Capital-Skill Complementarity, Biased Technical Change and (Un)Employment

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Abstract

Capital-skill complementarity (CSC) has often been cited as an explanation of rising low skilled unemployment. The CSC hypothesis is usually investigated by the use of the translog function. This paper shows that results of previous studies are biased due to methodological inaccuracy. Considering this fact, their results do not support the CSC unambiguously. Own translog cost function estimates for West - Germany confirm the supposition that the CSC does not exist if omitted variables and non – neutral technological progress are considered. Rather a skill-biased technical change and low high skilled complementarity is found. Finally, the implicit estimated skill specific labour demand is used to explain the high and low skilled unemployment developments. The results show a high explanatory quality and verify the existence of a growing low skilled gap.

Keywords: Capital-skill complementarity, unemployment, technological change, translog function

JEL classification: J23, E24, O30, C32

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1. Introduction

The capital-skill complementarity explanation of unemployment is usually examined using a translog cost framework. For both time series and cross section data, the majority of these studies supports the capital-skill complementarity Hypothesis (CSC).

However, some methodological inaccuracy raises the question, if the results and interpretations might be biased. This bias is explained by the following four reasons:

1. The weak separability of omitted variables is not checked.
2. The CSC is discussed in terms of the Allen – Uzawa elasticity of substitution only.
3. In most of the studies Hicks neutral technical progress is assumed merely.
4. The data used refer to blue and white collar workers and not to low and high skilled labour.

First, in most of the studies known to the author weak separability is not checked. They focus on the investigation of capital and labour, the latter in different categories, but do not take material and energy into account. This misspecification leads to a bias in the cost shares. Second, the estimation results are usually interpreted in terms of Allen – Uzawa elasticity of substitution. However, as Blackorby and Russell (1989) pointed out, this is not the right measure of the ease of substitution if more than two production factors are used. A better way to express the ease of substitution is to use the Morishima elasticity of substitution because it takes the own price elasticity into account. Third, non – neutral technical progress is neglected in most studies. This probably leads to a bias in the estimated parameters which support an absolute complementarity relation between two factors. For the CSC that means for example that the Allen – Uzawa elasticity of substitution between capital and high skilled labour will be negative. Fourth, because of the lack of data on skills of labour, data of blue and white collar workers are used in most studies. This approximation can also lead to a bias in the estimation.

On account of the second point it is worth to reconsider the results of existing studies. Beyond that the availability of new data on skills of labour for West-Germany for the period 1976 - 1994 allows to perform a new estimation which takes the four aspects into account. We estimated a five factor translog cost function (capital, low skilled, high skilled, material, and energy) with non – neutral technical progress. Both linear and non – linear separability tests indicate that neither a factor nor non - neutral technical progress is weak separable. The results will be discussed with the help of cross price elasticities and Allen – Uzawa as well as Morishima substitution elasticities. Out of these elasticities eight complementarity conditions are established to test the CSC. In addition implicit estimated labour demand of the high and low skilled are used to explain the development of the unemployment of each skill - group. The connection between the estimated labour demand, out of a translog cost function, and the development of the unemployment has not been studied so far. Yet, it is important to understand which skill – group is affected more by prices and technological progress.

On the basis of the complementarity conditions the CSC must be rejected in most studies. The CSC must also be rejected in the preferred model on the basis of these conditions. Instead skill-biased technical change (SBTC) and a labour-labour complementarity is found. If material is omitted in the estimates, like in most studies, a CSC can be accepted. In addition if non – neutral technical progress is included, regardless of how much factors are considered, no negative cross price elasticity and hence Allen – Uzawa substitution elasticity is found.

A further important finding is that the order of magnitude of the second derivation parameters could change if the cost function specification is changed. Beyond that the sign of insignificant parameters change in some cases. Both effects are important for any complementarity hypothesis, because the order of magnitude and the sign of the parameters are the basis for the inference concerning substitutability or complementarity. A last important finding is, concerning the preferred model, that the implicit estimated labour demand of the high and low skilled can explain the development of the unemployed with a high explanatory quality.

To sum up the following can be said concerning low and high skilled labour. Capital has no complementarity relation to any kind of labour. The used production technology is skill biased. For the low skilled labour demand we have two effects. First, the low skilled price rises faster than every other price. This lead to a relative high substitution of low skilled labour. Second, the direction of the production technology was affected by this price expectation and perhaps by globalisation effects (a shift in the output – market conditions). The reason for this supposition is the importance of technical progress for the low skilled labour demand. Both effects hurt the unskilled (un)employed for the most part.

