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Hans Gersbach
Achim Schniewind

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Hans Gersbach

*Alfred Weber Institute, University of Heidelberg
and IZA, Bonn*

Achim Schniewind

Alfred Weber Institute, University of Heidelberg

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IZA

P.O. Box 7240
D-53072 Bonn
Germany

Tel.: +49-228-3894-0
Fax: +49-228-3894-210
Email: iza@iza.org

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ABSTRACT

Uneven Technical Progress and Unemployment*

In a two-sector model with real wage rigidity, we examine how technical progress in one sector affects unemployment in the whole economy. We show that aggregate unemployment decreases for uneven technical change in the case of Cobb-Douglas production functions. For every type of technical progress, however, there are also elasticities of substitution in production and utility functions leading to a rise in unemployment. Moreover, we identify polar cases when unemployment strongly decreases.

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Hans Gersbach
Alfred-Weber-Institut
Universität Heidelberg
Grabengasse 14
69117 Heidelberg
Germany
Tel.: +49-6221-54 3173
Fax: +49-6221-54 3578
Email: hans@gersbach.de

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1 Introduction

Productivity improvements are the most important factors leading to economic growth and an increase in material well-being. In contrast, sectoral productivity improvements are often associated with job losses and therefore lead to worker opposition.

The problem behind this apparent contradiction is that technological progress does not usually take place uniformly across all sectors in the economy. This may occur temporarily, but uneven technical progress may occur over very long time horizons as well. This has been indicated by the differential growth rates in total factor productivity between the manufacturing and the service industry in industrial countries for many decades. Sectoral productivity improvements typically occur also when state-owned industries are privatized. Examples can be observed in transition economies but also in developed countries (see the deregulation of telecommunication in West European countries and the US). An insightful exploration of uneven technological progress can be found in Baumol, Blackman and Wolf (1989).¹

In this paper we examine the short-term relationship between technical progress in only one sector and unemployment. In a two-sector model with real wage rigidity, we examine the three standard types of uneven technological progress (Hicks neutral, Harrod neutral and Solow neutral). We allow for different degrees of complementarities between consumption goods *and* between production factors as expressed by different elasticities of substitution.

We show that if both sectors produce with Cobb-Douglas technologies and the same labor and capital shares, unemployment unambiguously decreases when technical progress (of any kind) occurs. We also show that aggregate unemployment may rise or fall given any type of technical progress. Whether unemployment rises or falls is determined by the joint levels of elasticities of substitution between consumption goods on the demand side and production factors (labor and capital) on the supply side.

Our paper may have applications for the impact of product market reforms concerning unemployment in Europe. Promoting competition in product markets is concerned with relaxing entry and exit barriers through regulation or deregulation. Extreme

¹See also Dollar and Wolf (1993), van Ark and Pilat (1993), Baily and Gersbach (1995).

cases are the privatization and deregulation of the telecommunication and postal service industries. As discussed in a series of papers based on productivity studies at the McKinsey Global Institute (Baily 1993, Baily and Gersbach 1995, Gersbach and Sheldon 1996, Börsch-Supan [1999]), product market reforms in Europe have the potential to foster total factor productivity gains in a variety of industries. Furthermore, Anderson [2000] highlights that product market integration in Europe may lead to a more unequal distribution of wages and employment, despite aggregate gains in terms of higher real incomes and employment. Burda [1999] shows that shop closing laws tend to have a negative effect on employment and output. The effect on welfare is ambiguous when there are gains from synchronization of time. Gersbach [2000] provides a survey on whether product market reforms could help to reduce unemployment in Europe.

Moreover, the comprehensive econometric studies by Green and Mayes [1991], Hay and Liu [1997] and Nickell [1996] provide evidence that productivity levels or growth rates are, on average, negatively correlated with market power. Thus, increasing competition may cause productivity improvements by inducing organizational and design changes.² Our paper focuses on short term effects of product market reforms, i.e. sectoral productivity improvements and their short-term impact on unemployment. When elasticities of substitution are known or can be estimated with sufficient precision, our paper can be used to predict whether or not product market reforms lead to a decline in aggregate unemployment.

The question of how productivity improvements in one sector affect employment in that sector as well as in the economy as a whole is an old issue in economics. The modern answers date back at least to Baumol [1967]. In his unbalanced productivity model, Baumol analyzed costs per unit of output for fixed wage growth as well as the employment distribution among sectors for fixed output ratios. However, Baumol did not focus on unemployment caused by labor market rigidities.

