages can countercyclically fluctuate.

(2) Although the mechanism differs, the consequences that the increase in capital intensity has a compressive effect on wage inequality, but an unfavorable effect on income inequality almost hold. However, when the bargaining power of skilled labor is relatively low, the movements of

wages and employment in skilled labor tend to synchronize with those in the unskilled labor. Thus, the increase in capital can increase both wages and unemployment in both skilled and unskilled labor. However, the consequence that the capital increase can produce more unskilled unemployment is likely to still hold.

(3) Although the mechanism differs, the consequences that skill-biased technical change is likely to lead to increase in both wage and income inequality almost hold. However, the movements of wages and employment in skilled labor tend to synchronize with the movements of those in unskilled labor. Thus, the skill-biased technical change can increase both wages and unemployment in both skilled and unskilled labor. However, the consequence that this technical change can produce more unskilled unemployment is likely to still hold.

Table 1. Effects of shocks on wages, wage inequality, employment and labor shares

	w_1	w_2	w_1 / w_2	L_1	L_2	L_1 / L_2	s_{L1}	s_{L_2}	s_{L1} / s_{L2}
Constant reservation wage (v = 0)									
η	+	−	+	+	+	−	−	+	−
K	−	+	−	+	−	−	+	−	+
A	?	+	?	?	−	?	?	−	?
Perfectly flexible reservation wage (v = 1)									
η	?	−	+	?	+	−	−	+	−
K	?	+	−	?	−	−	+	−	+
A	?	+	?	?	−	?	?	−	?

Note: empirically relevant capital-skill complementarity case $\sigma_2 > 1 > \sigma_1$

[Insert Figures 4a, 4b, 5a, 5b, 6a, and 6b]

Table 1 summarizes the results. Figures 4a, 4b, 5a, 5b, 6a, and 6b show the proposition. We have two remarks. First, the proposition statements can apply if the relevant capital-skill complementarity production technologies do not have a structure that is too extreme. Specifically, if the two elasticities of substitution are near unity, and moreover the bargaining power of skilled

labor is low. It implies that these conditions induce the movements of wages and employment in skilled labor in order to synchronize with the movements of those in unskilled labor. Indeed, in the case of Cobb-Douglas technology, wages and employment in skilled and unskilled labor are perfectly synchronized, and thereby both wage inequality and income inequality do not occur. However, if there is larger substitutability between capital and unskilled labor and larger complementarity between capital and skilled labor, then the results are almost the same as those in the case of constant reservation. It implies that these cases of extreme production technology become technological barriers against economic shocks for skilled labor except in the case of capital increase.

Second, even in the case of reservation wage flexibility, the deregulation of the skilled labor market can destabilize wages and employment in that market. In other words, the rigidity of the reservation wage in skilled labor can play an anchoring role for the stabilization of wages and employment in the skilled labor market. However, even if deregulation prevails, our results show that income inequality can occur even in the medium-run.

In sum, these consequences confirm the conjecture made by Autor (2014) that technological progress, deunionization, and globalization can produce wage inequality. Furthermore, our results add that the ongoing new technology and labor market deregulation can create inequalities and increasing unemployment, particularly in unskilled labor. Therefore, our analysis may suggest multi-dimensional policies for new technology and market deregulation.

4. Concluding Remarks

Introducing capital-skill complementarity production technology into the framework that reflects the monopolistic competitive general equilibrium and efficient bargaining model, we explored the effects of medium-run shocks on inequalities prevailing in OECD countries and the implications of labor market deregulation. In particular, in some empirically relevant capita-skill complementarity, when there is labor market deregulation, such as the reservation wage in skilled labor depends on the unskilled wage, the movement of wages and employment in skilled labor can synchronize with the movement of these in unskilled labor. In this case, medium-shocks such as capital increase and skill-biased technical progress can create inequalities as well as unemployment in both labors, especially in unskilled labor. Hence, ongoing new technology, deunionization, and globalization can create inequalities and these factors also increase unemployment, particularly of unskilled labor.

However, to analyze the effect on wage inequality and unemployment in the dynamic process, the approaches of capital accumulation and asset dynamics are needed. These issues are to be dealt with in future research.

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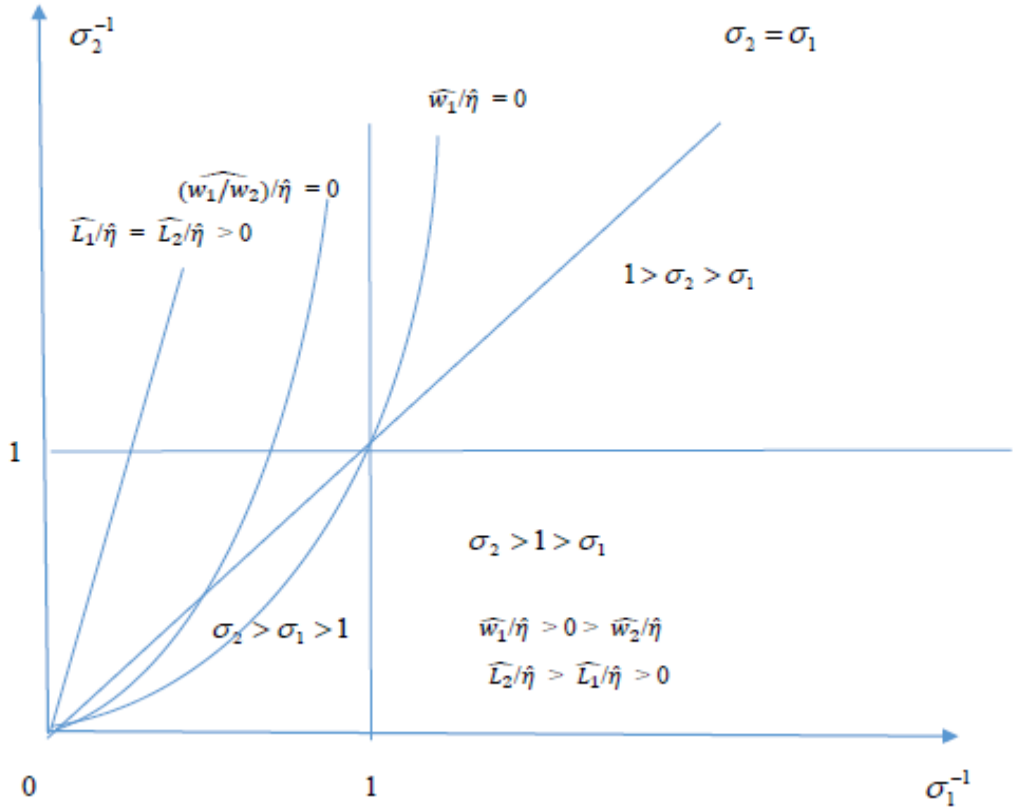