The paper is organised as follows. In section 2 the CSC and its empirical implications just as the problem of ease of substitution and a new method of measurement for the CSC are discussed. The results and re-interpretations of existing studies in this research area are reported and discussed in section 3. In section 4 we review the translog function, discuss the problems of separability and specification and connect in a second model the implicit estimated labour demand with unemployment. The main estimation results are reported in this section. Section 5 contains a discussion of the results concerning the elasticities and biased technical change. Section 6 concludes.

2. The capital-skill complementarity hypothesis

The CSC is quite popular, because it is an explanation for increasing demand of high skilled relative to low skilled labour and an – as often observed – absolute decrease in demand of low skilled. Regardless of the CSC being the cause, if this phenomenon is observed empirically, it has to be observable especially in the development of the low skilled unemployment. Another explanation for a growing low skilled unemployment is SBTC. The effects of SBTC on employment are the same as the effects of CSC, however, capital has not a complementarity relation to the high skilled.

In addition to that it is important to take the labour force growth into account. This growth effect can strengthen or weaken the effect of the labour demand. In the following we answer two main questions. Is it possible to explain the skill specific unemployment developments with labour demand derived from the cost function and labour force growth? If so, is this change of relative labour demand really based on the CSC? To answer these questions, we first analyse in short the consequences of the CSC and SBTC for the development for the skill specific unemployment and then develop conditions to test the CSC. We use these complementarity conditions to check if the existing studies and the own estimations really support the CSC.

The CSC is based in general on the theory, that with an increasing use of capital the use of high skilled labour increases too, whereas the demand for low skilled labour (relative) decreases. The effects on the skill specific unemployment are unambiguous. In addition, as equally empirically observed, an increasing skill specific labour supply raised the effect on the low skilled unemployment. The total effect on the high skilled is not unambiguous. The same effects appear if SBTC is the driving force of the factor demand. Hence, the difference between CSC and SBTC lies in the role of capital.

It is usual to discuss the CSC in terms of the well known condition that the Allen – Uzawa elasticity (Uzawa (1962)) of substitution (AUS) is higher for capital and low skilled than for capital and high skilled. The AUS (σ_{ij}) and own elasticity (σ_{ii}) are defined as:

$$\sigma_{ij} \equiv \frac{CC_{ij}}{C_i C_j} = \frac{\eta_{ij}}{s_j} \tag{1}$$

$$\sigma_{ii} \equiv \frac{CC_{ii}}{C_i C_i} = \frac{\eta_{ii}}{s_i}, \tag{2}$$

In (1) and (2), C are the total costs and C_i and C_{ij} respectively are the first and the second derivations. s_j and s_i are the cost shares of the factors x_j and x_i. The cross price elasticity (η_{ij}) and own price elasticity (η_{ii}) are developed by Allen (1934).

$$\eta_{ij} \equiv \frac{\ln x_i}{\ln p_j} = \frac{p_j C_{ij}}{C_i} = \frac{x_j p_j}{C} \sigma_{ij} = s_j \sigma_{ij} \tag{3}$$

$$\eta_{ii} \equiv \frac{\ln x_i}{\ln p_i} = \frac{p_i C_{ii}}{C_i} = \frac{p_i x_i}{C} \sigma_{ii} = s_i \sigma_{ii} \tag{4}$$

Whereas the cross price elasticities are non-symmetric ($\eta_{ij} \neq \eta_{ji}$) the AUS is symmetric ($\sigma_{ij} = \sigma_{ji}$). The equations (1)-(4) show, that they are directly connected through the cost shares. Hence the cross price elasticity contain more information than the AUS and the own price elasticity contain more information than the own elasticity.