²An overview of the potential impact of regulatory reform in product markets in Europe can be found in OECD (1997). The ongoing changes in production technologies can be interpreted as a third paradigm – sometimes called agile production – which replaces craft or mass production to some extent [see Baily and Gersbach 1995]. The transition towards a new production paradigm has potentially large effects on wage and employment, and may raise the wage and job opportunities of some workers relative to others [see e.g. Lindbeck and Snower 1995, Lindbeck and Snower 1996].

Analyzing the effects of restructuring state-owned industries, Blanchard recently explored how labor-saving productivity improvement can cause unemployment with fixed real wages [Blanchard 1998]. The recent literature has emphasized that the relationship between technical progress and unemployment may be ambiguous. Aghion and Howitt (1994 and 1998) have examined a model in which technological progress makes old skills obsolete and forces former workers to train and move elsewhere, which may increase unemployment.³

A two-sector model in which technical progress alternatively raises sectoral productivity has been developed by Cohen and Saint-Paul [1997]. Goods are assumed to be complements, and consequently higher productivity in one sector leads to a fall in the corresponding prices. By introducing labor-market imperfections such as bargaining and costly worker re-allocation, the dynamic model shows job destruction in the sector which benefits from technical progress and job creation in the less productive sector.

Our model treats this topic in a simplified manner, because we do not endogenize technical progress. Rather, we allow for arbitrary combinations of elasticities of substitution on the demand side and in the production sectors which allow us to clarify the link between uneven technical progress and unemployment. In the next section the basic model shall be outlined. Chapters 3 and 4 discuss the impacts caused by uneven technical progress on unemployment. Chapters 5 and 6 summarize and conclude.

³A different approach has been developed by Peretto (1999). Here innovations are introduced by existing firms that do not drive other firms out of the market. In this case, higher growth may lead to higher unemployment.

2 The Model

We explore a simple model analyzing the employment effects caused by uneven technical change for any combination of substitution elasticities on the demand side and in both production sectors. Our model consists of two sectors, with technological progress taking place in sector 1. Inputs into production in both industries are labor and capital.⁴ The production functions are of the CES type:

$$q_1 = C \left(\beta (AL_1)^{\frac{\sigma_1-1}{\sigma_1}} + (1-\beta)(BK_1)^{\frac{\sigma_1-1}{\sigma_1}} \right)^{\frac{\sigma_1}{\sigma_1-1}} \quad (1)$$

$$q_2 = \left(\beta L_2^{\frac{\sigma_2-1}{\sigma_2}} + (1-\beta)K_2^{\frac{\sigma_2-1}{\sigma_2}} \right)^{\frac{\sigma_2}{\sigma_2-1}} \quad (2)$$

Subscripts 1 and 2 denote the first and second sector, respectively. σ_1 and σ_2 are the corresponding elasticities of substitution between production factors in sector 1 and 2. We assume that technical progress takes place in sector 1, whereas the rest of the economy, i.e. sector 2, remains unchanged. We distinguish between a rise in total factor productivity (a rise in C), labor saving technical progress (a rise in A) and capital saving technical progress (a rise in B). They correspond to the three standard forms discussed in the literature: Hicks neutral, Harrod neutral and Solow neutral technical change, respectively.

We assume that labor is supplied inelastically for the whole economy.⁵ Total labor supply is \bar{L} . As we are analyzing short-term effects of uneven technical change, capital in either sector is also assumed to be inelastically supplied. In contrast to labor, capital in our model is assumed to be industry-specific. This essentially means that the physical capital is immobile across sectors. The total supply is given by \bar{K}_1 and \bar{K}_2 , respectively. We assume that price-taking firms in each industry compete for the available capital that is supplied inelastically. An alternative framework runs as follows. Firms in each sector can obtain capital in a “global” market at price r^* when capital is supplied completely elastically. Our main argument for the case of Cobb-

⁴Capital can include physical and human capital.

⁵Our model could be complemented by a labor/leisure tradeoff. Since we focus on employment rather than on aggregate output, adding a labor/leisure tradeoff would not affect our basic results.