Figure 1a Effect of demand shock in the case of constant reservation wage ($v = 0$)

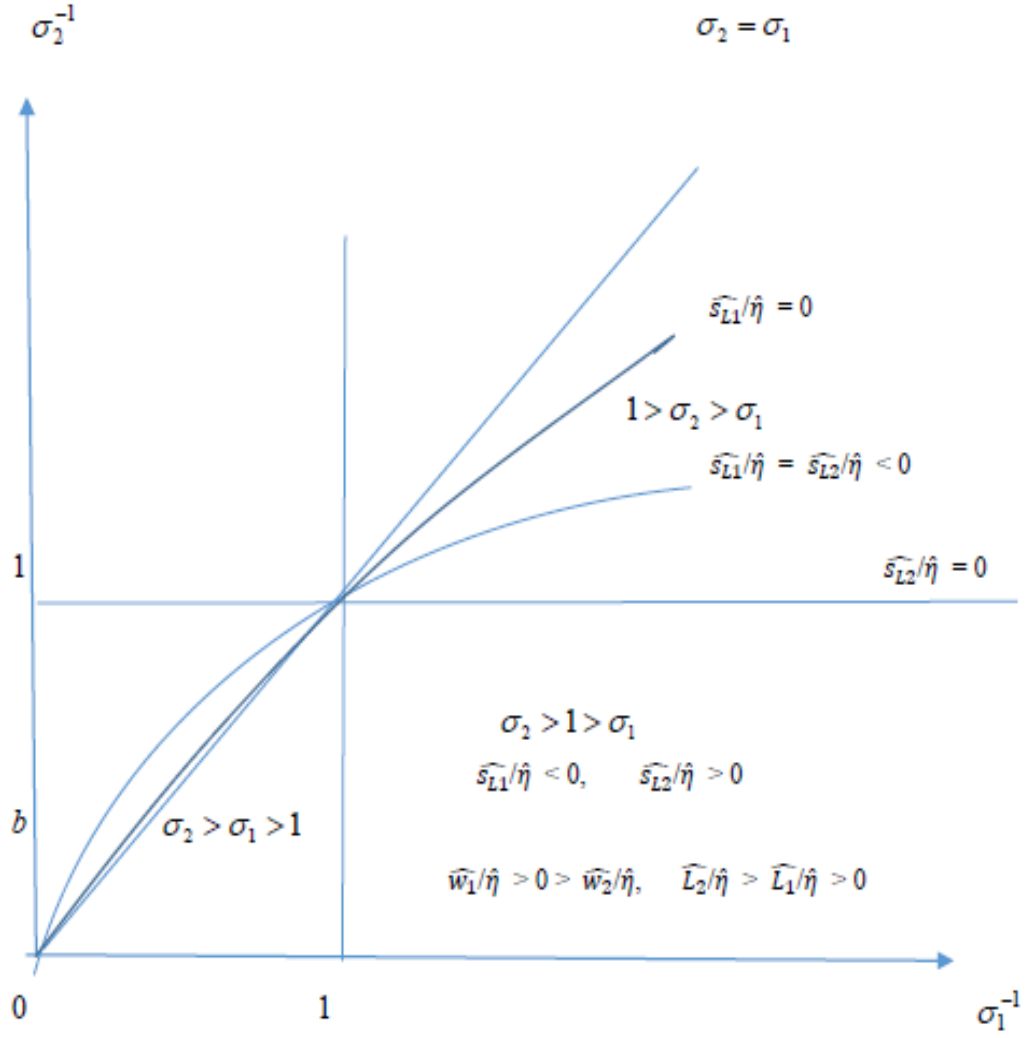

Figure 1b Effect of demand shock in the case of constant reservation wage ($v = 0$)

