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Technological Change, Relative Wages, and Unemployment

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Abstract

This paper examines the effect of skill-biased technological change on the structure of wages, the composition of employment and the level of unemployment in a two-sector economy with a heterogeneous work force. Efficiency wage considerations and minimum wage legislation lead to labor market segmentation. A technological shock that reduces the demand for unskilled labor and raises the demand for skilled labor in the primary, high-wage sector is shown to increase the relative wage of skilled workers and reduce aggregate employment as well as the employment level of unskilled workers in that sector. The net effect of the shock on the employment level of skilled workers is mitigated by the existence of efficiency factors.

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Summary

Well-documented features of the labor market in several industrial countries in the 1980s have been a fall in the relative wage of unskilled workers and a relative increase in employment of highly educated workers. The existing evidence suggests that, at least for the United States, both phenomena may have been caused by skilled-biased technological progress.

The paper examines analytically the effect of this type of technological shock on the structure of wages, the composition of employment, and the level of unemployment. It develops a dual labor market model that incorporates efficiency wages, worker heterogeneity, minimum wage legislation, and unemployment benefits. The first part of the paper shows that, in such a setting, a wage differential emerges in equilibrium as a result of efficiency wage considerations in the primary sector. Equilibria with full employment or unemployment of skilled workers are shown to be possible outcomes, depending on the perceived disutility of effort and the structure of unemployment benefits.

The second part of the paper shows that a technological shock that reduces the use of unskilled labor while raising the use of skilled workers always reduces the demand for unskilled labor in the primary sector. In contrast, the net effect on the demand for skilled labor reflects two conflicting factors: a direct technological effect, which is positive; and an indirect effect, which is negative and operates through changes in the efficiency wage paid to skilled workers. If efficiency considerations play a limited role, the technological shock has no effect on wages and on total employment in the primary sector; employment of skilled workers rises by the same magnitude as the fall in employment of unskilled workers. When efficiency considerations are moderately important, the adoption of the new technology raises the relative wage of skilled workers, reduces aggregate employment as well as the employment level of unskilled labor in the primary sector, and will in general raise the employment level of skilled workers. However, if efficiency considerations are very important in the primary sector, the indirect effect of the technological shock may completely offset the direct, positive effect, and the level of employment of skilled workers may remain unchanged. Thus, the effect of technological shocks on the employment level of skilled workers depends crucially on the strength of efficiency considerations in the primary sector.

The analysis also shows that the technological shock can move the economy from an initial equilibrium in which there is no unemployment to a situation where skilled workers that are unable to obtain a job in the primary sector may choose to remain unemployed rather than seek employment in the secondary sector. To offset this adverse effect, policymakers may need to reduce unemployment benefits to restore the incentive to work.

I. Introduction

Well-documented features of the labor market in several industrial countries in the 1980s have been a fall in the relative wage of unskilled workers, and a relative increase in employment of highly-educated workers. Lawrence and Slaughter (1993) have found, for instance, that in the United States the ratio of average payroll wages of non-production workers relative to those of production workers rose by nearly 10 percent between 1979 and 1989 in the manufacturing sector. During the same period, as documented by Katz and Murphy (1992), the ratio of non-production to production workers in manufacturing rose by almost 25 percent. Along the same lines, Bound and Johnson (1992) have found that between 1979 and 1988 the ratio of the average wage of college graduates increased by over 15 percentage points relative to the average wage of high school graduates. Similar trends have been identified for Italy (Demekas, 1994), Japan, the United Kingdom and--mostly since the mid-1980s--France (Katz et al., 1994).

While several explanations have been proposed to account for these dramatic changes in the wage structure and the composition of employment, the prevailing consensus among economists--at least for the United States--seems to be that both phenomena were caused by a large shift in relative labor demand away from workers with limited qualifications and towards those with high skill levels. In addition, several authors have concluded that this relative demand shift resulted primarily from technological progress biased towards skilled labor rather than "supply" factors, such as increases in the participation rate of unskilled workers, or a deceleration in the rate of growth of the relative supply of college-educated workers. ^{1/}

The purpose of this paper is to propose a formal analytical framework that allows examining the effect of technological shocks of the type alluded to above on the structure of wages, the composition of employment, and the level of unemployment. The model that we develop has a number of appealing features in that regard. It relates to an economy in which the existence of efficiency considerations and minimum wage legislation in a "primary" sector lead to a dual labor

^{1/} See Berman et al. (1994), Bound and Johnson (1992), Krueger (1993), and Mincer (1991) for the United States. Berman et al. and Krueger, in particular, present direct evidence on the relationship between skill-biased technological change and changes in the wage structure. The large increase in the supply of unskilled labor through legal and illegal migration from neighboring developing countries is generally not viewed as having had a very significant effect on relative wages at the national level. Katz et al. (1994), however, have argued that the deceleration in the rate of growth of the relative supply of highly-educated workers may have had a large effect on skill differentials, in both the United Kingdom and the United States. Borjas and Ramey (1994) have emphasized changes in the composition of external trade.

market and the emergence of equilibrium unemployment. Specifically, our analysis is based on the shirking model of Stiglitz and Shapiro (1984), extended to a setting where the labor force is heterogeneous. Efficiency wages are paid only to skilled workers, while unskilled workers in the primary sector earn a legally-binding minimum wage. This formulation is particularly attractive as a description of the labor market in a variety of institutional settings. It accords well with the evidence for industrial countries which suggests that, while there exists sectors where efficiency considerations may lead to wages that are "too high" in equilibrium, there also exists a large segment of the labor market in which wages are determined through a market-clearing mechanism. ^{1/} In our framework, the nature of the equilibria that emerge depends crucially on the type of interactions that take place between the different segments of the labor market (as is typical of dual labor market models), as well as the structure of the unemployment benefit scheme available to workers.

The remainder of the paper is organized as follows. Section II describes the analytical framework and focuses on the case where only high-ability workers may face unemployment. Section III examines the implications of a large technological shift that economizes on the use of unskilled labor and raises the use of skilled labor in the primary sector. It discusses, in particular, the effect of the shock on relative wages and the employment level of both categories of workers in the primary sector, and identifies the policy responses that may be appropriate to mitigate adverse movements in employment. Section IV summarizes the main results of the analysis. The Appendix extends the initial setup to incorporate the possibility of unemployment of low-ability workers as well as unemployment of skilled workers.

II. The Analytical Framework

The economy considered here employs two categories of workers and possesses two production sectors, which are distinguished by two sets of characteristics: differences in wage formation, and the production technology. In the primary sector, production requires highly-qualified workers as well as workers with limited qualifications. Labor legislation is binding and wages are set by government fiat (for unskilled labor) or firms' optimizing decisions (for skilled

^{1/} See Dickens and Lang (1988). Models of dual labor markets in which efficiency wages are determined along the lines suggested by Shapiro and Stiglitz have been developed by Bulow and Summers (1986) and Jones (1987). In particular, Jones shows that a large enough differential between the primary- and secondary-sector wages removes the need for (involuntary) unemployment as a "discipline device," as emphasized by Stiglitz and Shapiro. However, all these studies consider only the case of a homogeneous work force.

labor). 1/ In the secondary sector, the production process requires only workers with limited qualifications, and wages adjust instantaneously to clear the labor market. Skilled workers may, however, seek employment as unskilled workers in the production of the secondary-sector good. There are no physical or institutional impediments to mobility across sectors, for either category of workers.