Douglas production functions holds in this framework as well, since firms adjust capital optimally.⁶

We assume that all types of households have the same CES utility function, so that aggregate demand by households can be derived from a representative consumer with the utility function:

$$u = \left(\alpha c_1^{\frac{\sigma_u-1}{\sigma_u}} + (1-\alpha) c_2^{\frac{\sigma_u-1}{\sigma_u}} \right)^{\frac{\sigma_u}{\sigma_u-1}} \quad (3)$$

c_1 and c_2 denote the consumption levels of good 1 and good 2. σ_u is used to denote the elasticity of substitution between the two goods.

The institution in the labor market upon which we focus, is an exogenously given real wage $\bar{r}\bar{w}$ for workers in either sector. At the beginning, we assume the real wage to exceed the market clearing level, which means that it is binding and leads to unemployment. That is, throughout the paper, we assume $\bar{L} > L_1 + L_2$ except in a special case where $L_1 + L_2$ can exhaust \bar{L} . The nominal wage w is equal to $p \cdot \bar{r}\bar{w}$, where p denotes the price index. A variety of regulations can cause a real wage floor: explicit minimum wages, an unemployment benefit system or institutional wage settings. Our focus is the interaction between technological progress and unemployment. Thus, any motivation for real wages to be set above market clearing levels serves our purpose.

2.1 The System of Equations

The equilibrium with real wage rigidities is determined by the following system of equations. Using utility maximization, we obtain the following demand functions for goods 1 and 2:

$$c_1 = \frac{b}{p_1 + p_2 \left(\frac{p_1(1-\alpha)}{p_2 \alpha} \right)^{\sigma_u}} \quad (4)$$

⁶Other results in our paper, however, would need to be modified in the presence of completely elastic capital supply.

$$c_2 = \frac{b}{p_2 + p_1 \left(\frac{p_2 \alpha}{p_1 (1 - \alpha)} \right)^{\sigma_u}} \quad (5)$$

b denotes the households' budget. In order to derive the aggregated demand function of the representative consumer, we must replace the budget b by the aggregate income of the whole economy (the CES demand functions are unit-elastic with respect to income). Therefore, we set $b = p_1 q_1 + p_2 q_2$.

In each industry we consider a representative firm that takes the wage and the capital cost in the sector as given. As was previously noted, the physical capital is industry-specific and thus immobile while labor is mobile across sectors. The industries' profit functions are sales with factor costs subtracted:

$$\pi_1 = p_1 q_1 - w L_1 - r_1 K_1 \quad (6)$$

$$\pi_2 = p_2 q_2 - w L_2 - r_2 K_2 \quad (7)$$

We assume all goods markets and the capital market to be perfectly competitive. Additionally, firms are assumed to be price takers in the labor market. By taking the derivative of profits 1 and 2 with respect to the production factors L_1, K_1, L_2 and K_2 for $\sigma_1 \neq 1$ and $\sigma_2 \neq 1$, we obtain four first-order conditions for profit maximization:

$$\frac{\partial \pi_1}{\partial L_1} = p_1 \beta C A \frac{\sigma_1 - 1}{\sigma_1} \cdot q_1^{\frac{1}{\sigma_1}} \cdot L_1^{\frac{-1}{\sigma_1}} - w = 0 \quad (8)$$

$$\frac{\partial \pi_1}{\partial K_1} = p_1 (1 - \beta) C B \frac{\sigma_1 - 1}{\sigma_1} \cdot q_1^{\frac{1}{\sigma_1}} \cdot K_1^{\frac{-1}{\sigma_1}} - r_1 = 0 \quad (9)$$

$$\frac{\partial \pi_2}{\partial L_2} = p_2 \beta q_2^{\frac{1}{\sigma_2}} \cdot L_2^{\frac{-1}{\sigma_2}} - w = 0 \quad (10)$$

$$\frac{\partial \pi_2}{\partial K_2} = p_2 (1 - \beta) q_2^{\frac{1}{\sigma_2}} \cdot K_2^{\frac{-1}{\sigma_2}} - r_2 = 0 \quad (11)$$

Market clearing for good 1 implies:

$$c_1 = q_1 \tag{12}$$

Inserting the aggregated income of the whole economy ($p_1q_1 + p_2q_2$) into the budget entering the demand function c_1 , we obtain the following equivalent condition for market clearing:

$$c_1 = q_1 = \frac{p_1q_1 + p_2q_2}{p_1 + p_2 \left(\frac{p_1(1-\alpha)}{p_2\alpha} \right)^{\sigma_u}}$$