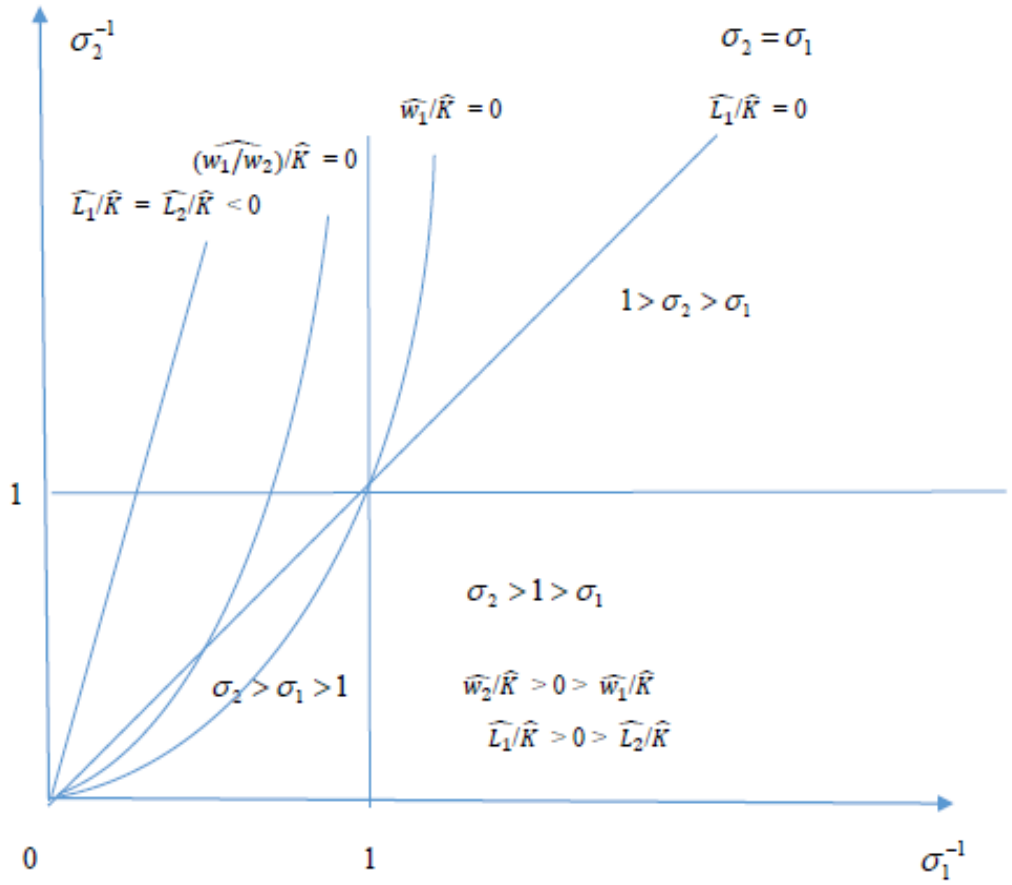

Figure 2a Effect of increasing capital in the case of constant reservation wage ($v = 0$)

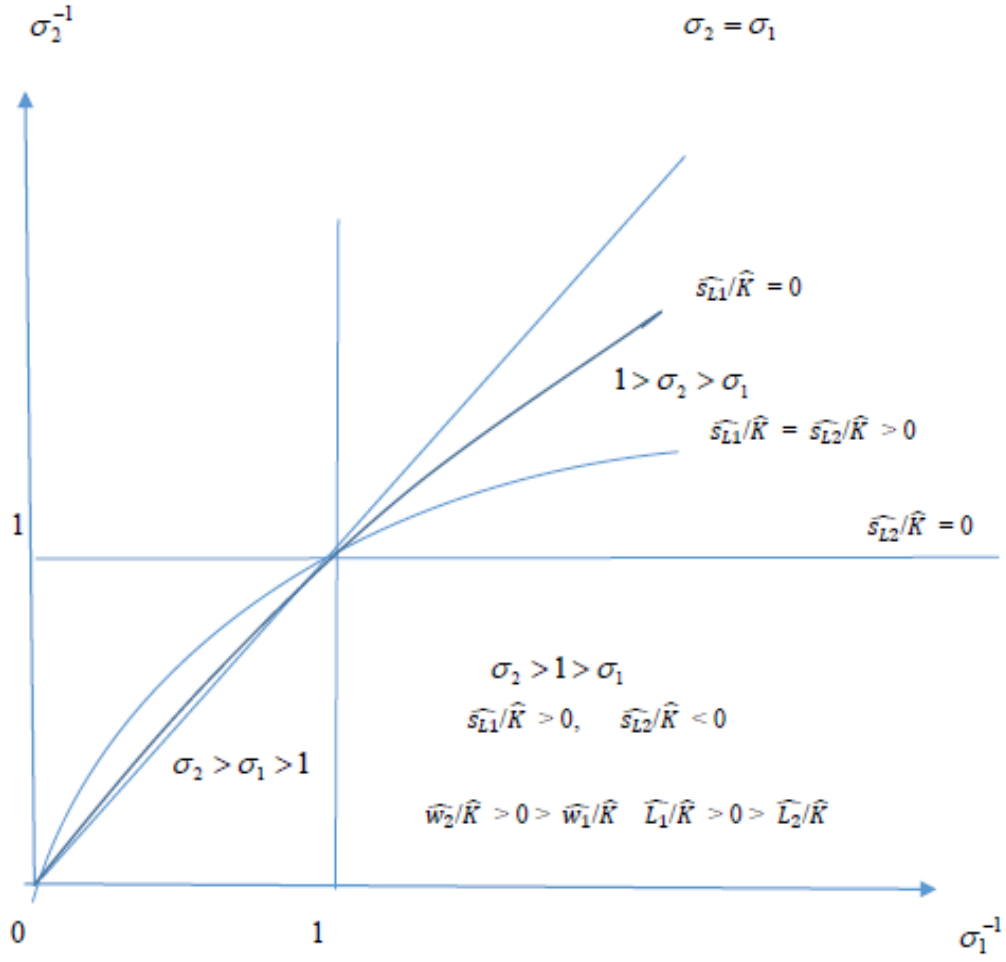

Figure 2b Effect of increasing capital in the case of constant reservation wage (v = 0)