1. Workers' decisions

The total labor force is fixed and equal to \bar{L} . The number of skilled or "educated" workers is equal to \bar{L}_E , and the number of unskilled workers is $\bar{L}_U = \bar{L} - \bar{L}_E$. Skilled workers are risk-neutral and dislike effort. Their instantaneous utility function takes the linear form $u(\omega, e) = \omega - e$, where ω is the earned wage (which varies depending on the sector of employment) and e the level of effort demanded by employers. As in Shapiro and Stiglitz (1984), effort when employed in the primary sector is a discrete variable: high-ability workers either supply the constant positive level of effort required from them ($e = e_E > 0$) or no effort at all ($e = 0$). When employed in the secondary sector, however, skilled workers always provide the level of effort $e = e_U$, where $0 \leq e_U < e_E$ represents the constant level of effort provided by unskilled workers, regardless of the sector of occupation. Unskilled workers are also risk neutral, so that their instantaneous utility function (appropriately normalized) can be written as $u(\omega, e_U) = \omega - e_U$. However, employment in the primary sector provides an additional, nonpecuniary benefit--such as an enhanced social status--which induces unskilled workers to look for job opportunities in that sector first. 2/ Both categories of workers have infinite lives, and discount future earnings at the constant rate $\rho > 0$. Neither group may lend or borrow.

2. Firms' wage and employment decisions

There exists a fixed number of firms operating in each production sector. Firms in the flexible wage, secondary sector produce a quantity Q_S of a traded good whose domestic price is set at unity,

1/ More generally, it could be assumed that the government sets a minimum wage for both categories of labor in the primary sector, but that the legislated wage is binding only for unskilled workers.

2/ For simplicity, we do not model explicitly the nonpecuniary benefit. This treatment does not affect in any substantive way the results discussed below. It only implies that in equilibrium the market-clearing wage for unskilled workers can be either higher or lower than the legal minimum wage.

using unskilled labor in quantity L_{SU} . Supervision and monitoring are costless, so that employed workers (as indicated above) always provide the required level of effort e_U . The production technology is characterized by diminishing returns to labor and takes a quadratic form for tractability:

$$Q_S(L_{SU}) = h_0 + h_1 L_{SU} - h_{11} L_{SU}^2 / 2. \quad h_1, h_{11} > 0 \quad (1)$$

The demand for unskilled workers in the secondary sector is therefore determined by

$$L_{SU}^d = Q'_S{}^{-1}(\omega_U) = (h_1 - \omega_U) / h_{11}, \quad (2)$$

where ω_U denotes the market-clearing wage for low-ability workers, which is determined below.

Firms in the primary sector use both skilled and unskilled labor to produce a quantity Q_P of a traded good whose price is also normalized to unity. The production function is also approximated by a quadratic form, as for instance in Akerlof and Yellen (1990):

$$Q_P(L_E, L_{PU}) = a_0 + a_1 L_E + a_2 L_{PU} - a_{11} L_E^2 / 2 - a_{22} L_{PU}^2 / 2 + \sigma L_E L_{PU}, \quad (3)$$

where a_1 , a_2 , a_{11} , and a_{22} are positive. Specification (3), being a second-order approximation, is consistent with a large variety of underlying production technologies. The coefficient σ can be positive, in which case skilled and unskilled labor are (gross) complements in the production of the primary sector good, or σ can be negative, in which case skilled and unskilled labor are (gross) substitutes. The existing evidence for industrial countries suggests that production and non-production workers are Hicks-Allen substitutes, that is, that the output-constant cross elasticities of demand for each category of labor are positive (see Hamermesh, 1993). This, however, does not preclude the possibility that these two groups of workers may be gross complements, or that the output effect dominate the substitution effect. ^{1/} In what follows, we will assume that $\sigma > 0$. As will be made clear below, while this condition is sufficient to establish the main results of the paper, it is not

^{1/} In addition, it can be shown that if the production function exhibits constant returns to scale and if the only inputs are the two labor types, then the two inputs are complements. For a constant returns-to-scale production function with more than two inputs, the "average" pairs of inputs are also complements (see for instance Becker, 1971, p. 117).

necessary. The main requirement is that the concavity terms in the production function be large enough in relation to σ , so that $a_{11} + \sigma > 0$ and $a_{22} + \sigma > 0$. These conditions hold trivially if the two labor categories are gross complements.

Unskilled workers employed in the primary sector provide, as indicated earlier, a constant level of effort $e_U < e_E$. However, firms in the primary sector cannot monitor perfectly on-the-job effort by high-ability workers. The monitoring technology is assumed to be such that there exists a constant probability q that a skilled worker engaged in shirking is caught. 1/ If caught, the worker is fired and faces two options. He either remains unemployed in the primary sector and receives an unemployment benefit that is proportional to the going wage for skilled workers, or he seeks employment as unskilled labor in the secondary sector. 2/ In general, the choice between these options depends on a variety of factors, both non-economic (such as the loss of social prestige) and economic--for instance, whether secondary employment has an adverse signaling effect, or whether it is easier to seek employment in the primary sector by remaining unemployed or working in a secondary sector job. 3/ Here the choice is assumed to depend solely on whether the unemployment benefit is higher or lower than the going wage in the secondary sector, adjusted for the disutility of effort. Firms in the primary sector set the wage of skilled workers so as to deter them from shirking and induce them to provide positive effort.

1/ For an efficiency-wage model in which the monitoring technology is endogenous, see Chatterji and Sparks (1991).

2/ A third possibility would be for a skilled worker to seek employment as unskilled labor in the primary sector. We exclude this case by assuming that an employer whose aim is to minimize frictions among co-workers would refrain from hiring skilled workers to work as unskilled labor, along with highly-qualified workers in skilled positions. This tendency is reflected in the observed practice of not employing overqualified workers.

3/ We exclude the possibility of on-the-job search in the secondary sector. Evidence in support of this assumption is rather mixed. The findings summarized by Layard et al. (1991, pp. 235-50) suggest that search for a high-quality job may be more successful when unemployed than if employed in a low-quality job. In a more recent study Pissarides and Wadsworth (1994) have found that skilled workers have a preference for searching while employed, although search intensity may vary with job tenure. In any case, allowing for on-the-job search in the present framework would not alter significantly the basic decision problem--and subsequent results--as long as searching while unemployed is taken to be more efficient.

Let b denote the exogenous turnover rate per unit time for skilled workers. Following Shapiro and Stiglitz (1984), we use the "asset equations" to derive the wage of skilled workers. Let V_{Ps}^E denote the expected lifetime utility of a high-ability worker currently employed in the primary sector who chooses to shirk, and let V_{Pn}^E be the expected utility stream if the employed worker is not shirking. The asset equations are given by

$$\rho V_{Ps}^E = \omega_E + (b+q)(V_N^E - V_{Ps}^E), \quad (4a)$$

$$\rho V_{Pn}^E = \omega_E - e_E + b(V_N^E - V_{Ps}^E), \quad (4b)$$

where ω_E is the equilibrium wage for skilled workers and V_N^E the expected lifetime utility of a high-ability worker that is not employed in the primary sector. Equations (4a) and (4b) indicate that the interest rate times the asset value equals the flow benefits (dividends) plus the expected capital gain (or loss). For instance, if a skilled worker shirks, he obtains the wage ω_E without providing any effort but faces a probability $b+q$ of losing his job, thus incurring a loss in welfare equal to $V_{Ps}^E - V_N^E$.

To elicit a positive effort level requires that $V_{Pn}^E \geq V_{Ps}^E$, so that

$$\omega_E \geq \rho V_N^E + e_E \Lambda / q, \quad \Lambda \equiv \rho + b + q \quad (5)$$

Equation (5) is the no-shirking condition (NSC) derived by Shapiro and Stiglitz (1984). In equilibrium this condition holds as an equality, and a rational worker will be indifferent between working and not working--in which case we assume he chooses to work.