Blackorby and Russell (1989) come to the conclusion, that the AUS has no great value for quantitative measurement if there are more then two factors considered. With regard to qualitative measurement the elasticity only distinguishes between substitutes ($\sigma_{ij} > 0$) and complements ($\sigma_{ij} < 0$) on the basis of the cross price elasticity sign. They conclude, that the Morishima (1967) elasticity of substitution (MES) is a superior instrument.[1] This elasticity is defined as follows:

1 They based their conclusion on three reasons. First, the MES is a measure of ease of substitution. Second, it is a sufficient statistic for assessing the effects of changes in price or quantity ratios on relative factor share. Third, it is a logarithmic derivative of a quantity ratio with respect to a marginal rate of substitution or a price ratio. These three aspects are not satisfied in the AUS. See Blackorby and Russel (1989, 883).

$$\mu_{ij} \equiv \frac{p_i C_{ij}}{C_j} - \frac{p_i C_{ii}}{C_i} = \eta_{ji} - \eta_{ii} \tag{5}$$

This elasticity is non-symmetric and (5) defines only the substitution elasticity if p_i changes. There are two effects: First, the effect of p_i on input x_j, and second, the effect of p_i on input x_i. If p_i changes, then μ_{ij} expresses the percentage change of the input ratio of x_i and x_j, whereas σ_{ij} "only" expresses the percentage change of demand of input factor x_i.

Beyond that it is necessary to consider the consequences. We know σ_{ij} is symmetric and so both factors are either substitutes or complements in both directions. For μ_{ij} and μ_{ji} this need not to be so. On the one hand, the absolute value of the negative η_{ji} must be greater than η_{ii} because η_{ii} is negative. On the other hand, μ_{ji} could be positive if μ_{ij} is negative. That means, two factors could be complements related to one price and be substitutes related to the other price.

From (1), (2) and (5) it follows:

$$\mu_{ij} = s_i\left(\sigma_{ij} - \sigma_{ii}\right) \tag{6}$$

$$\mu_{ji} = s_j\left(\sigma_{ij} - \sigma_{jj}\right) \tag{7}$$

These equations show, that σ_{ij} indicates a absolute complementary case faster than μ_{ij} and μ_{ji}.

Since the AUS is not an appropriate measure of the ease of substitution it is not an appropriate measure for the CSC, too. The sole right elasticity to identify the CSC is the MES. Since the MES contain the cross and own price elasticities, we develop fist conditions that based only on the cross price elasticity. The advantage of this strategy is, that we can identify if the CSC is not accepted due to the cross or own price elasticities. We use the following complementarity conditions to identify if two pairs of production factors are relative complementarity. All conditions are based on the consideration that the level of the cost shares cannot be the reason why some production factors are relative complements or not. We assume that x_i, x_o are relative complementarity to x_i, x_j. Because we use the conditions later to check other complementarity hypothesis we use here $i = K$, $j = L$ and

$o = H$. For the purpose of comparison we show here the usual condition based on the AUS.

$$\sigma_{ij} > \sigma_{io} \tag{8}$$

Because of the asymmetry of the cross price elasticities we need four conditions. It is intuitively clear that if the prices of x_j and x_o increase it is easier for x_i to substitute x_j, and if the price of x_i rises it has to be easier for x_j to substitute x_i. This is the logical implication of Griliches relative complementarity. These are the conditions one and two:

$$\text{C1: } \eta_{ij} > \eta_{io} \tag{9}$$

$$\text{C2: } \eta_{ji} > \eta_{oi} \tag{10}$$

If both conditions are satisfied then at least one more condition has to be fulfilled, since in any case η_{ij} or η_{ji} is higher than η_{io} and η_{oi}. If this is true for both, we get the conditions three and four (amongst one and two), and call x_i and x_o strong complements if all four cross price conditions are satisfied.[2]

$$\text{C3: } \eta_{ij} > \eta_{oi} \tag{11}$$

$$\text{C4: } \eta_{ji} > \eta_{io} \tag{12}$$

Now we ask for the more important conditions of the MES. As a matter of principle of the formula it is now additionally necessary to look at the own price elasticity. If the latter is zero, the MES agrees with the corresponding cross price elasticity. The higher the (negative) own price elasticity, the higher MES. The additional characteristic for the next conditions is, if some factors are more substitutable than others, their own price elasticities have to be higher. The MES complementarity conditions are therefore.

$$\text{C5: } \mu_{ij} > \mu_{io} \tag{13}$$

$$\text{C6: } \mu_{ji} > \mu_{oi} \tag{14}$$

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2 If the conditions one – four are satisfied the AUS condition is satisfied, too. But reverse this is not necessarily valid.

From the same idea of condition three and four we construct the Morishima conditions seven and eight, which lead again to strong conditions if all four are satisfied.

C7: $\mu_{ij} > \mu_{oi}$ (15)

C8: $\mu_{ji} > \mu_{io}$ (16)

On the basis of these complementarity conditions we can identify unambiguous if the relative CSC or any other complementarity hypothesis exists or not. In the following we use these conditions to discuss complementarity hypothesis.