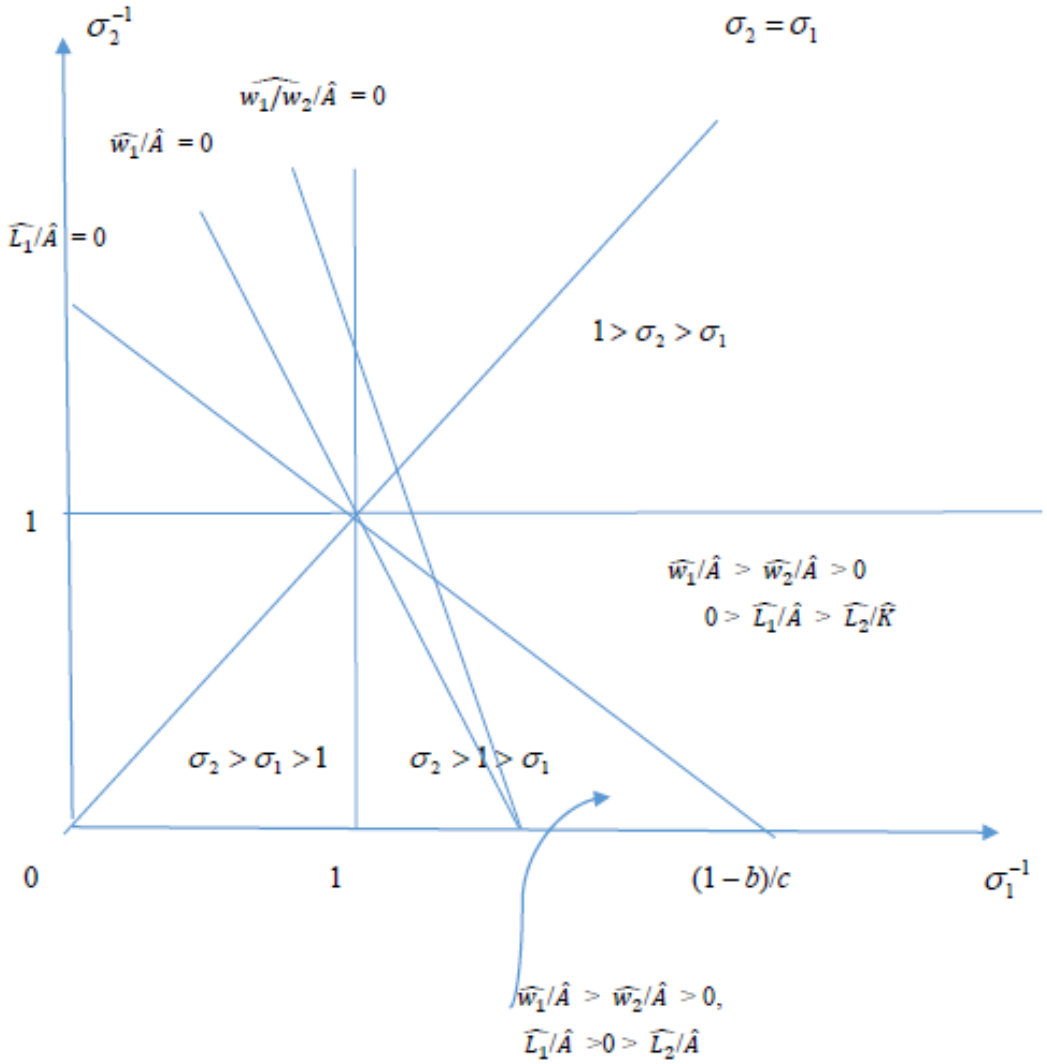

Figure 3a Effect of skill-biased technical change in the case of constant reservation wage (v = 0)

