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ABSTRACT

Uneven Technical Progress and Unemployment*

In a two-sector-economy with real wage rigidity, we examine how technical progress in one sector affects aggregate unemployment. We show that aggregate unemployment decreases for uneven technical change in the case of Cobb-Douglas production functions. For every type of technical progress 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.

JEL Classification: D58, E24, J60, L13

Keywords: uneven technical progress, elasticities of substitution, unemployment

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1 Introduction

Productivity improvements are the most important cause of economic growth and the increase in material well-being. In contrast, sectoral productivity improvements are often associated with job destruction and therefore lead to opposition from the workers.

The problem behind this apparent contradiction is that technological progress usually does not take place uniformly across all sectors in the economy. This may occur temporarily, but the differential growth rates in total factor productivity between the manufacturing and the service industry for many decades suggest that uneven technical progress can occur over very long time horizons, too. Sectoral productivity improvements typically occur 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 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) takes place. We also show that aggregate unemployment may rise or fall for every type of technical progress. The direction of the change 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. Only precise knowledge about the elasticities of substitution in production and on the demand side can allow conclusions about how uneven technological change affects unemployment.

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

Our paper may have applications for the impact of product market reforms on unemployment in Europe. Promoting competition in product markets is concerned with relaxing entry and exit barriers through regulation or deregulation. Extreme 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, Börsch-Supan 1999, Gersbach and Sheldon 1996), 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, even though there are 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 while 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, and thus sectoral productivity improvements, 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

² An 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, raising the wage and job opportunities of some workers relative to others [see e.g. Lindbeck and Snower 1995, Lindbeck and Snower 1996].

employment distribution among sectors for fixed output ratios. However, Baumol did not focus on unemployment caused by labor market rigidities.

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 on growth has emphasized that the relationship between technical progress and unemployment can 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 retrain 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 prices. By introducing labor-market imperfections such as bargaining and costly worker reallocation, the dynamic model shows job destruction in the sector which benefits from technical progress and job creation in the least productive sector.

Our model is much more simple than the new growth literature, because we do not endogenize technical progress. In contrast, we allow for arbitrary combinations of elasticities of substitution on the demand side and in the production sectors which allows us to clarify the link between uneven technical progress and unemployment. The following section of the paper outlines the basic model. Chapters 3 and 4 discuss the impacts of uneven technical progress on unemployment. Chapter 5 concludes.

³ A 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. He obtains a negative relationship between unemployment and growth.

2 The Model

We explore a simple model analyzing the employment effects of 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, Solow neutral technical change, respectively. We assume that labor is supplied inelastically, hence focusing on the demand side of the labor market.⁵ As we are analyzing short-term effects of uneven technical change, capital in either sector is assumed to be *fixed*.

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

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

⁴ Capital can include physical and human capital.

⁵ Our 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.

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 we focus upon is an exogenously given real reservation wage $\overline{r\overline{w}}$ for workers in either sector. At the beginning we assume the reservation wage to exceed the market clearing level, which means that it is binding and leads to unemployment. The nominal wage w is then $p \cdot \overline{r\overline{w}}$, 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. Since we focus on the interaction between technological progress and unemployment, any reason for real wages to be set above market clearing levels would serve our purpose.

2.1 The System of Equations

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

$$c_1 = \frac{b}{p_1 + p_2 \left(\frac{p_1 \alpha_2}{p_2 \alpha_1}\right)^\sigma} \quad (4)$$

$$c_2 = \frac{b}{p_2 + p_1 \left(\frac{p_2 \alpha_1}{p_1 \alpha_2}\right)^\sigma} \quad (5)$$

b denotes the households' budget. To derive the aggregated demand function of the representative consumer, we have to 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 $b = p_1 q_1 + p_2 q_2$.

The industries' profit functions are sales minus factor costs:

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

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

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 we obtain four first-order conditions for profit maximization:

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

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

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

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

Market clearing for good 1 implies:

$$c_1 = q_1 \quad (12)$$

If we insert the aggregated income of the whole economy into the budget entering the demand function c_1 , we obtain the following equivalent condition for market clearing:

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

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

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

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

$$w = \bar{r}\bar{w} \cdot p \quad (15)$$

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

$$p_2 = 1 \quad (16)$$

The equilibrium is determined by the system of equations 4, 5, 8, 9, 10, 11, 13, 14, 15.

The unknown variables are $c_1, c_2, L_1, r_1, L_2, r_2, p_1, p, w$.

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 because 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 rises, which certainly has a positive impact on employment under 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. As a starting point for our analysis, we will always focus on a situation with unemployment in both industries before the productivity improvements in sector 1 take place. For the Cobb-Douglas case we then have:

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 rises, production of good 1 and 2 rises 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 the same as before, with β being the share for labor. With a fixed real wage, more real income on labor means that more people must be employed.⁶

Note that for proposition 1 to hold we do not need any assumption about the elasticity of substitution in the utility function σ_u . This elasticity determines *where* 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 direction of the aggregate employment effect can go in either direction for any type of technical change. We identify polar cases where technological progress of any kind over-proportionally 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 aggregate demand for labor for a given real wage. Now we will show first that aggregate employment can also decrease when uneven Hicks neutral technical progress takes place. Second, we will show that there may also be 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

⁶ So far we have assumed that the unemployed receive nothing. Introducing unemployment benefits that are lower than the minimum real wage would not change our arguments.

