Are the Unskilled Hurt by Biased Technological Change? 
Some Qualifications from a General Equilibrium Perspective*

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Abstract

Our two-sector model with wage setting on imperfect labor markets reveals that the conventional wisdom with regard to the effects of biased technological change needs some qualifications. Based on a general equilibrium framework we show that the unskilled can indirectly profit from biased technological change via two channels: the increase in aggregate demand and the reduction in wage pressure due to a decline in the aggregate price level. Harmful employment consequences for the unskilled are only obtained under a solidaristic wage policy designed to let the unskilled participate in the productivity gains of the skilled. Furthermore, our results suggest that a decline in real wages for low-skilled workers cannot be explained by the hypothesis of skill-biased technological change alone.

Keywords: Biased technological change, skill-specific unemployment, skill premium

JEL classification: E24, J51, J64

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1 Introduction

There is an ongoing debate on the causes of the unfavorable labor market performance of low-skilled workers in industrialized countries (e.g. Krugman 1994, Gregg, Manning 1997, Berman et al. 1998). In the literature it is often taken as granted that the unskilled are hurt by biased technological change per se. The argument is supported by partial analysis, which only considers the direct effect of biased technological change on the labor demand curves (e.g. Layard et al. 1991, Nickell, Bell 1995). Our paper investigates whether the assertion holds if general equilibrium effects in a two-sector model with wage setting on imperfect labor markets are taken into account.

2 A two-sector model with biased technological change

Consider a closed economy that consists of two sectors each operating under constant returns to scale. In order to simplify the analysis, we neglect factor substitution within sectors. In our model the substitution of factors is implicitly brought about by changes in the relative demand for goods. The first sector \((L)\) employs low-skilled workers, while the second \((H)\) needs highly-skilled labor only. The efficiency of low-skilled and high-skilled labor is described by the variables \(A_L\) and \(A_H\), respectively. Under these assumptions the production functions are \(Y_i = A_i N_i\), where \(Y_i\) and \(N_i\) denote output and employment in sector \(i = \{L, H\}\), respectively. If written in relative changes, one gets
\[
\hat{Y}_i = \hat{A}_i + \hat{N}_i, \quad i = \{L, H\},
\]
where a hat over a variable denotes relative changes. To keep things as simple as possible, perfect competition is assumed on the goods markets. Taking the price of \(L\)-sector goods as numéraire, the following relation between relative changes of wages and prices must hold in equilibrium
\[
\hat{W}_L = \hat{A}_L \quad \text{and} \quad \hat{W}_H = \hat{P}_H + \hat{A}_H, \quad \hat{A}_i \geq 0.
\]
In this equation \(W_L\) and \(W_H\) denote wages for the respective skill group and \(P_H\) the relative price for \(H\)-sector goods. On the skill-specific labor markets, wages are determined by
wage bargains between firms and labor unions. It is well-known from the literature that bargaining models lead to a wage equation with consumers’ real wages being a negative function of the unemployment rate and a positive function of “wage-push variables” as, for instance, technological progress and the generosity of the unemployment compensation system (see, e.g., Layard et al. 1991 and Manning 1993, 1995). Neglecting taxes and denoting the aggregate price level by $P$, we write the wage equations as

$$\frac{W_i}{P} = a_i f_i(u_i), \quad \frac{\partial f_i(u_i)}{\partial u_i} < 0, \quad i = \{L, H\},$$  \hspace{1cm} (3)$$

where $a_i$ describes the group-specific effect of technological progress on wage setting and arguments other than the unemployment rate $u_i$ in the functions $f_i$ have been omitted. If eq. (3) is written in relative changes, one obtains

$$\hat{W}_i - \hat{P} = \hat{a}_i - \eta_i \hat{u}_i, \quad \eta_i = \left| \frac{\partial f_i(u_i)}{\partial u_i} \frac{u_i}{f_i(u_i)} \right|, \quad i = \{L, H\},$$ \hspace{1cm} (4)$$