In the case where $\sigma_u > 0$ we can write the market clearing as:

$$\frac{p_2}{p_1} = \left(\frac{1-\alpha}{\alpha} \right) \left(\frac{q_1}{q_2} \right)^{\frac{1}{\sigma_u}} \tag{13}$$

The appropriate consumer price index is defined by (see e.g. Dixon and Rankin [1995])

$$p = \left[\frac{\alpha^{\sigma_u}}{\alpha^{\sigma_u} + (1-\alpha)^{\sigma_u}} p_1^{(1-\sigma_u)} + \frac{(1-\alpha)^{\sigma_u}}{\alpha^{\sigma_u} + (1-\alpha)^{\sigma_u}} p_2^{(1-\sigma_u)} \right]^{\left(\frac{1}{1-\sigma_u} \right)} \tag{14}$$

This price index guarantees that changes in prices do not affect the households' utility as long as real incomes remain constant. Nominal minimum wages for workers in both industries are therefore given by:

$$w = \bar{r}\bar{w} \cdot p \tag{15}$$

Moreover, market clearing in the capital market requires

$$K_1 = \bar{K}_1 \tag{16}$$

$$K_2 = \bar{K}_2 \tag{17}$$

Finally, we normalize the price of the second good to 1, i.e.

$$p_2 = 1 \tag{18}$$

The equilibrium is determined by the system of equations 4, 5, 8, 9, 10, 11, 13, 14, 15 16, 17. The unknown variables are c_1 , c_2 , L_1 , K_1 , r_1 , L_2 , K_2 , r_2 , p_1 , p , w . Since

capital is supplied inelastically in each sector, market clearing implies that K_1 and K_2 , demanded by the representative firms in each sector are equal to $\overline{K_1}$ and $\overline{K_2}$. We shall continue working directly with the equilibrium values K_1 and K_2 without using the $\overline{K_1}$ and $\overline{K_2}$ notation.

Obviously, we assume in general that each sector contains more than one firm. In this case, the derivation of the equilibrium must be adjusted accordingly. That is we would obtain $K_1 = \frac{\overline{K_1}}{n_1}$ and $K_2 = \frac{\overline{K_2}}{n_2}$, where n_1 and n_2 are the number of firms in sector 1 and 2, respectively. Note that prices of industry-specific capital are only relevant to our arguments in the next section. In the polar cases of section 4, the argument does not depend on the equilibrium reactions of r_1 and r_2 .

3 Technical Progress: Cobb-Douglas Production Functions

In this section, we consider our *benchmark* case, in which all production functions are Cobb-Douglas, i.e. $\sigma_1 = \sigma_2 = 1$. In this case, we cannot differentiate between a rise in total factor productivity (tfp), labor saving or capital-saving technical progress in sector 1, as all types of technical progress are equivalent. In general, such uneven productivity improvements have two direct impacts on employment. First, marginal productivity of labor in sector 1 increases, which has a positive impact on employment using a fixed real wage regime. Second, due to higher productivity in sector 1, the price of good 1 falls relative to the price in sector 2. This has negative consequences for employment in sector 1 and positive employment effects in sector 2. We will always focus on a situation when there is unemployment in both sectors before the productivity improvements in sector 1 take place. For the Cobb-Douglas case we obtain:

Proposition 1

Suppose $\sigma_1 = \sigma_2 = 1$ in the two-sector economy. Then, a rise of productivity in sector 1 raises aggregate employment.

The proof is given in the appendix. The reasoning runs as follows: as the productivity of industry 1 increases, the production of good 1 and 2 increase as well, which in turn increases the real income of the whole economy. The same Cobb-Douglas functions in

both sectors imply that the income distribution must remain identical with β being the share of labor. With a fixed real wage, an increase in real income means that the employment rate must be higher.⁷

It is unnecessary to make assumptions about the elasticity of substitution in the utility function σ_u in order for proposition 1 to hold. The elasticity determines in *which sector* the positive employment effect takes place. Proposition 1 only shows that *aggregate* employment increases, without specifying the sector.

In what follows, we demonstrate that the aggregate employment effect can be positive or negative for any type of technical change. We identify polar cases where technological progress of any kind strongly decreases or increases aggregate unemployment (compared to the Cobb-Douglas case).