3. CSC Studies reconsidered

The majority of studies concerning the capital-skill complementarity (CSC), which is based on time series or cross section data, supports the Hypothesis, which goes back to Griliches (1969). The CSC has usually been examined in a translog production/cost framework. Table 1 shows six translog cost function studies that contain two different kinds of labour. Since these types of labour are not necessarily different skill levels, they get the specifications B for blue collar and W for white collar. In the following we use abbreviations for the authors names: Berndt and Christensen (BC74), Freeman, Medoff (FM82), Panas (P91), Berger (B84), Berndt and Morrison (BM79) and Bergström and Panas (BP92).

Table 1: Elasticities of translog cost function estimates with blue and white collar workers

	BC74[1]	***BM79***[2]	***FM82***[3]	***B84***[4]	***P91***[5]	***BP92***[6]
σ_{KB}	2,92	0,91	0,95	1,05	0,36	0,11
σ_{KW}	-1,94	1,09	0,53	1,01	0,32	0,05
σ_{BW}	5,51	3,70	-0,02	-0,77	0,23	1,28
η_{KB}	1,56	0,16	0,49	0,20	0,10	0,04
η_{BK}	0,53	0,04	0,23	0,47	0,11	0,04
η_{KW}	-0,56	0,13	0,12	0,32	0,08	0,01
η_{WK}	-0,35	0,05	0,13	0,45	0,16	0,02
η_{BW}	1,58	0,44	-0,01	-0,24	0,08	0,34
η_{WB}	2,94	0,65	-0,01	-0,39	0,13	0,52
μ_{KB}	1,53	0,33	0,84	1,04	0,35	0,10
μ_{BK}	3,66	1,424	0,72	0,41	0,20	0,42
μ_{KW}	0,65	0,34	0,74	1,02	0,40	0,08
μ_{WK}	2,04	0,85	0,25	0,46	0,31	0,55
μ_{BW}	5,05	1,91	0,22	-0,17	0,23	0,89
μ_{WB}	4,17	1,16	0,12	-0,11	0,30	0,87

Kind of data	ts	ts	cs	ts	ts	ts
Number of x_i	3	5	3	4	3	3

The MES are own calculations, other elasticities are taken from the authors. σ_{ij} AUS, η_{ij} cross price elasticity, μ_{ij} MES, K capital, B blue collar worker, W white collar worker, ts time-series, cs cross-section. [1]: Berndt and Christensen (1974); [2]: Berndt and Morrison (1979); [3]: Freeman, Medoff (1982); [4]: Berger (1984); [5]: Panas (1991); [6]: Bergström and Panas (1992).

If we use as usual the AUS to investigate if there is any complementarity and to distinguish between absolute and relative complements (equation (8)) we get the following results. The only absolute CSC is found by BC74.[3] FM82, BP92, B84, and P91 determine a relative CSC. BM79 reject the CSC and received the opposite. Hence, five of six studies support the CSC.

If we apply the complementarity conditions we get quite different results. Condition one and two are satisfied by BC74, FM82 and BP92 whereas P91 and BM79 only fulfil condition one and B84 only condition two. BM79 satisfies condition three and P91 satisfies condition four just as B84. BC74, FM82, and BP92 also satisfy the condition three and four and therefore the first strong condition.[4] At this point these three studies support the CSC and comply with all the necessary cross price conditions.

FM82 and BC74 satisfy the conditions five and six. BM79 satisfy only condition six and B84, P91 and BP92 only condition five. For the strong Morishima condition we can establish none of the studies can satisfy this condition. BP92, BC74, and BM79 satisfy only condition eight and B84 as well as FM82 satisfy only condition seven. P91 satisfies neither seven nor eight.

All in all the half of these studies, P91, B84, and BM79 do not support the hypothesis because they satisfy no strong conditions. At least only the cross-section study of FM82 and the time-series studies of BC74 and BP92 fulfil only the first strong condition and support the CSC weak.

However, to assess these results three points are important. First, cross-section studies are a snapshot of the economy and do not reproduce an economic development like in FM82. Second, technical progress could play a major role in the explanation of the factor demand. This point is directly connected with the first, because cross-section studies cannot contain non-neutral technical progress. Technical progress is only take into account in BM79,

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[3] Absolute in the sense of the sign, because the cross price elasticities between capital and high skilled labour are negative.