Fact 1:

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

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

$$q_2 = \min(L_2, K_2) \quad (17)$$

Any further worker would lead to capital being the binding production factor in sector 2. Profits of industry 2 could thus be written as

$$\pi_2 = p_2 K_2 - w L_2 - r_2 K_2 \quad (18)$$

The first-order condition with respect to labor is

$$\frac{\partial \pi_2}{\partial L_2} = -w = 0 \quad (19)$$

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

$$u = \min(c_1, c_2) \quad (20)$$

As q_2 cannot rise, q_1 cannot rise either, since otherwise marginal utility and thus p_1 and w would become 0. However, a higher *tfp* in sector 1 implies that, *ceteris paribus*,

production of good 1 will increase. Consequently, L_1 must fall to prevent this, which establishes fact 1.

In the next step we analyze the opposite extreme, where a rise of tfp causes a very large positive employment effect.

Fact 2:

A rise in tfp leads to more employment than in the benchmark case if the elasticities of substitution on the demand side and for 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 $\sigma_u \rightarrow \infty$, independently of the quantities q_1 and q_2 . This is caused by the substitutional utility function which evolves for $\sigma_u \rightarrow \infty$, implying the following constant marginal utility:

$$u = \alpha c_1 + (1 - \alpha) c_2 \quad (21)$$

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

$$q_1 = C\left(\beta L_1 + (1 - \beta)K_1\right) \quad (22)$$

We have set in this case $A=B=1$. Now neither the marginal product of labor nor the price of good 1 will drop if more people are employed in sector 1. Let us now take a look at the profit function of industry 1:

$$\pi_1 = p_1 \cdot C\left(\beta L_1 + (1 - \beta)K_1\right) - wL_1 - r_1K_1 \quad (23)$$

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

$$\frac{\partial \pi_1}{\partial L_1} = p_1 C \beta - w = 0 \quad (24)$$

Now let the nominal reservation wage be binding. The nominal reservation is described as

$$\bar{r}w \cdot p > p_1 C \beta \quad (25)$$

before the increase of C and

$$\bar{r}w \cdot p \leq p_1 C \beta \quad (26)$$

after the increase. This means that *nobody* in sector 1 is employed before the *tfp* improvement and *everybody* (up to full employment) is employed afterwards.

The example in fact 2 is certainly 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 want to demonstrate that, as in all other cases, the direction of employment development depends crucially on the elasticities of substitution.

Fact 3:

Labor-saving technical progress leads to a loss of jobs if the elasticity of substitution between production factors in sector 1 is sufficiently small.

For fact 3 we consider $\sigma_1 \rightarrow 0$, i.e. let q_1 be Leontief:

$$q_1 = \min(AL_1, K_1) \quad (27)$$

where we have set $B=C=1$. When A increases, the second production factor, i.e. capital, becomes binding, so that the profit function becomes

$$\pi_1 = p_1 K_1 - w L_1 - r_1 K_1 \quad (28)$$

The first-order condition amounts to

$$\frac{\partial \pi_1}{\partial L_1} = -w = 0 \quad (29)$$

so that we would have $w=0$. This implies that, in order to achieve positive labor income (reservation wage), L_1 must decline. Note that we have not used any price changes for this argument, i.e. the magnitude of σ_u was not essential. Therefore our argument also holds in a one-sector economy where no relative goods-price changes can occur (see also Blanchard [1998]). In the next step, we consider the opposite case in which the elasticity of substitution between production factors in sector 1 is high.

Fact 4:

Labor-saving technical progress leads to a more extreme rise of jobs than in the benchmark case if the elasticities of substitution are sufficiently high on the demand side and between production factors in sector 1 .

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

$$\pi_1 = p_1 \left(\beta A L_1 + (1 - \beta) K_1 \right) - w L_1 - r_1 K_1 \quad (30)$$

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

$$\frac{\partial \pi_1}{\partial L_1} = p_1 \beta A - w = 0 \quad (31)$$

Once more we obtain the best-case scenario if

$$\overline{rw} \cdot p > p_1 \beta A \quad (32)$$

before the increase of A and

$$\overline{rw} \cdot p \leq p_1 \beta A \quad (33)$$

after the increase. Again 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.

Fact 4 illustrates the extreme case where productivity improvements can help labor to increase the marginal (equal to the average) product until it is higher than the real reservation wage. As a consequence of the linear technology, all labor 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. 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 loss of jobs if the elasticities of substitution between the consumption goods and between production factors in sector 2 are sufficiently low.