4 Technical Progress: Polar Cases

4.1 A Rise in Total Factor Productivity

We have established that for our benchmark case, i.e. the Cobb-Douglas production functions with "intermediate" elasticities of substitution, uneven technical progress always increases the aggregate demand for labor for a given real wage. We now go on to show that aggregate employment can also decrease when uneven Hicks neutral technical progress takes place. We will continue with a discussion of the circumstances in which the increase of employment is even higher than in the benchmark case. All of the following facts refer to the two-sector model outlined in section 2. We obtain

Fact 1:

A rise in tfp in sector 1 leads to higher unemployment provided the elasticities of substitution on the demand side and the production factors in the remaining sector are sufficiently small.

⁷So far we have assumed that the unemployed have no income. Introducing unemployment benefits that are lower than the minimum real wage would not change our arguments.

Fact 1 follows from the following considerations. Let σ_u and $\sigma_2 \rightarrow 0$. Production in sector 2 becomes thus Leontief:

$$q_2 = \min(L_2, K_2) \quad (19)$$

The profits of industry 2 could thus be written as

$$\pi_2 = p_2 K_2 - w L_2 - r_2 K_2 \quad (20)$$

If capital is binding, any further worker employed cannot increase output. Hence, the first-order condition with respect to labor in this case is

$$\frac{\partial \pi_2}{\partial L_2} = -w = 0 \quad (21)$$

and thus $w = 0$. This reflects that the marginal productivity of any further worker employed in sector 2 would be zero if capital is binding, so that nobody else can be employed there for the given real wage. Thus, with fixed capital, production of q_2 cannot increase. Since $\sigma_u \rightarrow 0$, the utility function becomes

$$u = \min(c_1, c_2) \quad (22)$$

As q_2 cannot increase, q_1 cannot increase either, since otherwise marginal utility and thus p_1 and w would go to zero. This follows from the market clearing condition (13). If $q_1 > q_2$ we obtain $p_1 = 0$ for $\sigma_u \rightarrow 0$. As can be seen from the first-order condition for profit maximization (8), this would cause the value of marginal productivity of labor in sector 1 to be zero, i.e. $w = 0$. The latter cannot be an equilibrium as $w = \bar{r} \bar{w} \cdot p > 0$ because $p_2 = 1$ and thus p cannot become zero. However, a higher tfp in sector 1 implies that, ceteris paribus, production of good 1 tends to increase. Consequently, L_1 must decrease in order to prevent this since K_1 remains unchanged, which establishes fact 1.

We continue with an analysis of the opposite extreme, where a rise of tfp causes a very large positive employment effect.

Fact 2:

A sufficient rise in tfp leads to a higher employment level than in the benchmark case provided the elasticities of substitution on the demand side and the production factors in sector 1 are sufficiently high.

To establish fact 2, let σ_u and $\sigma_1 \rightarrow \infty$. From the market clearing condition (13), we observe that $p_1 = \frac{\alpha}{1-\alpha}$ if $\sigma_u \rightarrow \infty$, independent of the quantities q_1 and q_2 . This is caused by the perfect substitution for $\sigma_u \rightarrow \infty$, implying a utility function with constant marginal utility of the type:

$$u = \alpha c_1 + (1 - \alpha) c_2 \quad (23)$$

When $\sigma_1 \rightarrow \infty$ as well, production in sector 1 also becomes substitutional implying constant marginal productivity of the production factors:

$$q_1 = C \left(\beta L_1 + (1 - \beta) K_1 \right) \quad (24)$$

We have set $A=B=1$ in this case. If there is a higher employment level in sector 1, neither the marginal product of labor nor the price of good 1 will decrease. We now examine the profit function of industry 1:

$$\pi_1 = p_1 \cdot C \left(\beta L_1 + (1 - \beta) K_1 \right) - w L_1 - r_1 K_1 \quad (25)$$

The first-order condition for profit maximization with respect to labor is

$$\frac{\partial \pi_1}{\partial L_1} = p_1 C \beta - w = 0 \quad (26)$$

Now consider a scenario with a binding nominal wage

$$w = \bar{r}\bar{w} \cdot p > p_1 C \beta \quad (27)$$

before the increase of C and

$$w = \overline{r\overline{w}} \cdot p \leq p_1 C \beta \quad (28)$$

after a sufficient increase of C. This implies that before the *tfp* improvement there is zero employment in sector 1 and after the improvement there is full employment.⁸

The example in fact 2 is an extreme case and serves only to illustrate the implications of the more realistic case where σ_1 and σ_u are large, but finite.