The wage for unskilled labor in the primary sector is set by the government at the minimum level ω_U^* . ^{1/} The demand for unskilled labor in the primary sector is thus determined by $\omega_U^* = \partial Q_P / \partial L_{PU}$, which, using equation (3), can be written as

^{1/} An alternative formulation would be to assume that the primary-sector wage for unskilled labor is set by a trade union. Assuming that firms and the trade union bargain only over wages, it can easily be shown that in equilibrium the primary-sector wage for unskilled labor would be set as a mark-up over the market-clearing wage.

$$L_{PU}^d = (a_2 - \omega_U^* + \sigma L_E^d) / a_{22}.$$

For a given level of ω_E , the demand for skilled workers is given by, using also equation (3):

$$L_E^d = (a_1 - \omega_E + \sigma L_{PU}^d) / a_{11}.$$

Solving these last two equations yields

$$L_{PU}^d(\omega_U^*, \omega_E; \sigma) = [(a_2 - \omega_U^*)a_{11} + \sigma(a_1 - \omega_E)] / \Delta, \quad (6a)$$

$$L_E^d(\omega_U^*, \omega_E; \sigma) = [a_{22}(a_1 - \omega_E) + \sigma(a_2 - \omega_U^*)] / \Delta, \quad (6b)$$

where $\Delta = a_{22}a_{11} - \sigma^2$ can be shown to be positive, by examining the second-order conditions for profit maximization. Equations (6) show that the effect of an increase in the minimum wage on the demand for skilled labor as well as the effect of an increase in the efficiency wage on the demand for unskilled labor depends on whether skilled and unskilled workers are complementary or not. Since σ is assumed positive here, $\partial L_{PU}^d / \partial \omega_E < 0$ and $\partial L_E^d / \partial \omega_U^* < 0$.

3. Equilibrium and unemployment

The equilibrium solution of the model requires solving for the market-clearing wage for unskilled workers and calculating V_N^E , the expected lifetime utility of a skilled worker not employed in the primary sector, to determine ω_E . As indicated before, a skilled worker that is not hired in the primary sector can either work in the secondary sector (and supply the constant level of effort e_U) or enter the unemployment pool and receive an unemployment benefit without providing any effort. The decision between these options depends on the perceived costs and benefits of remaining unemployed, compared to working in the secondary sector. The high-ability worker gets utility (per unit time) of $\omega_U - e_U$ in secondary employment and a benefit of $\theta \omega_E$ if unemployed, where $0 \leq \theta \leq 1$ is the unemployment benefit rate. ^{1/}

^{1/} In practice, most unemployment benefit schemes phase out financial assistance gradually. The assumption that θ remain constant over time is, nevertheless, consistent with our focus on the steady-state behavior of the economy. We also abstract in what follows from the budget constraint that the government may face in financing the unemployment benefit scheme.

For simplicity, we will assume that a skilled worker perceives the transition probabilities into a primary job out of each of these two states as identical and equal to the exogenous hiring rate, α --thus ignoring "deskilling" or "demotivation" effects associated with unemployment. The asset equation for a high-ability worker that is not employed in the primary sector is therefore equal to

$$\rho V_N^E = \theta \omega_E + \alpha(V_P^E - V_N^E), \quad \omega_U - e_U \leq \theta \omega_E \quad (7a)$$

$$\rho V_N^E = \omega_U - e_U + \alpha(V_P^E - V_N^E), \quad \omega_U - e_U > \theta \omega_E \quad (7b)$$

where it is assumed that, in equilibrium, the no-shirking condition (5) holds with equality so that $V_{Pn}^E = V_{Ps}^E = V_P^E$. The quantity $\alpha(V_P^E - V_N^E)$ in equations (7) is equal to the net expected utility gain of being employed in the primary sector, times the probability (per unit time) of being hired in that sector.

Solving (4b) and (7) simultaneously allows us to write the expected discounted utility of a skilled worker not employed in the primary sector as

$$\rho V_N^E = \Omega^{-1} \left\{ \theta(\Omega - \alpha)\omega_E + \alpha(\omega_E - e_E) \right\}, \quad \omega_U - e_U \leq \theta \omega_E \quad (8a)$$

$$\rho V_N^E = \omega_U - e_U + \alpha \Omega^{-1} \left\{ (\omega_E - e_E) - (\omega_U - e_U) \right\}, \quad \omega_U - e_U > \theta \omega_E \quad (8b)$$

where $\Omega = \alpha + \rho + b$. Using these results in (4b) yields

$$\omega_E \geq \Omega^{-1} \left\{ \theta(\Omega - \alpha)\omega_E + \alpha(\omega_E - e_E) \right\} + e\Lambda/q, \quad \omega_U - e_U \leq \theta \omega_E \quad (9a)$$

$$\omega_E \geq \omega_U - e_U + \alpha \Omega^{-1} \left\{ (\omega_E - e_E) - (\omega_U - e_U) \right\} + e\Lambda/q, \quad \omega_U - e_U > \theta \omega_E \quad (9b)$$

In a steady-state equilibrium, the flow of skilled workers in and out of employment in the primary sector must be equal, so that

$$bL_E^d = \alpha(\bar{L}_E - L_E^d). \quad (10)$$

Substituting equation (10) for α in equations (9) yields the steady-state NSC:

$$\omega_E \geq \frac{e_E}{q(1-\theta)} \left\{ \Lambda + \frac{bL_E^d}{\bar{L}_E - L_E^d} \right\}, \quad \omega_U - e_U \leq \theta \omega_E \quad (11a)$$

$$\omega_E - e_E \geq (\omega_U - e_U) + \frac{e_E}{q} \left\{ \rho + \frac{b\bar{L}_E}{\bar{L}_E - L_E^d} \right\}, \quad \omega_U - e_U > \theta \omega_E \quad (11b)$$

Equations (11) hold as equalities in equilibrium. They indicate that to induce skilled workers to work efficiently, firms must pay a going wage sufficiently high relative to the opportunity cost of effort. A higher rate of unemployment benefits (an increase in θ) raises the efficiency wage for skilled workers. The gap between the wage paid to high-ability workers and the market-clearing wage earned by those with limited qualifications is higher the higher is the required effort in the primary sector, the higher is the turnover rate, the higher is the discount rate--since future losses incurred if caught shirking are less valued--and the lower is the probability of being caught shirking and subsequently fired. An important difference between equations (11a) and (11b) is that in the first case, an increase in the market-clearing wage for unskilled workers has no effect on the efficiency wage (since, as indicated in equations (6), the demand for highly-qualified workers depends only on the legal minimum wage), while in the second case it has a positive effect.

The market-clearing wage for unskilled workers depends on whether high-ability workers seek employment in the secondary sector or not--or equivalently, on whether $\omega_U - e_U \geq \theta \omega_E$. If skilled workers choose to remain unemployed, the equilibrium wage is given by, using (2):

$$\bar{L}_U - L_{PU}^d = (h_1 - \omega_U)/h_{11}, \quad \omega_U - e_U \leq \theta \omega_E \quad (12a)$$

while if they seek employment in the secondary sector, we have

$$(\bar{L}_U - L_{PU}^d) + (\bar{L}_E - L_E^d) = (h_1 - \omega_U)/h_{11}, \quad \omega_U - e_U > \theta \omega_E \quad (12b)$$

Substituting equations (6) in equations (12) yields the market-clearing wage:

$$\omega_U = h_1 + h_{11} \left\{ \Delta^{-1} [a_{11}(a_2^* - \omega_U^*) + \sigma(a_1 - \omega_E)] - \bar{L}_U \right\}, \quad \omega_U - e_U \leq \theta \omega_E \quad (13a)$$

$$\omega_U = h_1 + h_{11} \left\{ \Delta^{-1} [a - \omega_U^*(a_{11} + \sigma) - \omega_E(a_{22} + \sigma)] - \bar{L} \right\}, \quad \omega_U - e_U > \theta \omega_E \quad (13b)$$

where $a = a_1 a_{22} + a_2 a_{11} + \sigma(a_1 + a_2) > 0$.