BP92, and P91. Third, estimated elasticities have no real meaning if the question of separability of the input factors is not answered. If one or more inputs are neglected based on wrong assumptions (or data problems), like in every reported study, except BM79, the conclusion on the basis of these estimations are not safe.[5] Beyond that, as Frondel and Schmidt (2001) pointed out, the number of cost shares is important. The more factors are included, the lower are the cost shares of each factor. This have an influence on the CSC, too. In view of these methodical aspects only one reported study stands this criticism. It is BM79 which do not support the CSC. Finally one inaccuracy remains. The use of blue and white collar for the division of labour is not necessarily a good approximation of different skill levels. These insights support the necessity of the following translog cost function which takes these facts into account.

Before we specify and estimate the translog model, we take a glance at the elasticities concerning the blue and white collar. The BW elasticities are sometimes higher and sometimes lower (in some cases absolute complements) than the others. These values leave no clear picture at the moment, but this will change as we will see below.

4. Specification, estimation, and results

Almost 30 years ago Berndt and Christensen (1973b) where the first who used the translog function as an approximation of the production function. Since then a lot of work in this research area has been published and the capital-skill complementarity debate, that was mainly based on this functional form, is almost withered.[6] The general starting point of the discussion is the aggregate production function. We distinguish between materials (M), energy (E), capital (K), high skilled (H), and low skilled labour (L). As a matter of principle the only appropriate measure of output in this case is the gross output and not the value-added output.[7] Thus, unless the production function is weakly separable, output (Q) is a function of all inputs and technology (τ):

$$Q = F(M, E, K, H, L, \tau) \tag{17}$$

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4 It is no surprise that BC74 satisfies all four conditions because the elasticities η_{KW} and η_{WK} are negative which illustrate an absolute CSC.

5 BC74 tests the functional separability but only between capital and the two types of labour.

6 The same is true for the capital-energy complementarity debate.

7 For a discussion of this problem, see Yuhn (1991).

Before we look at the question of separability we specify the translog model. In comparison with the cost function a production function has the disadvantages that the factor quantities are possibly endogenous variables themselves and that the multicollinearity problem arises in the estimation quantities more than in the estimation of prices.[8] For these reasons most studies prefer the translog cost function. The cost function associated with equation (17) is:

$$C = C(p_M, p_E, p_K, p_H, p_L, Q, \tau) = C(\mathbf{p}, Q, \tau) \tag{18}$$

In the following we use the logarithm of the unit or average cost ($\ln c = \ln C - \ln Q$). If we expand $\ln c(\mathbf{p},\tau)$ in a second – order Taylor series about the point $\ln \mathbf{p} = \mathbf{0}$, and identify these derivatives as coefficients, we receive the translog cost function

$$\ln c = \alpha_0 + \alpha_\tau \ln \tau + \sum_i \alpha_i \ln p_i + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \ln p_i \ln p_j + \sum_i \gamma_{i\tau} \ln p_i \ln \tau + \frac{1}{2}\gamma_{\tau\tau}(\ln \tau)^2 \tag{19}$$

where p_i represents the price of input i, α_i are the first-order and γ_{ij} the second-order parameter. The translog cost function is linear homogenous in prices and satisfy the conditions corresponding to a well-behaved production function, which implies the following restrictions:[9]

$$\sum_{i=1}^{n} \alpha_i = 1 \tag{20a}$$

$$\sum_{i=1}^{n} \gamma_{ij} = \sum_{j=1}^{n} \gamma_{ij} = \sum_{i=1}^{n} \gamma_{i\tau} = 0 \tag{20b}$$

Further, symmetry is imposed:

$$\gamma_{ij} = \gamma_{ji}\,,\ \gamma_{i\tau} = \gamma_{\tau i} \tag{20c}$$

If $\gamma_{ij} = 0$ for all inputs, the function reduces to a Cobb-Douglas function. The cost-minimising factor demand is obtained by applying Shephards' Lemma (1953),

$$x_i = \frac{\partial C(\mathbf{p}, Q, \tau)}{\partial p_i} = \frac{Q \partial c(\mathbf{p}, \tau)}{\partial p_i} \tag{21}$$

8 For detailed explanation of these reasons, see for example Binswanger (1974).

9 See Christensen, Jorgensen, and Lau (1973).

and the resulting cost-minimising factor cost share is

$$s_i = \frac{p_i x_i}{C} = \frac{\partial \ln c(\mathbf{p}, \tau)}{\partial \ln p_i} = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \gamma_{i\tau} \ln \tau \tag{22}$$

where s_i is the cost share of input i. The additional term τ, that takes technical progress into account, is used to estimate a factor bias.