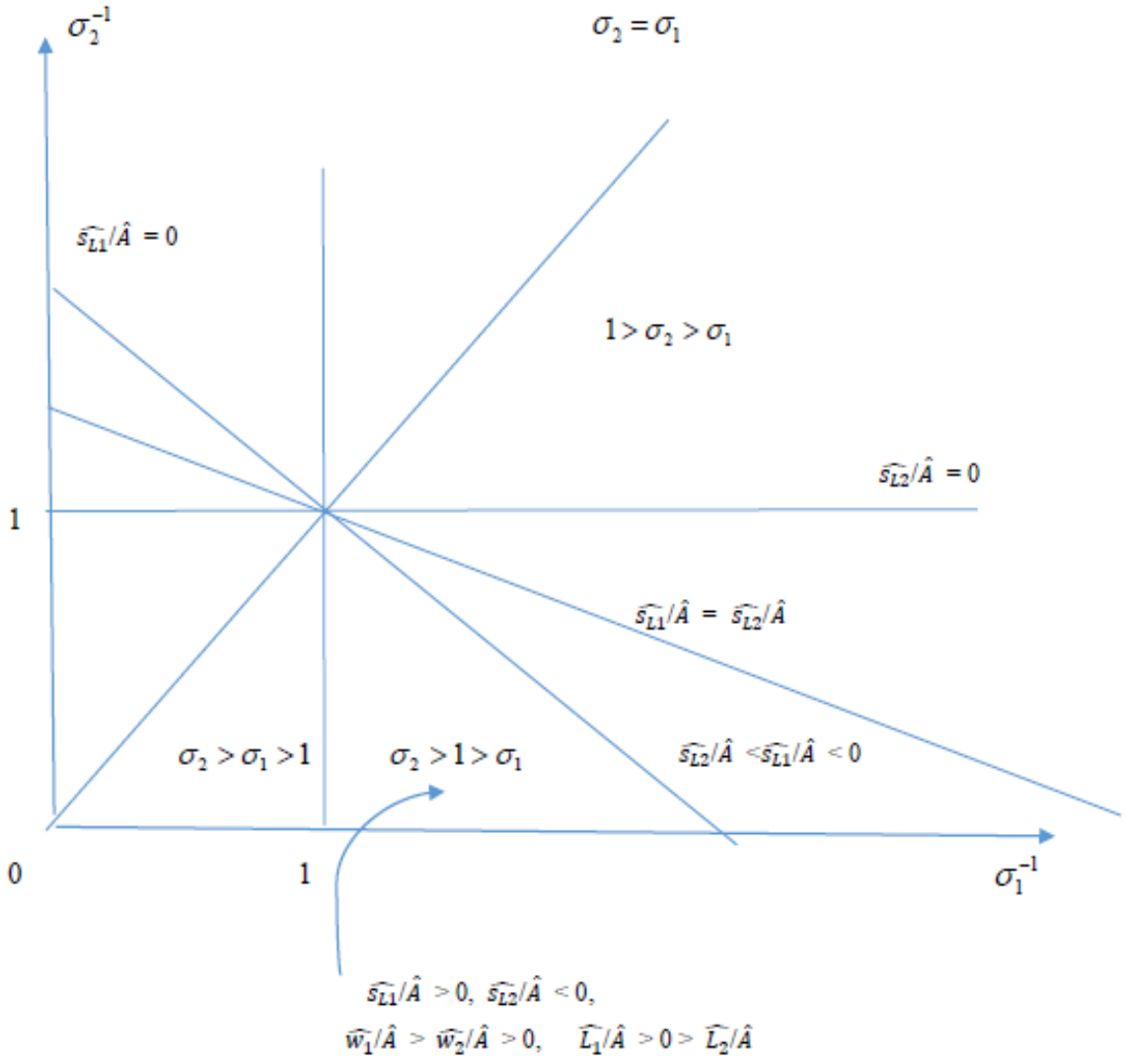

Figure 3b Effect of skill-biased technical change in the case of constant reservation wage (v = 0)

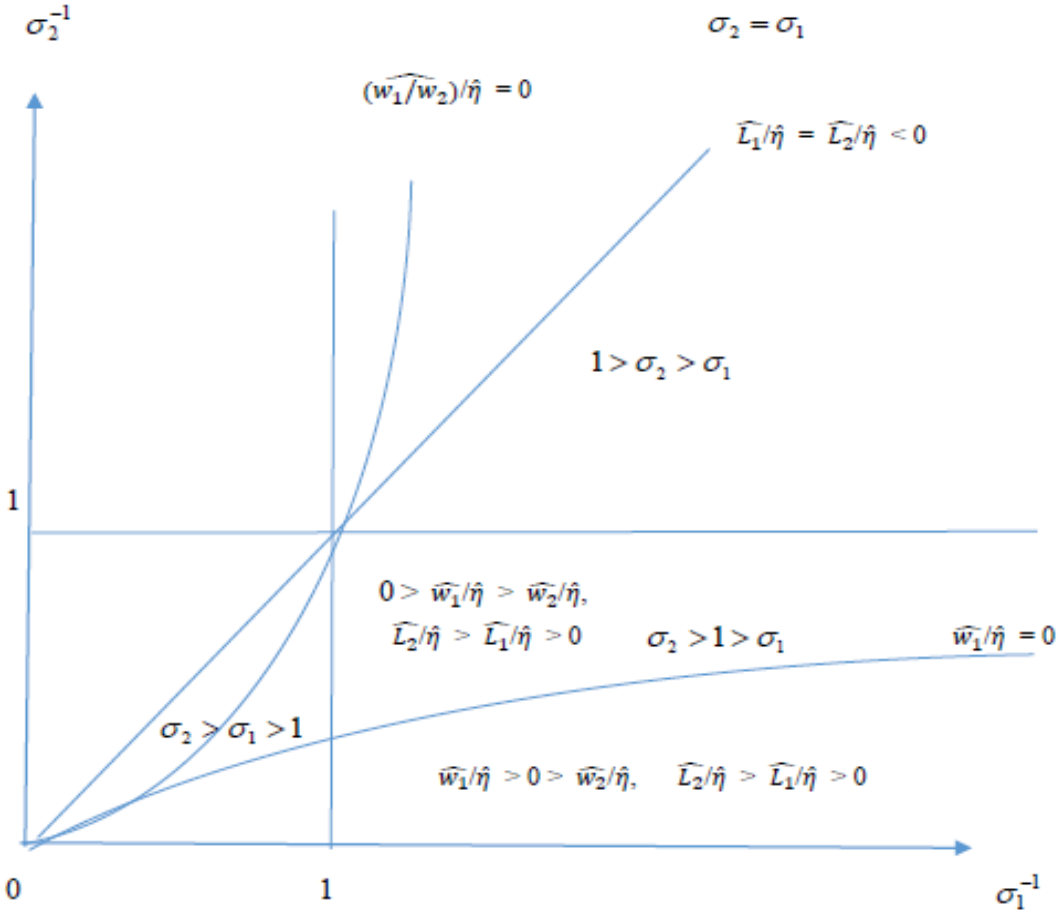

Figure 4a Effect of demand shock in the case of perfectly flexible reservation wage ($v = 1$)
Case $\rho < a/(a + b)$