Equations (13) show that an increase in the minimum wage reduces the market-clearing wage for unskilled workers, because it lowers demand for that category of labor in the primary sector and raises the supply of labor in the secondary sector. An increase in the efficiency wage also lowers the market-clearing wage, since (given our assumption that $\sigma > 0$) it reduces the demand for both skilled and unskilled labor in the primary sector, thus raising the supply of workers in the secondary sector. 1/ Finally, an increase in the total labor force (equation 13a) or in the total number of unskilled workers (equation 13b) reduces the market-clearing wage.

The two possible equilibria that may emerge in this model are illustrated in Figures 1 and 2. In the first case, the market-clearing wage for unskilled workers--net of the disutility of effort--exceeds the unemployment benefit ($\omega_U - e_U > \theta\omega_E$), high-ability workers subject to job rationing accept to work as unskilled labor in the secondary sector, and there is no unemployment. The full employment equilibrium is illustrated in Figure 1. Substituting equation (6b) for the demand for skilled workers in the NSC equation (11b)--holding with equality--yields a positive relation between ω_E and ω_U , which is shown in the North-West quadrant of the diagram. The position of the NSC curve depends on the minimum wage, as indicated in the figure. When skilled workers choose to seek employment in the secondary sector the no-shirking efficiency wage will depend, through ω_U , on the level of employment of both categories of workers in the primary sector. In the North-East quadrant of the diagram, the demand curves for skilled and unskilled workers in the primary sector are shown to be inversely related to the efficiency wage--reflecting our assumption that $\sigma > 0$. The supply constraint constituted by the given size of the labor force is shown in the South-East quadrant. The 45 degree line in that quadrant allows reporting the demand for unskilled labor in the primary sector from the North-East quadrant to the South-West quadrant, while the total supply of labor curve \bar{L} determines, given the level of employment of skilled workers, the supply of unskilled labor in both sectors, $\bar{L} - L_E^d = \bar{L}_U + (\bar{L}_E - L_E^d)$, at point B. This quantity is also equal to total demand for low-ability workers, the demand curve of which is also shown in the South-West quadrant as $L_{PU}^d + L_{SU}^d()$. By subtracting vertically from the total demand curve the level of employment of unskilled workers in the primary sector, the demand curve for unskilled labor in the secondary sector and the market-clearing wage are obtained. The equilibrium wage for unskilled workers is determined at point C, which then determines the efficiency

1/ In the case where $\omega_U - e_U > \theta\omega_E$, there is of course a feedback effect from ω_U to ω_E as indicated by equation (11b).

Figure 1

Full Employment Equilibrium

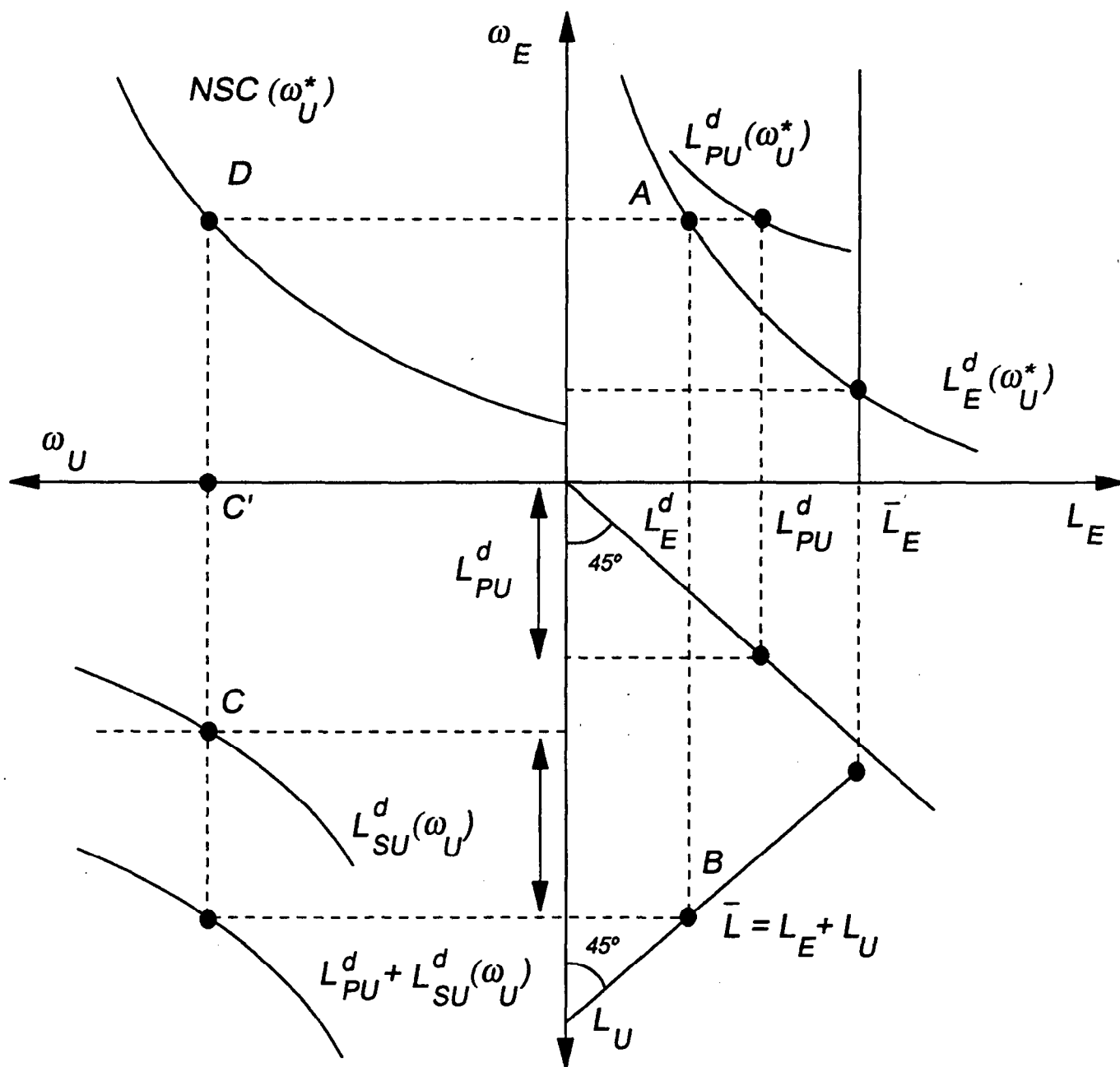
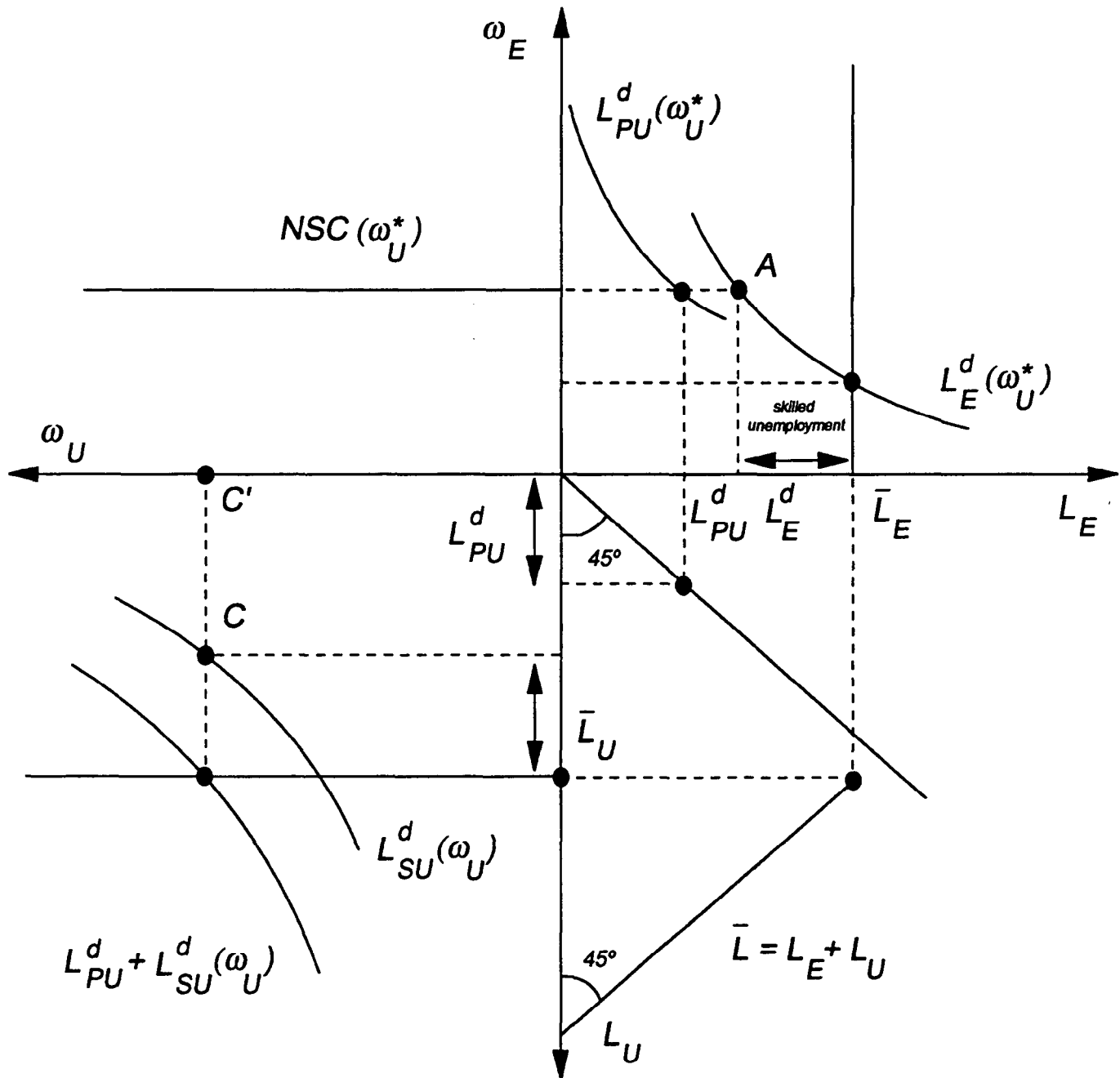