$$\varphi_i = \frac{\partial s_i}{\partial \tau} \frac{\tau}{s_i} = \frac{\gamma_{i\tau}}{s_i} \tag{23}$$

The parameter φ_i is the bias of the technical progress of input i. If $\varphi_i = 0$ for all inputs, the progress is Hicks neutral (HNTP). In this case all $\gamma_{i\tau} = 0$, because the cost shares are subject to the restriction $0 < s_i < 1$. If $\varphi_i = 0$ for one input, we have factor i neutral progress. If $\varphi_i > 0$ the technology is factor i using whereas $\varphi_i < 0$ indicates a factor i saving technological progress.

Let us now look briefly at the question of weak separability. Since equation (19) does not give any information about the marginal rate of technical substitution, separability cannot defined from this equation. Yuhn (1991) has shown, that the inputs i and j are weakly separable from k if and only if

$$s_i \frac{\partial s_j}{\partial \ln p_k} = s_j \frac{\partial s_i}{\partial \ln p_k}. \tag{24}$$

Berndt and Christensen's (1973, 1974) linear separability (and Yuhn's (1991) additive weak separability) of inputs i and j from input k implies the parameter restriction:

$$\gamma_{ik} = \gamma_{jk} = 0 \tag{25}$$

Berndt and Christensen's non-linear separability (and Yuhn's connective weak separability) requires more restrictive constraints on the parameters:

$$\frac{\alpha_i}{\alpha_j} = \frac{\gamma_{ik}}{\gamma_{jk}} = \frac{\gamma_{i\tau}}{\gamma_{j\tau}} = \frac{\gamma_{io}}{\gamma_{jo}}, \qquad o = 1, 2, \cdots, n \tag{26}$$

For the technological progress we test HNTP against NNTP. For this we combine equation (26) with the restriction:

$$\gamma_{M\tau} = \gamma_{E\tau} = \gamma_{K\tau} = \gamma_{L\tau} = \gamma_{H\tau} = 0 \tag{27}$$

The elasticities discussed above can be computed out of the translog cost function as follows:

$$\eta_{ij} = \frac{\gamma_{ij}}{s_i} + s_j = s_j \sigma_{ij} \tag{28}$$

$$\eta_{ji} = \frac{\gamma_{ij}}{s_j} + s_i = s_i \sigma_{ij} \tag{29}$$

$$\eta_{ii} = \frac{\gamma_{ii}}{s_i} - 1 + s_i = s_i \sigma_{ii} \tag{30}$$

$$\sigma_{ij} = 1 + \frac{\gamma_{ij}}{s_i s_j} = \frac{\eta_{ij}}{s_j} = \frac{\eta_{ji}}{s_i} \tag{31}$$

$$\sigma_{ii} = 1 + \frac{\gamma_{ii} - s_i}{s_i^2} = \frac{\eta_{ii}}{s_i} \tag{32}$$

$$\mu_{ij} = \frac{\gamma_{ij}}{s_j} - \frac{\gamma_{ii}}{s_i} + 1 = s_i \left(\sigma_{ij} - \sigma_{ii} \right) = \eta_{ji} - \eta_{ii} \tag{33}$$

$$\mu_{ji} = \frac{\gamma_{ij}}{s_i} - \frac{\gamma_{jj}}{s_j} + 1 = s_j \left(\sigma_{ij} - \sigma_{jj} \right) = \eta_{ij} - \eta_{jj} \tag{34}$$

We estimate the system of translog cost functions with the *Three Stage Least Squares Method* (Zellner and Theil 1962). Because of the restrictions in (20) and the problem of a singular covariance matrix, the $N-1$ prices are divided by the Nth price. Now the Parameter matrix loses one column and one row and we obtain a nonsingular system by dropping the Nth share equation.[10] As usual we chose the material share equation and material prise respectively.

In the empirical investigation on West-Germany we used eight system estimations with the time period 1976 until 1994. This restriction is due to the data availability.[11] The unit cost function (19) may be included if desired, however, since this equation (19) uses partly 19 parameters the application of this model would lead to an over – parameterised estimation.

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10 See Greene (1997).

The same goes not for the share equations. We estimate four different specification concerning the production factors and each of them with Hicks neutral technical progress (HNTP) and non – neutral technical progress (NNTP).