where $\eta_i$ denotes the sector-specific elasticity of the wage-setting function with respect to unemployment (in absolute values). It is always possible to express employment in terms of unemployment, since $N_i = (1 - u_i) M_i$, where $M_i$ denotes the exogenously given labor force, $i = \{L, H\}$. If written in relative changes, one gets

$$\hat{N}_i = -\gamma_i \hat{u}_i, \quad \text{where} \quad \gamma_i = \frac{u_i}{1 - u_i}, \quad i = \{L, H\}.$$ \hspace{1cm} (5)$$

Note that for plausible values for the initial unemployment rate (i.e. unemployment rates of less than 50 percent) it holds that $\gamma_i < 1$. For modeling consumer’s choice we use the CES-utility function

$$U = \left[ \alpha C_L^{-\rho} + (1 - \alpha) C_H^{-\rho} \right]^{-1/\rho},$$ \hspace{1cm} (6)$$

where $C_L$ and $C_S$ denote consumption of goods from the $L$ and $H$ sector, respectively. Utility of a representative household is maximized under the budget constraint $C_L + \hat{P} C_H = \hat{I}$, where $\hat{I}$ stands for household income (in terms of the numéraire). In general equilibrium it must hold that $\hat{I} = Y_L + \hat{P} Y_H$. Utility maximization yields the following relation for the relative demand of goods:

$$\frac{C_L}{C_H} = \left( \frac{\alpha}{1 - \alpha} \right)^\sigma \hat{P}^{\sigma},$$ \hspace{1cm} (7)$$

2
where $\alpha$ denotes a preference parameter for $L$-sector goods and $\sigma := 1/(1+\rho)$ the elasticity of substitution. In general equilibrium demand equals supply, hence $C_i = Y_i$, $i = \{L, H\}$. Taking the equilibrium condition into account and writing eq. (7) in relative changes leads to

$$\bar{Y}_L - \bar{Y}_H = \sigma \bar{P}_H.$$

The aggregate price level $P$ corresponding to the CES-utility function (6) is a positive function of sector $H$ prices

$$P = \{\alpha^\sigma + (1 - \alpha)^\sigma P_H^{1-\sigma}\}^{1/(1-\sigma)},$$

or, written in relative changes

$$\bar{P} = \beta \bar{P}_H, \quad \text{with } \beta \equiv (1 - \alpha)^\sigma \left(\frac{P_H}{P}\right)^{1-\sigma} = \left[1 + \left(\frac{\alpha}{1-\alpha}\right)^\sigma P_H^{\sigma-1}\right]^{-1}. $$

From the definition of $\beta$ follows that $0 < \beta < 1$. Note that $\beta$ is the lower the higher the preference parameter $\alpha$ for $L$-sector goods. If $\sigma > 1$ ($\sigma < 1$) a higher relative price $P_H$ in the initial equilibrium implies a lower (higher) parameter $\beta$.

The complete model is now given by the equations (1), (2), (4), (5), (8) and (10) for the endogenous variables $\bar{P}$, $\bar{P}_H$, $\bar{Y}_i$, $\bar{W}_i$, $\bar{N}_i$, $\bar{u}_i$, $i = \{L, H\}$. The variables $\hat{A}_L$ and $\hat{A}_H$ are exogenous.