Figure 2

Equilibrium with Unemployment of Skilled Workers



wage through the *NSC* curve at point *D*. 1/ Total employment in the secondary sector is measured by *CC'*. Finally, given the *NSC*, the demand for skilled labor is determined at point *A*.

In the second case, where the market-clearing wage for unskilled labor (adjusted for the disutility of effort in the secondary sector) is too low relative to the unemployment benefit received by high-ability workers subject to demand rationing in the primary sector ($\omega_U - e_U \leq \theta \omega_E$), skilled workers prefer to remain unemployed, rather than work in the secondary sector. The unemployment equilibrium is illustrated in Figure 2, which is constructed essentially in the same manner as Figure 1. The *NSC*, however, is now horizontal--since it does not depend on ω_U --as shown in the North-West quadrant of the diagram. The demand for skilled workers is again determined at point *A*, but unemployment prevails, at the rate $(\bar{L}_E - L_E^d) / \bar{L}_E$.

Thus, in this basic framework, unemployment affects only skilled workers, and can be deemed voluntary and involuntary. It is involuntary in the sense that employment opportunities requiring highly-qualified labor are demand constrained, and all skilled workers would prefer to work at the efficiency wage. It is also voluntary, however, in the sense that skilled workers could find employment in the secondary sector but opt not to seek a secondary-sector job--because unemployment benefits are "too high" relative to the return offered by available employment opportunities. By choosing an appropriate value of θ , the unemployment benefit rate, the government could eliminate the source of frictions in the labor market. 2/ The Appendix extends the basic framework to consider the possibility that unskilled workers may also face unemployment.

III. Technological Shocks, Wages and Unemployment

As argued in the introduction, several economists have attributed the shift in relative wages and the distribution of employment observed during the 1980s in some industrial countries to a large change in the composition of labor demand induced by biased technological change towards skilled labor. The dual labor market model developed in the previous section provides a particularly convenient framework for a formal examination of the long-run effects

1/ Note that the market-clearing wage for unskilled workers is always lower than the efficiency wage paid to skilled workers.

2/ If skilled workers differ in their perceived disutility derived from working in the secondary sector, an equilibrium in which "partial" unemployment can also emerge. In such conditions, an adjustment in the unemployment benefit rate may not be sufficient to eliminate unemployment.

of technological shocks of this type. In our setup, a pro-skilled, anti-unskilled change in technology can be modeled as consisting of an increase in the parameter a_1 coupled with a fall in the parameter a_2 in the production function of the primary sector good, given by equation (3).

For simplicity, suppose that initially there is no unemployment of skilled labor, so that the condition $\omega_U - e_U > \theta \omega_E$ holds, and that at the initial level of wages in the primary sector (ω_E, ω_U^*) the resultant aggregate change in the total demand for labor in the primary sector induced by the technological shock ($da_1 > 0$, $da_2 < 0$) is zero, that is, $d(L_{PU}^d + L_E^d) = 0$. This assumption is particularly appropriate here, since it rules out employment effects induced (at the initial level of wages) by a reduction in the demand for labor in the primary sector. Equations (6) imply therefore that the effect of the change in technology can be measured by

$$da_1/da_2 = - (a_{11} + \sigma)/(a_{22} + \sigma) < 0. \quad (14)$$

Holding total labor supply fixed, equations (3) and (6) yield the output effect of the technological shock:

$$sg(dQ_P) = sg[(a_1 - \omega_E) - (a_2 - \omega_U^*)]. \quad (15)$$

Equation (15) indicates that the effect of the technological shock on primary sector output is positive only if the "excess" of the initial productivity of skilled workers over the efficiency wage exceeds the corresponding "excess" productivity of unskilled workers. 1/ Equations (6) and (12b) imply that

$$\bar{L} = \Delta^{-1}[(a_2 - \omega_U^*)a_{11} + (a_1 - \omega_E)a_{22} + \sigma(a_1 + a_2 - \omega_E - \omega_U^*)] + (h_1 - \omega_U)/h_{11}, \quad (16)$$

from which it can be induced that, using (14) and since $a_{22} + \sigma > 0$, $d\bar{L} = 0$:

$$\frac{d\omega_U}{d\omega_E} = - \frac{h_{11}(a_{22} + \sigma)}{\Delta} < 0. \quad (17)$$

1/ Note that a_1 measures the marginal productivity of the "first" skilled worker, and similarly for a_2 .

Equation (17) indicates that the induced change in the ratio of the market-clearing wage of unskilled workers over the efficiency wage of skilled workers is negative. From equations (6b) and (11b), we have

$$d\omega_E(1+\Delta^{-1}a_{22}\gamma) = d\omega_U + \frac{\gamma da_1}{\sigma+a_{11}}, \quad \gamma \equiv e_E b \bar{L}_E / q(\bar{L}_E - L_E^d)^2 \quad (18)$$

which yields, using equation (17):

$$\frac{d\omega_E}{da_1} = \frac{\gamma\Delta/(a_{11}+\sigma)}{\Delta+\gamma a_{22}+h_{11}(a_{22}+\sigma)} > 0. \quad (19)$$

Equation (19) shows that the absolute change in skilled workers' wage induced by the technological shock is positive.