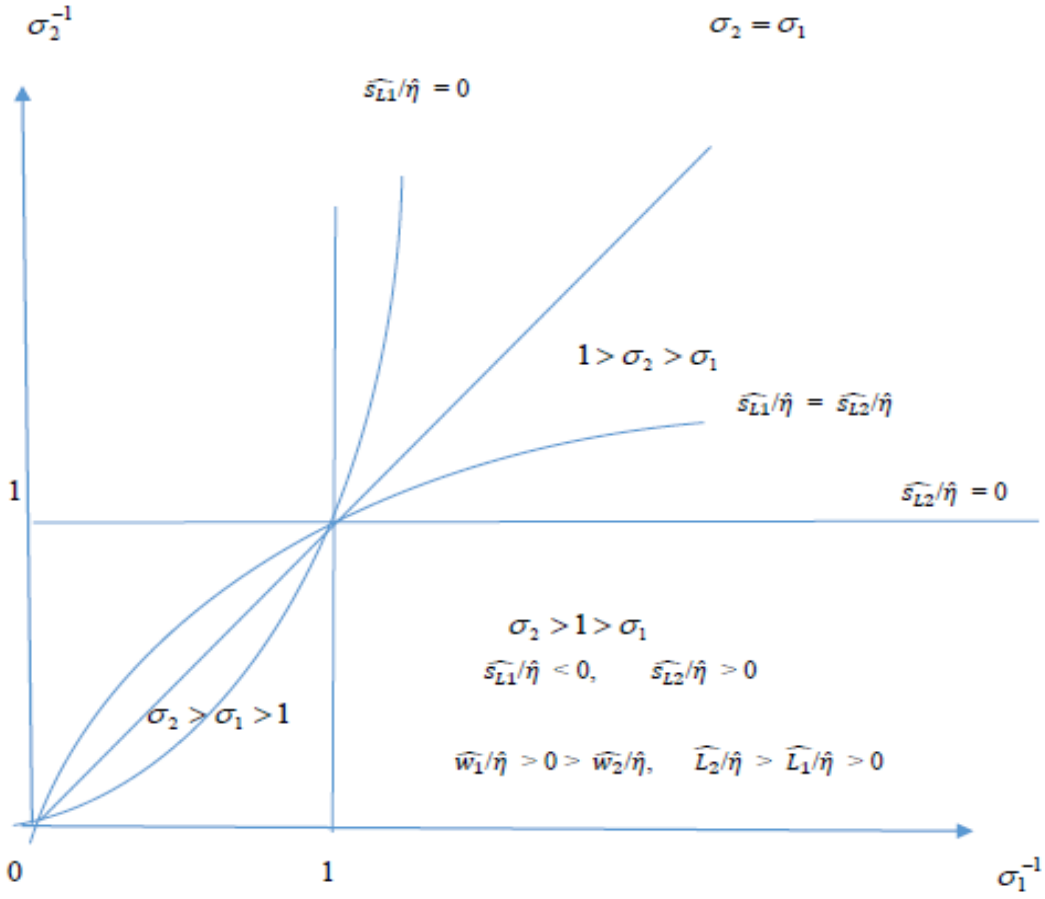

Figure 4b Effect of demand shock in the case of perfectly flexible reservation wage (v = 1)

Case $\rho < a/(a + b)$

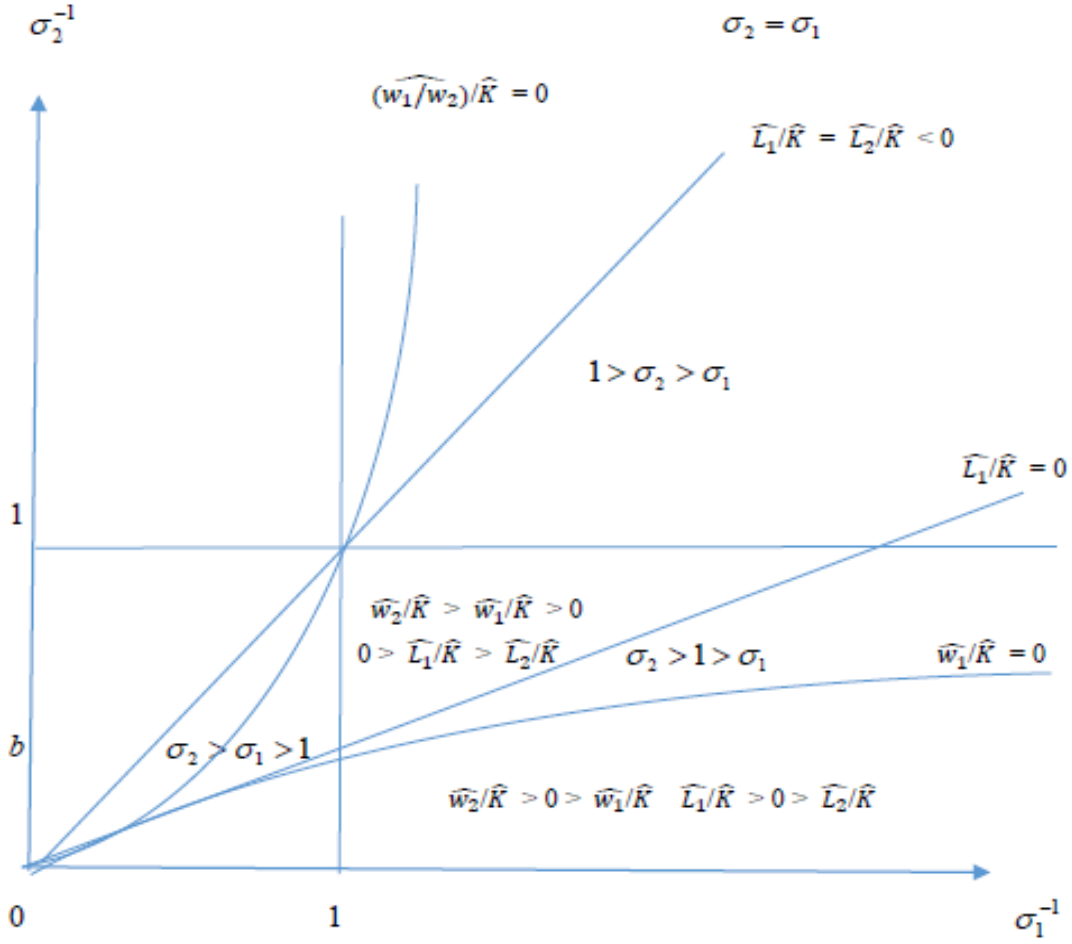

Figure 5a Effect of increasing capital in the case of perfectly flexible reservation wage ($v = 1$)
Case $\rho < a/(a + b)$.