3 The consequences of biased technological change

Biased technological change implies that $\hat{A}_H > \hat{A}_L$. Assuming $\hat{A}_L = 0$ simplifies the resulting expressions without changing the qualitative results. Equating eqs. (2) and (4) and eliminating $\bar{P}$ by eq. (10) then leads to

$$\bar{a}_L - \eta_L\bar{u}_L = -\beta \bar{P}_H \quad \text{and} \quad \bar{a}_H - \eta_H\bar{u}_H = \hat{A}_H + (1 - \beta) \bar{P}_H.$$

Taking account of eqs. (1) and (5) in eq. (8) and solving the resulting expression for $\bar{P}_H$, it follows that

$$\bar{P}_H = \sigma^{-1} (\gamma_H \bar{u}_H - \gamma_L \bar{u}_L - \hat{A}_H).$$
By inserting eq. (12) in eq. (11) one arrives at a two-equation system for the two endogenous variables \( \tilde{u}_L \) and \( \tilde{u}_H \), which can be written as

\[
\begin{pmatrix}
\tilde{u}_L \\
\tilde{u}_H
\end{pmatrix} = J^{-1} \begin{pmatrix}
\sigma \tilde{a}_L - \beta \tilde{A}_H \\
\sigma \tilde{a}_H - (\sigma - (1 - \beta)) \tilde{A}_H
\end{pmatrix},
\]  

where the matrix \( J \) is defined as

\[
J \equiv \begin{pmatrix}
\eta_L \sigma + \beta \gamma_L & -\beta \gamma_H \\
-\gamma_L (1 - \beta) & \eta_H \sigma + \gamma_H (1 - \beta)
\end{pmatrix}. \tag{14}
\]

Since \( 0 < \beta < 1 \), it unambiguously follows that

\[
|J| = \sigma [\sigma \eta_L \eta_H + \gamma_H (1 - \beta) \eta_L + \gamma_L \beta \eta_H] > 0. \tag{15}
\]

Before deriving the comparative-static results note that several effects are caused by sector-specific productivity growth. First, relative prices will change and will affect the relative demand for goods. Second, real income in the economy will increase generating a higher demand for products of both sectors. Third, for a given level of demand, productivity growth leads to labor saving. Fourth, the wage claims in terms of producers’ real wages will change in both sectors because wage-setters are oriented towards the real wage in terms of the overall price index. Fifth, productivity growth may exert a direct influence on wage pressure.

**Variant I: Passive labor unions**

For the wage-pressure variables \( \tilde{a}_i \), different assumptions are possible. In a first variant of the model we assume that efficiency gains in the \( H \)-sector do not affect the wage-setting functions in neither sector, i.e. \( \tilde{a}_L = \tilde{a}_H = 0 \). Note that this assumption does not require the level or change of real wages to be equal across skill groups. We start our analysis with the effect of skill-biased technological change on unemployment of the unskilled. Applying Cramer’s rule to eq. (13) reveals that unemployment of the unskilled unambiguously falls:

\[
\tilde{u}_L = -\frac{\beta (\eta_H + \gamma_H)}{\sigma \eta_L \eta_H + \gamma_H (1 - \beta) \eta_L + \gamma_L \beta \eta_H} \tilde{A}_H < 0. \tag{16}
\]
To understand the mechanisms of the model, first consider the development of the price variables. With \( \hat{a}_L = 0 \) and \( \hat{u}_L < 0 \) it is obvious from eq. (11) that the relative price of skill-intensive products \( P_H \) falls. From eq. (10) it then follows that the aggregate price level is also declining, but by less than \( P_H \). It becomes evident that conflicting forces are at work. On the one hand, changes in relative prices are unfavorable for the relative demand of goods produced with low-skilled labor (see eq. (8)). On the other hand, for a given level of unemployment wage pressure in terms of the real wage relevant to firms in the \( L \)-sector is reduced due to the decline of \( P \) (see eq. (4)). Furthermore, total demand for goods increases because of higher real income. The analytical result reveals that the positive effects dominate the negative one, so the employment situation of the unskilled improves. Moreover, it follows from eq. (4) that also the real consumption wage of the unskilled increases.