Model 1 (M1): High Skilled, Low Skilled, Capital, Material, Energy with NNTP

Model 2 (M2): High Skilled, Low Skilled, Capital, Material, Energy with HNTP

Model 3 (M3): High Skilled, Low Skilled, Capital, Energy with NNTP

Model 4 (M4): High Skilled, Low Skilled, Capital, Energy with HNTP

Model 5 (M5): High Skilled, Low Skilled, Capital, Material with NNTP

Model 6 (M6): High Skilled, Low Skilled, Capital, Material with HNTP

Model 7 (M7): High Skilled, Low Skilled, Capital with NNTP

Model 8 (M8): High Skilled, Low Skilled, Capital with HNTP

Table 2: Estimation results of all eight translog models

	M1	M2	M3	M4	M5	M6	M7	M8
α_M	0,5571	0,5737			0,5850	0,5989		
	(215,01)	(258,94)			(174,51)	(281,38)		
α_K	0,1040	0,1074	0,2093	0,2389	0,1029	0,1083	0,2236	0,2679
	(40,15)	(106,09)	(23,09)	(46,05)	(32,37)	(81,30)	(37,20)	(42,04)
α_L	0,2213	0,2034	0,5088	0,4636	0,2383	0,2139	0,5935	0,5228
	(83,52)	(71,36)	(92,94)	(77,17)	(67,90)	(81,27)	(89,65)	(77,78)
α_H	0,0652	0,0691	0,1510	0,1772	0,0738	0,0790	0,1829	0,2093
	(56,39)	(25,00)	(67,55)	(35,85)	(23,91)	(42,54)	(45,25)	(38,05)
α_E	0,0523	0,0464	0,1309	0,1203				
	(12,67)	(33,17)	(22,66)	(21,60)				
γ_M	0,0013	0,0029			0,0008	0,0018		
	(0,30)	(0,43)			(0,13)	(0,43)		
γ_K	0,0004	0,0007	0,0016	-0,0181	0,0000	0,0001	-0,0079	0,0083
	(3,77)	(7,29)	(0,16)	(-1,87)	(0,17)	(1,29)	(-0,61)	(0,33)
γ_L	0,0082	0,0274	0,0013	-0,0716	0,0093	0,0223	0,0189	0,2349
	(2,73)	(5,45)	(0,42)	(-2,74)	(1,82)	(6,37)	(1,70)	(11,81)
γ_H	0,0121	0,0406	0,0042	-0,0544	0,0136	0,0327	0,0321	0,3362
	(2,65)	(5,26)	(1,66)	(-1,75)	(1,82)	(6,29)	(2,03)	(11,19)
γ_E	0,0006	0,0006	0,0001	-0,0028				
	(4,35)	(6,53)	(0,04)	(-0,13)				
γ_{MK}	0,0002	0,0000			-0,0002	-0,0005		
	(1,15)	(0,11)			(-0,57)	(-1,83)		
γ_{ML}	0,0021	0,0078			0,0026	0,0064		

[11] The data for labour are taken from Reinberg and Hummel (1999), the data of capital are taken from the OECD (1996), and the other quantities and prices are taken from the Statistische Bundesamt (Fachserie 16 and 18) and the Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung.

	M1	M2	M3	M4	M5	M6	M7	M8
	(0,61)	(1,32)			(0,48)	(1,67)		
γ_{MH}	-0,0030	-0,0100			-0,0032	-0,0077		
	(-0,73)	(-1,44)			(-0,47)	(-1,65)		
γ_{KL}	-0,0007	-0,0020	0,0009	0,0260	-0,0006	-0,0016	0,0106	0,0465
	(-3,81)	(-7,62)	(0,19)	(2,13)	(-1,74)	(-6,57)	(0,85)	(2,08)
γ_{KH}	0,0005	0,0019	-0,0026	-0,0148	0,0008	0,0020	-0,0027	-0,0548
	(2,48)	(6,40)	(-1,09)	(-1,55)	(1,91)	(6,69)	(-0,18)	(-2,00)
γ_{LH}	-0,0098	-0,0331	-0,0018	0,0595	-0,0113	-0,0271	-0,0295	-0,2814
	(-2,65)	(-5,32)	(-0,76)	(2,21)	(-1,83)	(-6,34)	(-2,23)	(-11,56)
γ_{EM}	-0,0006	-0,0007						
	(-4,49)	(130,25)						
γ_{EK}	-0,0004	-0,0005	0,0001	0,0069				
	(-4,43)	(-7,08)	(0,02)	(0,65)				
γ_{EL}	0,0002	0,0000	-0,0004	-0,0139				
	(1,91)	(0,05)	(-0,14)	(-0,57)				
γ_{EH}	0,0002	0,0006	0,0002	0,0097				
	(3,69)	(2,82)	(0,08)	(0,36)				
$\gamma_{\tau M}$	0,0150				0,0142			
	(6,99)				(4,11)			
$\gamma_{\tau K}$	0,0027		0,0332		0,0063		0,0349	
	(1,34)		(3,67)		(2,27)		(5,87)	
$\gamma_{\tau L}$	-0,0233		-0,0538		-0,0280		-0,0650	
	(-10,33)		(-9,66)		(-7,70)		(-13,92)	
$\gamma_{\tau H}$	0,0105		0,0328		0,0075		0,0300	
	(8,73)		(14,71)		(2,20)		(9,47)	
$\gamma_{\tau E}$	-0,0048		-0,0122					
	(-1,31)		(-2,17)					