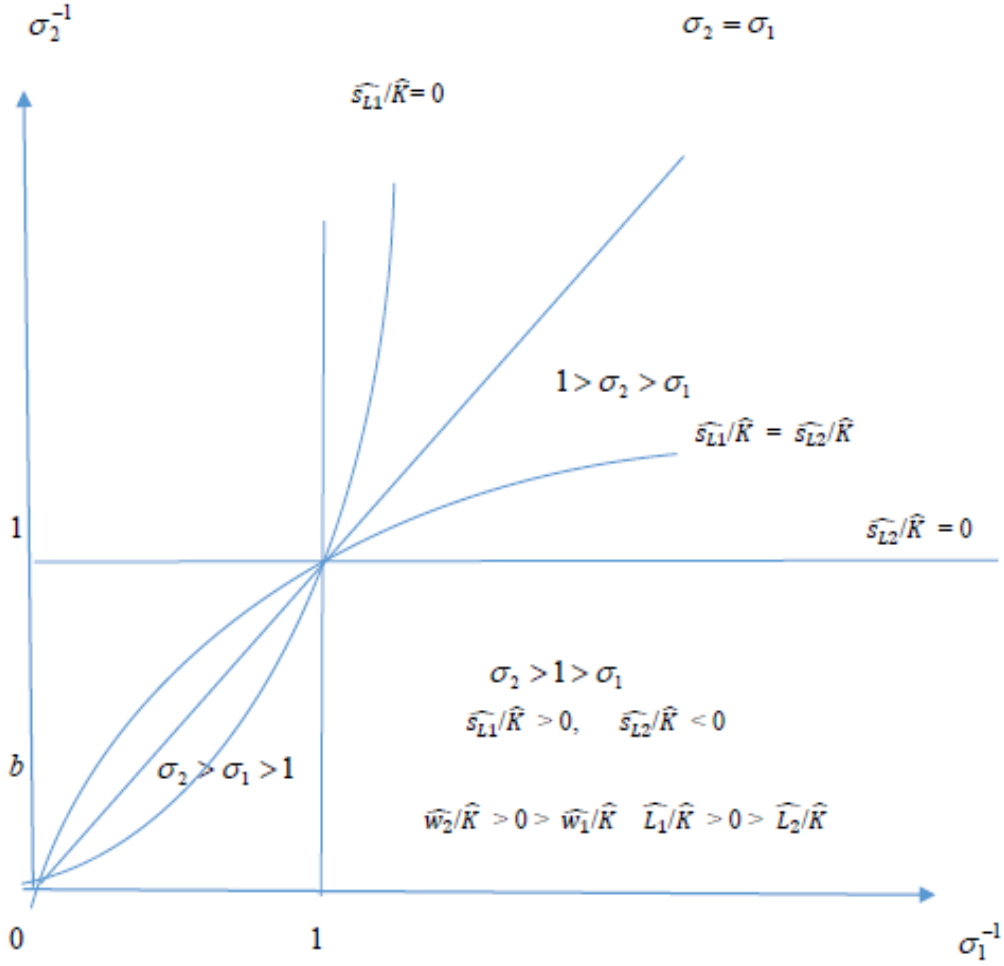

Figure 5b Effect of increasing capital in the case of perfectly flexible reservation wage ($v = 1$)