Taken together, the results displayed in equations (17) and (19) imply that the condition that must be satisfied for preventing unemployment of skilled workers ($\omega_U - e_U > \theta\omega_E$) becomes less likely to hold. This implication can be gauged graphically, as shown in Figure 3. The equation of the QQ curve shown in the North-West quadrant of the diagram is given by $\omega_E = \theta^{-1}(\omega_U - e_U)$ and represents the combinations of the efficiency wage and the market-clearing wage for which skilled workers are indifferent between unemployment in the primary sector and employment in the secondary sector. The initial equilibrium is at a point like D on the NSC curve, which must be located to the left of the QQ curve to ensure that $\omega_U - e_U > \theta\omega_E$. The effect of the technological shock is to shift the NSC curve upwards and increase its slope, as indicated by equation (18). If the shift is large enough, equilibrium may obtain at a point like D', located to the right of the QQ curve, hence implying the emergence of unemployment of skilled labor (approximated by the distance AF in the North-East quadrant) since we now have $\omega_U - e_U < \theta\omega_E$. ^{1/}

^{1/} The technological shock also shifts the position of the demand curves for labor in the North-East quadrant of Figure 3: the demand curve for skilled workers shifts to the right, while the demand curve for unskilled workers shifts to the left. The shifts in these curves are such that at the wage level corresponding to point A, total demand for labor in the primary sector does not change, as indicated earlier. These changes in turn affect the demand curve for unskilled labor shown in the South-West quadrant. For clarity, these changes are not shown. The measurement of unemployment of skilled workers by the distance AF in the Figure must thus be viewed as illustrative.

Consider now the effect of the technological shock on the composition of employment in the primary sector when wages of skilled workers are allowed to adjust. From equations (6),

$$d(L_{PU}^d + L_E^d)/da_1 = \Delta^{-1} \left\{ - (a_{22} + \sigma) \frac{d\omega_E}{da_1} + (a_{22} + \sigma) + (a_{11} + \sigma) \frac{da_2}{da_1} \right\},$$

which implies, using equation (14):

$$d(L_{PU}^d + L_E^d)/da_1 = - (a_{22} + \sigma) \Delta^{-1} \left(\frac{d\omega_E}{da_1} \right) < 0. \quad (20)$$

Equation (20) indicates that, given our assumption that labor inputs are complements, the aggregate effect of the technological shock on employment in the primary sector is negative. From equations (6) we also have

$$dL_{PU}^d/da_1 = \Delta^{-1} \left\{ a_{11} \frac{da_2}{da_1} + \sigma \left(1 - \frac{d\omega_E}{da_1} \right) \right\},$$

$$dL_E^d/da_1 = \Delta^{-1} \left\{ \sigma \left(\frac{da_2}{da_1} \right) + a_{22} \left(1 - \frac{d\omega_E}{da_1} \right) \right\},$$

so that, using equation (14):

$$dL_{PU}^d/da_1 = - \frac{1}{a_{11} + \sigma} - \sigma \Delta^{-1} \left(\frac{d\omega_E}{da_1} \right), \quad (21a)$$

$$dL_E^d/da_1 = \frac{1}{a_{11} + \sigma} - a_{22} \Delta^{-1} \left(\frac{d\omega_E}{da_1} \right). \quad (21b)$$

Equations (21) indicate that the effect of the technological shock on the employment level of each skill category can be decomposed in two parts. The first, measured by the term $1/(a_{11} + \sigma)$, is the direct effect. It reflects the replacement of unskilled labor by skilled labor. ^{1/} The second, indirect effect is proportional to $d\omega_E/da_1$ in

^{1/} The fact that unskilled labor is replaced by skilled labor is consistent with our assumption of gross complementary of labor inputs, because the technological shock induces a shift in the production possibility frontier itself, rather than a movement along the initial transformation curve.

both equations, and results from the change in the wage paid to skilled workers. A higher efficiency wage in the primary sector induces a drop in the demand for skilled labor, and changes the demand for low-ability workers in that sector according to the sign of σ .

Substituting equation (19) in equations (21) yields

$$dL_{PU}^d/da_1 = - \frac{1}{(a_{11}+\sigma)} \left\{ 1 + \frac{\sigma\gamma}{\Delta + \gamma a_{22} + h_{11}(a_{22}+\sigma)} \right\} < 0, \quad (22a)$$

$$dL_E^d/da_1 = \frac{1}{(a_{11}+\sigma)} \left\{ 1 - \frac{\gamma a_{22}}{\Delta + \gamma a_{22} + h_{11}(a_{22}+\sigma)} \right\} \geq 0. \quad (22b)$$

Equations (22) show that the level of employment of unskilled workers always declines as a result of the shock, while the employment level of high-ability workers may either rise or remain constant. The change in the demand for skilled labor reflects two conflicting forces: the direct, positive effect of the technological shock, which increases demand, and the higher efficiency wage, which reduces it. As shown in equation (11b), the premium earned by skilled workers (the efficiency wage minus the market-clearing wage for unskilled workers, both adjusted for the level of effort) is proportional to the efficiency factor, e_E . The proportionality factor increases with the level of employment of skilled workers, which follows from the use of the competitive, secondary-sector wage as a discipline device--whose effectiveness diminishes when the demand for skilled workers rises. If efficiency requirements for high-ability workers are not an important consideration for firms, ($e_E \rightarrow 0$), the technological shock does not call for a change in the wage earned by skilled labor: from the definition of γ given in equation (18), $\gamma \rightarrow 0$ if $e_E \rightarrow 0$ so that, from equation (19), $d\omega_E/da_1 \rightarrow 0$. ^{1/} In turn, using equation (20), this result implies that total employment in the primary sector remains constant: the firms' demand for skilled workers is satisfied from the pool of high-ability workers that were previously employed as unskilled labor in the secondary sector. As shown by equation (17), the reduction in the supply of labor in the secondary sector induced

^{1/} This experiment is a limiting case, since all workers are paid their marginal product when $\gamma = 0$. Note also that in the absence of wage efficiency considerations and in the presence of employment of skilled workers in the secondary sector, firms have no incentive to pay a wage premium, and hence $\omega_E = \omega_U$. It can be verified that in this case both the uniform wage and the level of employment in the primary sector will remain unaffected by the type of technological shocks considered here.

by this "reflow" of high-ability workers to the primary sector does not affect the market-clearing wage for low-ability workers ($d\omega_U = 0$): it is fully offset by the increase in the supply of unskilled workers who lose their jobs in the primary sector. 1/ In these circumstances, only the direct effect of the technological shock operates.

In the presence of efficiency considerations ($e_E > 0$), by contrast, the higher demand for skilled workers induced by the adoption of the new technology reduces the effective penalty incurred by skilled workers caught shirking, since the likelihood of finding a highly-paid job increases. Hence, the technological shock calls for a higher wage premium, generated by both an increase in the wage paid to high-ability workers and a corresponding decrease in the competitive wage for low-ability workers; both effects are proportional to e_E . 2/ In turn, this induces a secondary adjustment in labor demands, whose magnitude depends on σ . An increase in the required level of effort has the effect of bidding up the efficiency wage (as can be seen from equation 19), reducing the aggregate demand for labor in the primary sector (as indicated by equation 20) and hence lowering the market-clearing wage for unskilled labor. If the required level of effort is very large ($e_E \rightarrow \infty$), there is no change in the demand for skilled labor, as the secondary effect fully offsets the direct technological effect. Hence, we conclude that the adverse employment effect of the new technology is a direct consequence of efficiency considerations. When such considerations are important in the primary sector, the adverse employment effect of the technological shock is magnified, requiring a fall in the market-clearing wage for unskilled labor and an increase in the wage paid to skilled workers.