4.2 Labor-Saving Technical Progress

In this subsection we study labor-saving technical progress. We wish to demonstrate, as in all other cases, that the direction of employment development depends crucially on the elasticities of substitution.

Fact 3:

Labor-saving technical progress in sector 1 leads to an increase in unemployment provided the elasticity of substitution between production factors in sector 1 is sufficiently small.

We assume $\sigma_1 \rightarrow 0$, i.e. let q_1 be Leontief:

$$q_1 = \min(AL_1, K_1) \quad (29)$$

where we have set B=C=1. Suppose that capital is binding. When A increases, capital remains binding. Hence, from the profit function

$$\pi_1 = p_1 K_1 - wL_1 - r_1 K_1 \quad (30)$$

we obtain the first-order condition as

⁸Note that sector 2 is not affected by the productivity change.

$$\frac{\partial \pi_1}{\partial L_1} = -w = 0 \quad (31)$$

Therefore, we would have $w=0$. This implies that, in order to achieve positive labor income, L_1 must decrease. This is not compensated by higher employment in sector 2. Note that we have not used any price adjustments in this argument, i.e. the magnitude of σ_u is not essential. Therefore, our argument also holds in a one-sector economy where no relative goods-price changes can occur (see also Blanchard [1998]). We continue with a consideration of the opposite case in which the elasticity of substitution between production factors in sector 1 is high.

Fact 4:

A sufficiently large labor-saving technical change leads to a more extreme employment level increase than in the benchmark case provided the elasticities of substitution are sufficiently high on the demand and supply side in sector 1.

In order to show fact 4, let σ_u and $\sigma_1 \rightarrow \infty$. We obtain, once again, $p_1 = \frac{\alpha}{1-\alpha} = \text{constant}$ for $\sigma_u \rightarrow \infty$ from the market clearing equation (13). In the case of the substitutional production function we obtain the profit

$$\pi_1 = p_1 \left(\beta A L_1 + (1 - \beta) K_1 \right) - w L_1 - r_1 K_1 \quad (32)$$

where we set $B=C=1$. The first-order condition yields

$$\frac{\partial \pi_1}{\partial L_1} = p_1 \beta A - w = 0 \quad (33)$$

We again consider the constellation

$$\bar{r}\bar{w} \cdot p > p_1 \beta A \quad (34)$$

before the increase of A and

$$\bar{r}\bar{w} \cdot p \leq p_1 \beta A \quad (35)$$

after a sufficiently large increase. This means that in the first sector *nobody* is employed before the labor-saving improvement and *everybody* (up to full employment) is employed afterwards. This establishes fact 4 since employment does not change in sector 2.

Fact 4 illustrates the extreme case where productivity improvements increase the marginal (equal to the average) product of labor until it is above the real reservation wage. As a consequence of the linear technology, all workers can be employed after technological progress has taken place in sector 1.

4.3 Capital-Saving Technical Progress

Finally, we examine capital-saving technical progress. Our scenarios start with positive employment in both sectors. Again we demonstrate that both positive and negative consequences for employment may occur by considering polar cases.

Fact 5:

Capital-saving technical progress leads to a decrease in employment provided the elasticities of substitution on the demand and supply side in sector 2 are sufficiently low.

In order to show fact 5, let $\sigma_u \rightarrow 0$. According to the market clearing condition (13), we must have $q_1 = q_2$. Otherwise p_1 would be zero or infinity. In the first (second) case there can be no employment in sector 1 (sector 2) and therefore one sector is inactive which we have excluded.

Moreover, let $\sigma_2 \rightarrow 0$. Now suppose that B increases. For $\sigma_1 > 0$, q_1 rises, ceteris paribus. The market clearing condition (13) implies that q_2 would rise as well. With $\sigma_2 = 0$, capital being binding and fixed production factors in sector 2, q_2 cannot rise and no more workers can be employed there. Hence, q_1 cannot increase either, because otherwise p_1 would immediately approach 0, as would the wages in sector 1. As real wages are given by $\bar{r}\bar{w}$, L_1 must decline instead. The situation is different when the elasticity of substitution between the consumption goods is high. In this case we obtain:

Fact 6:

Capital-saving technical progress enhances employment more than in the benchmark case provided the elasticity of substitution on the demand side is sufficiently high.