A closer inspection of eq. (16) shows that the favorable employment effect for the unskilled is the stronger, the higher the parameter \( \beta \), i.e. the lower the preference parameter \( \alpha \) for their goods. The reason for this is that a lower \( \alpha \) implies a higher weight of \( H \)-sector goods in the definition of the aggregate price index. In this case the relative price decline of \( H \)-sector goods has a stronger impact on \( P \), which dampens wage pressure in sector \( L \). A strong reduction of unemployment also results if \( \eta_L \) is small, indicating that an improvement in the employment situation of the low skilled leads to a minor rise in wage pressure only. Furthermore, note that a higher elasticity of substitution dampens the positive labor market outcome for the unskilled. This is due to the more pronounced shift of relative demand which works in favor of the high-skilled sector.

The unemployment response to productivity changes in sector \( H \) obeys

\[
\hat{\bar{u}}_H = \frac{(\beta + \sigma - 1)\eta_L + \beta \gamma_L}{\sigma \eta_L \eta_H + \gamma_H (1 - \beta) \eta_L + \gamma_L \beta \eta_H} \hat{A}_H. \tag{17}
\]

For the unemployment rate of the high-skilled to decline, it is sufficient that \( \beta + \sigma > 1 \). However, with \( \beta + \sigma \) being sufficiently small, the opposite result could occur. To clarify the result one has to bear in mind that beside labor-saving productivity growth a second adverse effect occurs in sector \( H \). Since \( P_H \) declines more than \( P \), wage claims in terms
of the producer’s real wage are rising. This can be seen from eq. (4) and eq. (10), since with $\tilde{a}_H = 0$

$$\tilde{W}_H - \tilde{P}_H = (\tilde{P} - \tilde{P}_H) - \eta_H \tilde{u}_H = -(1 - \beta) \tilde{P}_H - \eta_H \tilde{u}_H. \quad (18)$$

The rise in wage pressure is the more pronounced the stronger the change in the wedge between $P$ and $P_H$. This change is the higher, the lower the parameter $\beta$, i.e. the lower preferences for skill-intensive goods. On the other hand the substitution effect works in favor of $H$-sector goods. With a sufficiently high elasticity of substitution and a sufficiently high $\beta$, the adverse effects are out-weighed by higher demand for $H$-sector goods triggered by lower relative prices and higher real income. In this case, employment in sector $H$ rises and the unemployment rate falls. With $\sigma$ and $\beta$ being sufficiently low, however, the relative demand for goods of the skill-intensive sector does not increase enough to compensate for the aforementioned adverse effects. This would even lead to higher unemployment of skilled workers.

Corresponding to the ambiguous result for unemployment in sector $H$, it follows from eq. (4) that also the change in real consumption wages depends on the expression $\sigma + \beta$. Only if this sum is sufficiently large, the implications of the model can be reconciled with the stylized fact that the real wage of skilled workers has increased.

**Variant II: Insider-like behavior of the skilled**

In the second variant of the model, $\tilde{a}_L = 0$ is only assumed for wage setting in sector $L$. Workers in the $H$-sector adjust the wage-pressure variable $a_H$ such that their unemployment rate remains constant. This corresponds to insider-like behavior of the skilled. The solution for the response of $L$-sector unemployment can then easily be computed from eq.(13):

$$\tilde{u}_L = -\frac{\beta}{\sigma \eta_L + \beta \gamma_L} \tilde{A}_H < 0. \quad (19)$$

Hence the unskilled can improve their employment situation under this setting as well. As in variant I, an increase in $\beta$, or a decrease in $\sigma$ or $\eta_L$ leads to a stronger decline in
unemployment of the unskilled. With \( \bar{u}_L = 0 \) one again obtains from eqs. (10) and (11) \( \bar{P}_H < 0 \) and \( \bar{P} < 0 \). Inserting eq. (19) into eq. (4), it can be seen that also in this variant the real consumption wage of the unskilled increases:

$$\bar{W}_L - \bar{P} = \frac{\beta \eta_L}{\sigma \eta_L + \beta \gamma_L} \bar{A}_H > 0.$$  \hspace{1cm} (20)