What can the government do to dampen the adverse effect of the technological shock on employment in the primary sector? In the above framework, the appropriate policy response is to reduce the unemployment benefit rate of skilled workers. Graphically, the reduction in θ rotates the QQ curve clockwise, to $Q'Q'$ (see Figure 3). The rotation must be large enough to ensure that the new NSC is located to the left of $Q'Q'$. Formally, a lower bound on the required adjustment in the unemployment benefit rate is determined by the condition that

1/ Implicit in this argument is the assumption that the initial, pre-shock excess supply of high-ability workers is large enough to accomodate the labor demand shift induced by the technological shock.

2/ The proportionality of $d\omega_E/da_1$ to e_E can be seen directly from equation (19). Substituting equation (19) in (17) yields

$$d\omega_U/da_1 = - \gamma[1 + \gamma a_{22} + \Delta^{-1} h_{11}(a_{22} + \sigma)]^{-1} h_{11}(a_{22} + \sigma) / (a_{11} + \sigma),$$

which is also proportional to e_E .

$$\omega_E d\theta = d\omega_U - \theta d\omega_E,$$

so that, using equation (17):

$$d\theta = - \left\{ \theta + \frac{\Delta}{h_{11}(\sigma + a_{22})} \right\} (d\omega_E / \omega_E), \quad (23)$$

which shows that the needed downward adjustment in the unemployment benefit rate increases with the initial rate, θ . Hence, in countries that operate very generous unemployment benefit systems, the appropriate reduction in benefits that is required to offset the adverse employment effect of a pro-skilled technological shock may be relatively large.

It is worth noting also what happens if the government, instead of reducing the unemployment benefit rate of high-ability workers, decides to lower the legal minimum wage paid to unskilled workers, ω_U^* —in an attempt to induce firms in the primary sector to increase their demand for that category of labor. It can be shown that the direction of the needed adjustment cannot be predicted unambiguously without more specific information regarding the various elasticities. This follows from the observation that a drop in ω_U^* may increase both the efficiency wage and the market-clearing wage in the secondary sector (by reducing the supply of labor), so that the impact of changing ω_U^* on the slope of the QQ curve is ambiguous. This finding illustrates the intuition according to which the best way to deal with a distortion is to intervene directly to correct the distorted margin. Unemployment of high-ability workers reflects the fact that previous unemployment benefits were too generous for an economy experiencing pro-skilled productivity improvements. Hence, the appropriate response is a downward adjustment in the benefit rate.

The foregoing analysis assumed that the technological shocks shifted the demand curves for each category of labor in the primary sector in opposite directions, while leaving aggregate employment unchanged at the initial level of wages. This assumption enabled us to isolate the employment effect of wage efficiency factors. The same methodology can be applied to evaluate the effect of shocks affecting only one of the demand functions.

Consider, to begin with, an increase in the productivity of skilled labor only ($da_1 > 0$). Using equations (13b), and (16) yields

$$\begin{bmatrix} \Delta & h_{11}(a_{22} + \sigma) \\ -1 & 1 + (a_{22}\gamma/\Delta) \end{bmatrix} \begin{bmatrix} d\omega_U/da_1 \\ d\omega_E/da_1 \end{bmatrix} = \begin{bmatrix} h_{11}(a_{22} + \sigma) \\ a_{22}\gamma/\Delta \end{bmatrix},$$

from which we have

$$\frac{d\omega_E}{da_1} = (D-\Delta)/D > 0, \quad \frac{d\omega_U}{da_1} = h_{11}(a_{22}+\sigma)/D > 0, \quad (24)$$

where $D = \Delta + \gamma a_{22} + h_{11}(a_{22} + \sigma)$.

Equations (24) show that an increase in the productivity of skilled labor raises both categories of wages. The net effect of the shock on the no-unemployment condition ($\omega_U - e_U > \theta \omega_E$) is thus ambiguous, but the possibility that the economy may shift to an unemployment equilibrium cannot be ruled out. Using equations (6) and (24) yields

$$dL_{PU}^d/da_1 = \sigma \Delta^{-1} \left\{ 1 - \frac{d\omega_E}{da_1} \right\} = \sigma/D, \quad (25a)$$

$$dL_E^d/da_1 = a_{22} \Delta^{-1} \left\{ 1 - \frac{d\omega_E}{da_1} \right\} = a_{22}/D > 0. \quad (25b)$$

These equations indicate that higher productivity of skilled labor increases the demand for both categories of labor, given our assumption of gross complementarity across inputs in the primary sector. In general, however, the cross effect can take either sign. In both cases, wage efficiency considerations dampen the magnitude of adjustment. In the limit, when the required level of effort is very large ($e_E \rightarrow \infty$), the technological shock induces no adjustment in labor demand.

Consider now the case where only the productivity of unskilled workers falls ($da_2 < 0$). Using again equations (13b) and (16) yields

$$\begin{bmatrix} \Delta & h_{11}(a_{22}+\sigma) \\ -1 & 1+(a_{22}\gamma/\Delta) \end{bmatrix} \begin{bmatrix} d\omega_U/da_2 \\ d\omega_E/da_2 \end{bmatrix} = \begin{bmatrix} h_{11}(a_{11}+\sigma) \\ \gamma\sigma/\Delta \end{bmatrix},$$

from which we get

$$d\omega_E = [\gamma\sigma + h_{11}(a_{11}+\sigma)]da_2/D < 0, \quad d\omega_U = h_{11}(a_{11}+\sigma-\gamma)da_2/D \gtrless 0, \quad (26)$$

where D is as defined above. Equations (26) show that a reduction in the productivity of unskilled labor ($da_2 < 0$) lowers the efficiency

wage and has an ambiguous effect on the market-clearing wage. ^{1/} Thus, as in the previous case, whether the no-unemployment condition will hold or not cannot be determined a priori. Using equations (6) and (26) yields

$$dL_{PU}^d = \Delta^{-1} \left\{ a_{11} - \sigma \left(\frac{d\omega_E}{da_2} \right) \right\} da_2 = (a_{11} + \gamma + h_{11}) da_2 / D < 0, \quad (27a)$$

$$dL_E^d = \Delta^{-1} \left\{ \sigma - a_{22} \left(\frac{d\omega_E}{da_2} \right) \right\} da_2 = (\sigma - h_{11}) da_2 / D \gtrless 0, \quad (27b)$$

$$d(L_{PU}^d + L_E^d) = (\sigma + a_{11} + \gamma) da_2 / D < 0. \quad (27c)$$

Equations (27) show that a reduction in the productivity of unskilled labor reduces the demand for unskilled labor, while the impact on the demand for skilled labor depends on whether labor inputs are complementary or not. In the case considered previously ($\sigma > 0$), the cross effect is thus ambiguous. However, despite this ambiguity, the lower productivity of unskilled workers reduces the aggregate demand for labor in the primary sector. It can also be verified that an increase in the required level of effort has an ambiguous effect on the behavior of total labor demand. In particular, the reduction in demand is magnified if the degree of input complementarity is not too large ($\sigma < h_{11}$).