In order to establish fact 6, let $\sigma_u \rightarrow \infty$, such that a higher production of good 1 does not lead to a price decline for the good. Now, if $\sigma_1 < \infty$, an increase of B increases marginal productivity of labor in sector 1. Thus, with real wages given by $\overline{r\bar{w}}$, employment must increase in the case of capital-saving technical progress. The increase is the highest in the case of $\sigma_1 = 0$.

5 Summary of the Results

The results of the six facts are summarized in table 1. The first row of the table shows the (described) constellation of elasticities of substitution leading to an increase of aggregate unemployment for every type of technical progress. The second row shows the constellations that lead to a stronger decrease of aggregate unemployment than in our benchmark case with Cobb-Douglas production functions.

Table 1 illustrates that for every type of technological progress, a suitable combination of elasticities on the demand side and elasticities in sector 1 and sector 2 may increase aggregate unemployment. While low elasticities of substitution between consumption goods generally tend to imply a negative relationship between productivity improvement and employment, high substitution elasticities of demand may lead to strongly positive reactions of employment. Of course, we have by no means exhausted all the interesting constellations of substitution elasticities on the supply and demand side. Our objective was simply to illustrate that any relationship between productivity improvements and unemployment can occur.

Table 1:

	total factor productivity improvement	labor-saving tech- nical progress	capital-saving technical progress
increase of aggregate unemployment	$\sigma_u \rightarrow 0, \sigma_2 \rightarrow 0$	$\sigma_1 \rightarrow 0$	$\sigma_u \rightarrow 0, \sigma_2 \rightarrow 0$
strong decrease of ag- gregate unemployment	$\sigma_u \rightarrow \infty, \sigma_1 \rightarrow \infty$	$\sigma_u \rightarrow \infty, \sigma_1 \rightarrow \infty$	$\sigma_u \rightarrow \infty, \sigma_1 \rightarrow 0$

6 Conclusion

Since technical change does often not affect an economy in a uniform way, we have analyzed the (short-term) effects of *uneven* technical progress. In a simple two-sector model with real wage rigidity, we have examined the impact on unemployment of rising total factor productivity, labor saving and capital saving technological progress. We have shown that for every type of uneven technical change, aggregate unemployment may rise or fall, depending on the elasticities of substitution on the supply and demand side.

Apart from technical progress, our analysis could be used to study the impact of uneven productivity improvements, which usually take place when state-owned firms are privatized and restructured as in transition economies. Whether or not, for instance, large-scale restructuring exercises in transition economies raise aggregate unemployment depends entirely on the combination of elasticities of substitution in the reorganized sector, in the rest of the economy and on the demand side.

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7 Appendix

Proof of Proposition 1:

We consider the following Cobb-Douglas production functions:⁹

$$q_1 = C L_1^\beta K_1^{1-\beta}$$

$$q_2 = L_2^\beta K_2^{1-\beta}$$

In the Cobb-Douglas case, the first-order conditions for profit maximization in sector 1 and 2 with respect to labor and capital are:

$$w = p_1 C \beta L_1^{(\beta-1)} K_1^{(1-\beta)} \quad (36)$$

$$w = \beta L_2^{(\beta-1)} K_2^{(1-\beta)} \quad (37)$$

$$r_1 = p_1 C (1 - \beta) L_1^\beta K_1^{-\beta} \quad (38)$$

$$r_2 = (1 - \beta) L_2^\beta K_2^{-\beta} \quad (39)$$

Note that firms are price takers with respect to all production factors. Therefore, the Cobb-Douglas nature of production implies $wL_1 = \beta p_1 q_1$, $wL_2 = \beta q_2$, $r_1 K_1 = (1 - \beta) p_1 q_1$ and $r_2 K_2 = (1 - \beta) q_2$, which follows from the first-order conditions above. The fact that the labor and capital shares are constant in each sector will be important later in the proof.