The wage-pressure variable \( a_H \) in the high-skilled sector is adjusted according to

$$\tilde{a}_H = \frac{\beta \gamma_L + (\sigma + \beta - 1) \eta_L}{\sigma \eta_L + \beta \gamma_L} \bar{A}_H.$$  \hspace{1cm} (21)

A sufficient condition for an increase in \( a_H \) is \( \beta + \sigma > 1 \). Since \( \bar{u}_H = 0 \), it follows from eq. (4) that

$$\bar{W}_H - \bar{P} = \tilde{a}_H.$$  \hspace{1cm} (22)

As a result, if \( \tilde{a}_H \) rises, the real consumption wage of skilled workers increases as well.

**Variant III: “Solidaristic” wage policy**

In the third variant, wage-setting institutions are “solidaristic”, i.e. it is pretended that each group should gain equally from efficiency growth. This case may be relevant for an economy characterized by corporatism.

In a first setting, we interpret the notion solidaristic wage policy in the sense that the wage-pressure variables are forced to be equal, hence \( \bar{u}_L \equiv \bar{u}_H \equiv \tilde{a} \). To determine the model solution, it is again assumed that \( \bar{u}_H = 0 \).\(^1\) In this case the result for unemployment of the unskilled can be derived as

$$\tilde{u}_L = \frac{\sigma - 1}{\sigma \eta_L + \gamma_L} \bar{A}_H.$$  \hspace{1cm} (23)

If \( \sigma < 1 \), the employment situation of the unskilled improves as in the other variants. Both a higher \( \sigma \) or \( \eta_L \) then lead to a smaller decline of \( u_L \). However, if \( \sigma > 1 \), the unemployment rate of the unskilled rises. In this case a rise in \( \eta_L \) dampens the increase

\(^1\)An equally possible assumption is that aggregate unemployment should remain constant. This leads to the same qualitative results.
in unemployment, whereas a rise in the elasticity of substitution reinforces the adverse employment effect.\footnote{In contrast to the variants discussed above, the parameter $\beta$ has no influence on $\hat{u}_L$. It can be shown that the derivatives of $\hat{P}$ and $\hat{a}$ with respect to $\beta$ are equal in absolute terms. Hence the positive effect of a decline in $P$ on wage pressure and the negative effect of an increase in $\hat{a}$ compensate each other.}

In what follows we only consider the case where $\sigma$ exceeds unity. Since $\hat{u}_H = 0$ and $\hat{A}_H > 0$, eq. (1) implies that $\hat{Y}_H > 0$. With $\hat{u}_L > 0$ and $\hat{A}_L = 0$ it also holds that $\hat{Y}_L < 0$. Hence it follows from eqs. (8) and (10) that the price variables $P_H$ and $P$ are both decreasing. Given that $W_L$ is constant, the real consumption wage of the unskilled increases. From the wage-setting equation for the unskilled one gets $\hat{a} > 0$. This can also be seen analytically, since for $\sigma > 1$

$$\hat{a} = \frac{\beta \gamma_L + \eta_L (\sigma + \beta - 1)}{\sigma \eta_L + \gamma_L} \hat{A}_H > 0. \quad (24)$$

With $\hat{a} > 0$, also the real consumption wage of skilled workers is higher in the new equilibrium. The result for relative wages can be obtained from the two wage-setting equations (4) as

$$\hat{W}_H - \hat{W}_L = \eta_L \hat{u}_L > 0. \quad (25)$$

Since unemployment of unskilled workers has increased, it is obvious that the changes in the relative wage are in favor of the skilled. Hence in this special case of “solidaristic” wage policy, biased technological change deteriorates the employment chances of the unskilled. At the same time, the skill premium increases.