Case $\rho < a/(a + b)$

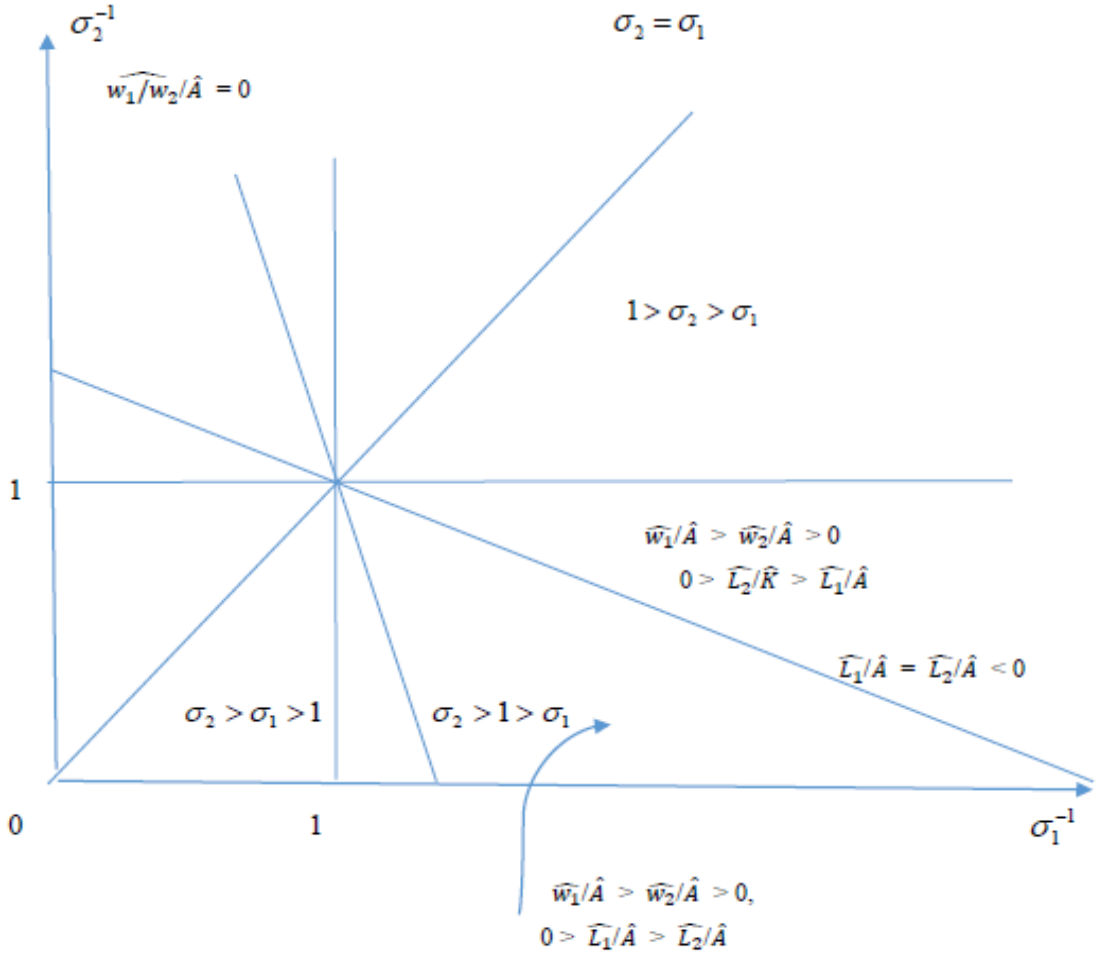

Figure 6a Effect of skill-biased technical change in the case of perfectly flexible reservation wage ($\nu = 1$)

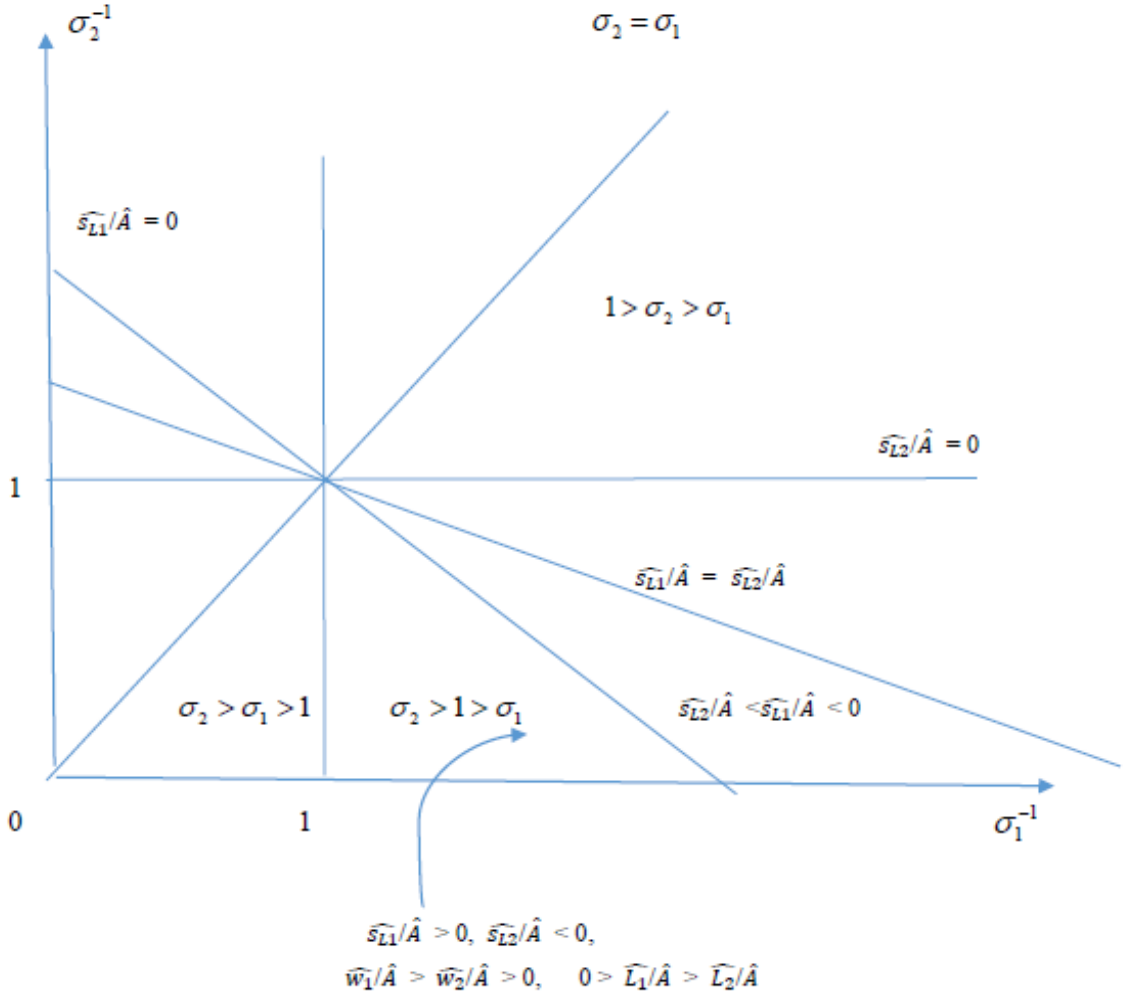

Figure 6b Effect of skill-biased technical change in the case of perfectly flexible reservation wage ($v = 1$)