Dividing the first-order condition (36) by (37) yields

$$1 = p_1 C \left(\frac{L_1}{L_2} \right)^{\beta-1} \left(\frac{K_1}{K_2} \right)^{1-\beta} \quad (40)$$

which leads to

⁹Since all types of technical progress are equivalent, a single parameter C for comparative statics is sufficient.

$$p_1 = \frac{1}{C} \left(\frac{L_1}{L_2} \right)^{1-\beta} \left(\frac{K_2}{K_1} \right)^{1-\beta} \quad (41)$$

The market clearing condition (13) is given by

$$p_1 = \left(\frac{\alpha}{1-\alpha} \right) \left(\frac{q_2}{q_1} \right)^{\frac{1}{\sigma_u}} \quad (42)$$

$$= \left(\frac{\alpha}{1-\alpha} \right) \left(\frac{1}{C} \right)^{\frac{1}{\sigma_u}} \left(\frac{L_2}{L_1} \right)^{\frac{\beta}{\sigma_u}} \left(\frac{K_2}{K_1} \right)^{\frac{1-\beta}{\sigma_u}} \quad (43)$$

implying

$$\left(\frac{L_1}{L_2} \right)^{1-\beta} = p_1^{\frac{\sigma_u(\beta-1)}{\beta}} \left(\frac{1-\alpha}{\alpha} \right)^{\frac{\sigma_u(\beta-1)}{\beta}} C^{\frac{\beta-1}{\beta}} \left(\frac{K_2}{K_1} \right)^{\frac{(1-\beta)^2}{\beta}} \quad (44)$$

Inserting this into 41 yields

$$p_1 = \frac{1}{C} \left(\frac{K_2}{K_1} \right)^{1-\beta} p_1^{\frac{\sigma_u(\beta-1)}{\beta}} \left(\frac{1-\alpha}{\alpha} \right)^{\frac{\sigma_u(\beta-1)}{\beta}} C^{\frac{\beta-1}{\beta}} \left(\frac{K_2}{K_1} \right)^{\frac{(1-\beta)^2}{\beta}} \quad (45)$$

Solving for p_1 we obtain

$$p_1 = \frac{1}{C^{\sigma_u(\beta-1) - \beta} \left(\frac{1-\alpha}{\alpha} \right)^{\frac{\sigma_u(\beta-1)}{\beta - \sigma_u(\beta-1)}} \left(\frac{K_2}{K_1} \right)^{\frac{1-\beta}{\beta - \sigma_u(\beta-1)}}} \quad (46)$$

$$= \frac{1}{C^{\sigma_u(\beta-1) - \beta}} \cdot \text{const.} \quad (47)$$

As $0 < \beta < 1$ and $\sigma_u \geq 0$, we have $\frac{\partial p_1}{\partial C} < 0$.

Solving the first-order condition of profit maximization in sector 2 (eq. 37) for labor demand, we obtain

$$L_2 = \left(\frac{\beta}{\overline{r\overline{w}} p} \right)^{\frac{1}{1-\beta}} K_2 \quad (48)$$

with $\overline{r\overline{w}} p$ being the nominal wage, i.e. fixed real wage $\overline{r\overline{w}}$ times the price index p . As p_1 decreases with C and $p_2 = 1$, $p = p(p_1, p_2)$ decreases with C as well, implying that L_2 increases. With fixed capital this means that production in sector 2 increases.

From the market clearing condition (eq. 42), we observe that in order for p_1 to decrease $\frac{q_1}{q_2}$ must increase. Since q_2 increases, q_1 must increase as well. Thus, we have an increase of production in sector 1, too.

As we have an increase in production of good 1 and 2, aggregate real income increases and so does real income received by capital $(r_1 K_1 + r_2 K_2)/p = (1 - \beta)(p_1 q_1 + q_2)/p$ and real income received by labor $(wL_1 + wL_2)/p = \beta(p_1 q_1 + q_2)/p$. In particular, for the Cobb-Douglas production functions, the *constant* income share for labor β is given by

$$\beta = \frac{\bar{r}\bar{w} L_1}{(p_1 q_1)/p} = \frac{\bar{r}\bar{w} L_2}{(p_2 q_2)/p} = \frac{\bar{r}\bar{w}(L_1 + L_2)}{(p_1 q_1 + p_2 q_2)/p} = \frac{w(L_1 + L_2)/p}{(p_1 q_1 + p_2 q_2)/p} \quad (49)$$

Since the real income of the economy, i.e. the denominator, increases, $L_1 + L_2$ must increase as well for a fixed real wage $\bar{r}\bar{w} = \frac{w}{p}$. QED.

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