IV. Summary and Conclusions

The purpose of this paper has been to examine the effect of technological shocks on relative wages, the distribution of the labor force, and unemployment. The analysis was based on a two-sector version of the shirking model developed by Shapiro and Stiglitz (1984), which incorporates worker heterogeneity, minimum wage legislation, and unemployment benefits. The first part of the paper presented the analytical framework, and showed that a wage differential emerges in equilibrium, as a result of efficiency wage considerations in the primary sector and costless monitoring of on-the-job effort in the secondary sector. Equilibria with full employment or unemployment of skilled workers were shown to be

^{1/} Note that if efficiency considerations were absent ($\gamma \rightarrow 0$), lower productivity of unskilled workers in the primary sector would reduce unambiguously the market-clearing wage because it would raise the supply of labor in the secondary sector.

possible outcomes, depending on the perceived disutility of effort and the level of the unemployment benefit rate. ^{1/}

The second part of the paper focused on the effects of a technological shock that reduces the use of unskilled labor, while raising the utilization of high-ability workers. It was shown that the effect of a technological shock of this type on the demand for unskilled labor in the primary sector is always negative, while the net effect on the demand for skilled labor reflects two conflicting factors: a direct technological effect (which is positive), and an indirect effect, which is negative and operates through changes in the efficiency wage paid to high-ability workers. The analysis showed that if efficiency considerations play a limited role, the technological shock has no effect on wages and no effect on total employment in the primary sector; employment of skilled workers rises by the same magnitude as the fall in employment of unskilled workers. When efficiency considerations are moderately important, the adoption of the new technology raises the relative wage of skilled workers, reduces aggregate employment as well as the employment level of unskilled labor in the primary sector, and will in general raise the employment level of skilled workers. However, if efficiency factors in the primary sector are very important, the indirect effect of the technological shock may completely offset the direct, positive effect, and the level of employment of skilled workers may remain unchanged. Thus, the effect of technological shocks on employment of skilled workers depends crucially on the strength of efficiency considerations in the primary sector.

The analysis also showed that, given the interactions between the two segments of the labor market induced by efficiency considerations, a skilled-biased technological shock can move the economy from an initial equilibrium in which there is no unemployment to a situation where highly-educated workers who are unable to obtain a primary-sector job may choose to remain unemployed rather than seek employment in the secondary sector. This somewhat paradoxical result may help explain why in several European countries (where unemployment benefit schemes are considerably more generous than in the United States) the unemployment rate of skilled workers has steadily increased in recent years, as documented for instance by Layard et al. (1991). To offset this adverse effect, policymakers may need to reduce the unemployment benefit rate to restore the incentive to work. Coordination of labor market policies may thus be a crucial issue in countries undergoing structural changes induced by large technological shocks.

^{1/} The Appendix shows that unemployment of unskilled workers may also emerge in equilibrium, if the decision to seek employment in the secondary sector or to queue for jobs in the primary sector is taken to depend, for that category of workers, on expected income in both sectors.

APPENDIX

Generalized Unemployment

This Appendix extends the basic framework developed in section II in order to account for the possibility of unemployment of low-ability workers. Suppose that wages in the secondary sector remain flexible. Since there are no barriers to entry in that sector, unemployment of unskilled labor may emerge only if workers with limited qualifications opt not to take a job in the secondary sector and instead opt to remain unemployed in the primary sector. Suppose also that low-ability workers in the primary sector perceive a benefit equal to a fraction v of the legal minimum wage, ω_U^* . Although, as argued in the text, the decision to queue for employment in the primary sector may depend on a number of economic and non-economic factors, let us assume that unskilled workers will decide to do so solely if the net expected utility stream of queueing is positive, that is, as long as

$$V_S^U \leq \pi(\omega_U^* - e_U)/\rho + (1-\pi)v\omega_U^*/\rho, \quad \pi = L_{PU}^d/L_{PU}^s \quad (A1)$$

where V_S^U denotes the discounted utility stream of an unskilled worker employed in the secondary sector, L_{PU}^s the unskilled labor force in the primary sector, and π the employment probability for low-ability workers in the primary sector. Assuming that firms' hiring decisions are random, π can be measured by the employment ratio of unskilled workers in the primary sector. 1/ The discounted utility stream associated with employment in the secondary sector is, given the assumed flexibility of wages, simply $V_S^U = (\omega_U - e_U)/\rho$. Equation (A1) holds with equality in the steady state so that, using the previous result:

$$\pi = 1 - \frac{\omega_U^* - \omega_U}{\omega_U^*(1-v) - e_U}, \quad (A2)$$

which indicates that the employment probability depends, in particular, on the wage differential across sectors for unskilled workers. To obtain an interior solution (that is, $0 < \pi < 1$) requires that the market-clearing wage adjusted for the disutility of effort in the secondary sector exceed the unemployment benefit, or that

1/ The decision process proposed here is conceptually close to the rural-urban migration mechanism proposed by Harris and Todaro (1970) for developing countries. As before, on-the-job search is excluded.

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$\omega_U - e_U > v\omega_U^*$; otherwise, all unskilled workers would opt to join the unemployment queue in the primary sector. Using equation (6a), equation (A2) can be solved for the size of the unskilled labor force in the primary sector, L_{PU}^S . There is no explicit solution to this equation, but it can be shown that

$$L_{PU}^S = L_{PU}^S(\omega_U, \omega_E; \omega_U^*, v), \quad (A3)$$

where the sign of the partial derivative with respect to ω_E depends on the sign of σ , while the effect of an increase in the unemployment benefit rate depends on the difference between the legal minimum wage and the market-clearing wage:

$$sg\left[\frac{\partial L_{PU}^S}{\partial \omega_E}\right] = sg(-\sigma), \quad sg\left[\frac{\partial L_{PU}^S}{\partial v}\right] = sg(\omega_U^* - \omega_U).$$

Since we have assumed that $\sigma > 0$, the first expression shows that an increase in the efficiency wage lowers the supply of low-ability workers in the primary sector. A rise in the wage paid to skilled workers lowers the demand for both categories of labor in the primary sector, thus reducing the probability of finding employment in that sector. The last expression shows that an increase in the unemployment benefit rate paid to low-ability workers raises the supply of unskilled labor in the primary sector as long as the minimum wage is higher than the market-clearing wage.

Assuming that the unemployment benefit rate θ is large enough to ensure that skilled workers who are not hired in the primary sector choose to remain unemployed, the market-clearing wage is now determined by, using equation (A3):

$$\bar{L}_U - L_{PU}^S(\omega_U, \omega_E; \omega_U^*, v) = (h_1 - \omega_U)/h_{11}, \quad \omega_U - e_U \leq \theta\omega_E \quad (A4)$$

Solving this equation yields

$$\omega_U = \omega_U(\omega_E; \omega_U^*, v), \quad (A5)$$

which shows that the market-clearing wage depends positively on the unemployment benefit rate for unskilled workers. Given that $\sigma > 0$, an increase in the efficiency wage lowers the market-clearing wage since it reduces the employment probability (through its adverse effect on demand), the supply of unskilled workers in the primary sector, and

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thus raises the number of job seekers in the secondary sector. Changes in the legal minimum wage for unskilled workers have, however, an ambiguous effect. This ambiguity results from the fact, that, as shown on the left-hand side of equations (A1) and (A2), an increase in ω_U^* raises the attractiveness of being in the primary sector (thus increasing supply), but lowers the employment probability, since it reduces the demand for low-ability workers in the primary sector of the economy.

Since the unemployment rate for unskilled workers u_U is equal to $1-\pi$, assuming that an interior solution obtains, equation (A2) yields

$$u_U = 1 - L_{PU}^d / L_{PU}^s = \frac{\omega_U^* - \omega_U}{\omega_U^*(1-v) - e_U} = u_U(\omega_U; \omega_U^*, v), \quad (A6)$$

which indicates that an increase in the unemployment benefit rate or a rise in the legal minimum wage in the primary sector has a positive effect on the unemployment rate of unskilled workers in the primary sector, while an increase in the market-clearing wage (since it reduces the incentive to queue for employment in the primary sector) has a negative effect. 1/ The sign of ω_U^* is unambiguous as long as $\omega_U - e_U > v\omega_U^*$, that is, as long as employment in the secondary sector is perceived by low-ability workers to be more attractive than unemployment.

1/ An increase in the market-clearing wage would also raise the efficiency wage if the unemployment benefit rate θ is low, as shown in equation (11b). Since $\sigma > 0$, this effect would reduce the demand for skilled as well as unskilled labor, thus exacerbating the rise in unemployment of low-ability workers in the primary sector.

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