To show fact 5, let $\sigma_u \rightarrow 0$. According to equation (21), we must have $q_1 = q_2$. Moreover, let $\sigma_2 \rightarrow 0$. Suppose that B increases. For $\sigma_1 > 0$, q_1 rises, ceteris paribus. Because of the market clearing condition (13) $q_1 = q_2$, q_2 rises as well. But, with

$\sigma_2 = 0$ and capital being the binding and fixed production factors in sector 2, q_2 cannot rise and no more workers can be employed there. So q_1 cannot rise either, because otherwise p_1 would immediately approach 0, as would the wages in sector 1. But due to the reservation wage, L_1 must decline instead. Things look very 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 if the elasticity of substitution on the demand side is sufficiently high.

To establish fact 6, let $\sigma_u \rightarrow \infty$, so that a higher production of good 1 does not lead to a price decline for the good. Now, if $\sigma_1 < \infty$ (take for instance the extreme $\sigma_1 = 0$), which means that labor and capital are complementary, an increase of B increases marginal productivity of labor in sector 1. Thus, with a fixed reservation wage, employment must increase in the case of capital-saving technical progress. The increase is strongest in case $\sigma_1 = 0$.

5 Summary of the Results

The results from 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 suited combination of elasticities on the demand side and elasticities in sector 1 and sector 2 can increase aggregate unemployment. While low elasticities of substitution between consumption goods generally tend to imply a negative relationship between productivity improvement and unemployment, high substitution elasticities of demand can 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 technical 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 aggregate 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 usually does 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:

In the Cobb-Douglas case the first-order conditions for profit maximization in sector one and two with respect to labor are:

$$w = p_1 C L_1^{(\beta-1)} K_1^{(1-\beta)} \quad (34)$$

$$w = L_2^{(\beta-1)} K_2^{(1-\beta)} \quad (35)$$

C stands for the productivity improvement. Dividing 34 by 35, we obtain

$$1 = p_1 C \left(\frac{L_1}{L_2}\right)^{\beta-1} \left(\frac{K_1}{K_2}\right)^{1-\beta} \quad (36)$$

which yields

$$p_1 = \frac{1}{C} \left(\frac{L_1}{L_2}\right)^{1-\beta} \left(\frac{K_2}{K_1}\right)^{1-\beta} \quad (37)$$

The market clearing condition is given by

$$p_1 = \left(\frac{\alpha}{1-\alpha}\right) \left(\frac{q_2}{q_1}\right)^{\frac{1}{\sigma_u}} \quad (38)$$

$$= \left(\frac{\alpha}{1-\alpha}\right) \left(\frac{1}{C}\right)^{\frac{1}{\sigma_u}} \left(\frac{L_2}{L_1}\right)^{\frac{\beta}{\sigma_u}} \left(\frac{K_2}{K_1}\right)^{\frac{1-\beta}{\sigma_u}} \quad (39)$$

implying

$$\left(\frac{L_1}{L_2}\right)^{1-\beta} = p_1^{\frac{\sigma_u(\beta-1)}{\beta}} \left(\frac{1-\alpha}{\alpha}\right)^{\frac{\sigma_u(\beta-1)}{\beta}} C^{\frac{\beta-1}{\beta}} \left(\frac{K_2}{K_1}\right)^{\frac{(1-\beta)^2}{\beta}} \quad (40)$$

Inserting this into 37 yields

$$p_1 = \frac{1}{C} \left(\frac{K_2}{K_1} \right)^{1-\beta} p_1^{\frac{\sigma_u(\beta-1)}{\beta}} \left(\frac{1-\alpha}{\alpha} \right)^{\frac{\sigma_u(\beta-1)}{\beta}} C^{\frac{\beta-1}{\beta}} \left(\frac{K_2}{K_1} \right)^{\frac{(1-\beta)^2}{\beta}} \quad (41)$$

Solving for p_1 we obtain

$$p_1 = C^{\frac{1}{\sigma_u(\beta-1)-\beta}} \left(\frac{1-\alpha}{\alpha} \right)^{\frac{\sigma_u(\beta-1)}{\beta-\sigma_u(\beta-1)}} \left(\frac{K_2}{K_1} \right)^{\frac{1-\beta}{\beta-\sigma_u(\beta-1)}} \quad (42)$$

$$= C^{\frac{1}{\sigma_u(\beta-1)-\beta}} \cdot \text{const.} \quad (43)$$

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

Solving the first-order condition for profit maximization in sector 2 (eq. 35) for labor demand, we obtain

$$L_2 = \left(\frac{1}{\bar{r}\bar{w} p} \right)^{\frac{1}{1-\beta}} K_2 \quad (44)$$

with $\bar{r}\bar{w} p$ being the nominal wage, i.e. fixed real wage $\bar{r}\bar{w}$ 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. 38) we observe that for p_1 to decrease $\frac{q_1}{q_2}$ must increase. Since the q_2 increases, q_1 must increase as well. So we have an increase of production in sector 1, too.

As we have an increase in production of good one and two, aggregate real income increases. For the Cobb-Douglas production functions, the constant income share for labor β is given by

$$\beta = \frac{\bar{r}\bar{w}(L_1 + L_2)}{(p_1 q_1 + p_2 q_2)/p} \quad (45)$$

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 $\bar{r}\bar{w}$. QED.

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