As an alternative, solidaristic wage policy could also be interpreted as a policy to prevent any changes in wage differentiation. This would mean that wage changes are equal across skill groups: $\hat{W}_H = \hat{W}_L$. In order to guarantee a solution to the model we again assume that skilled workers only agree to this wage policy if their unemployment rate remains constant, i.e. $\hat{u}_H = 0$. Together with $\hat{A}_L = 0$ it follows from eqs. (2) and (10) that $\hat{P}_H = -\hat{A}_H$ and $\hat{P} = -\beta \hat{A}_H$. Taking this into account in eq. (11) leads to the result that the change in wage-pressure in the high-skilled sector is proportional to changes in
For the unemployment rate of the unskilled one obtains from eqs. (11) and (12)
\[ \tilde{u}_L = \frac{\sigma - 1}{\gamma_L} \tilde{A}_H, \]  
and for the corresponding wage-pressure variable
\[ \tilde{a}_L = \left( \beta + \frac{\eta_L (\sigma - 1)}{\gamma_L} \right) \tilde{A}_H. \]

Hence if \( \sigma > 1 \), unemployment of the unskilled rises. Comparing the solutions for both groups, it turns out that for \( \sigma > 1 \) wage-pressure of the unskilled exceeds that of skilled workers. This has to expected because the wage of the unskilled has to keep pace with the general development although this group has no productivity gains. It can also be seen that the consumption wage for both groups rises:
\[ \tilde{W}_L - \tilde{P} = \tilde{W}_H - \tilde{P} = \beta \tilde{A}_H > 0. \]

A comparison of this result with eqs. (21) and (22) reveals that for \( \sigma > 1 \) the change in real consumption wages for high-skilled workers in variant II exceeds that given in eq. (29). Hence, in the case of insider-like behavior the high-skilled are better off than in the case of a solidaristic wage policy. For the unskilled the comparison yields a mixed result. Under a solidaristic wage policy they obtain a higher real consumption wage than in variant II, but suffer from employment losses.

4 Summary and Conclusions

Who wins and looses from biased technological change? There is almost no controversy in the literature that skilled workers can improve their situation with respect to employment and wages. In contrast, it is often taken for granted that the opposite is true for unskilled workers. The aim of our paper is to challenge a simplistic view that arises from
a partial equilibrium framework. Taking general equilibrium effects into account provides new insights into the mechanisms on goods and labor markets triggered by asymmetric productivity changes. The central message of our analysis is that biased technological change in some respects leads to an improvement, not a deterioration in the economic situation of unskilled workers. Although the development of relative prices is unfavorable for them, the unskilled profit via two indirect effects. First, productivity growth for skilled workers leads to higher real income in the economy and \( ceq. \ par. \) increases demand for all products. Second, the decline in the aggregate price level reduces wage pressure of unskilled workers in terms of producers’ real wages, because labor unions are oriented towards the real wage relevant to consumers. The analysis reveals that these positive effects outweigh the negative relative price effect as long as the unskilled remain “passive” in the wage-setting process, i.e. there are no additional forces generating higher wage pressure. We have shown that in this case both real consumption wages and employment of unskilled workers are rising. These qualitative results do not depend on whether the skilled stick to passive or insider-like behavior.

A different situation arises under a sort of “solidaristic wage policy” designed to let the unskilled participate in the productivity gains of the skilled. Two forms of solidaristic wage policy are considered, which are characterized by labor unions equalizing either wage pressure or wage growth across skill groups. Such policies lead to higher increases in the real consumption wage of the unskilled, but only at significant cost. Given the usual assumption of an elasticity of substitution exceeding unity, for the skilled these costs take the form of lower wage changes at constant employment, while the unskilled suffer from employment losses.

In all variants of the model we have not been able to generate the result that the unskilled experience real wage losses. We conclude that the well-documented evidence for the United States, where the real wage of unskilled workers dramatically declined, can hardly be explained by skill-biased technological change alone. However, for Germany and other countries, where solidaristic wage policy is of paramount importance for union behavior, the stylized facts seem to be roughly in line with a theoretical model based on
the hypothesis of skill-biased technological change.

References


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