Numbers in parenthesis are asymptotic t-statistics.

It would not be a good idea to discuss each parameter, but some general findings should be noted. First, the non - neutral technological progress (NNTP) is highly significant and is low skilled and energy saving and high skilled, capital, and material using. Second, the equations with all factors lead in all to quite better estimates then every reduced model. But on the other hand, some reduced models have a relative high explained variance, although they are possibly misspecified. However, as we will see later, this is not equate with a good approximation of labour demand and therefore of an explanation of the development of unemployment of the skilled and unskilled. Third, the models with HNTP have a significantly worse explanatory quality. Hence, one can suppose that M1 is the superior model.

Table 3: Coefficients of determination and Durbin – Watson statistics of all eight models

		M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**
s_K	R^2	0,791	0,794	0,441	-0,041	0,419	0,248		
	$\overline{R}^2$	0,705	0,731	0,269	-0,264	0,241	0,087		
	DW	1,706	2,050	0,767	0,541	1,201	0,669		
s_L	R^2	0,923	0,657	0,870	0,233	0,884	0,521	0,932	0,773
	$\overline{R}^2$	0,891	0,551	0,830	0,068	0,849	0,418	0,917	0,742

	DW	2,024	0,576	1,891	0,749	0,853	0,283	1.223	0,323
s_H	R^2	0,932	0,618	0,954	0,187	0,634	0,221	0,951	0,630
	$\overline{R}^2$	0,904	0,500	0,940	0,013	0,521	0,054	0,941	0.581
	DW	1,337	1,889	2,214	1,497	1,480	1,451	1,058	0,601
s_E	R^2	0,313	0,563						
	$\overline{R}^2$	0.027	0,429						
	DW	2,372	0,922						

For the parameters concerning material statistical information are not available for the sake of the specification. s_i are the cost shares of each factor, R^2 is the coefficient of determination, $\overline{R}^2$ is the adjusted coefficient of determination, and DW is the Durbin-Watson d statistic.

Now we follow up the consideration, that the implicit estimated labour demand must have some explanatory quality concerning the development of the unemployment. Statistically unemployment is the difference between labour supply (ℓ^S) and labour demand (ℓ). If both increase the effect on unemployment is not unambiguous, since an increasing labour supply raises and an increasing labour demand reduces the unemployment. For each skill group ($i = L, H$) we can say:

$$U_i = U\left(\underset{+}{\ell_i^S}, \underset{-}{\ell_i}\right) \tag{35}$$

As we pointed out above, both CSC and SBTC lead to an relative increase in labour demand for the high skilled and to an relative decrease in labour demand for the low skilled. Therefore theoretically the effect of labour demand is different for the two skill groups, whereas the effect of labour supply is equal for both groups.

Empirically we must observe for the low skilled labour a (strong) rising unemployment and for the high skilled labour a not unambiguous effect on unemployment. To evaluate the effects of the CSC and/or SBTC on the skill specific unemployment we use the implicit estimated labour demand ($\hat{\ell}_i$) of each model out of equation (22),

$$\hat{\ell}_i^{M_j} = \hat{s}_i^{M_j} \frac{C}{p_i} \tag{36}$$

where $i = L, H$ and $j = 1,2,\ldots,8$. We simply regress unemployment, aggregated and disaggregated, on labour demand and labour supply, whereas the latter is exogenous

$$U_i = \beta_i + \varepsilon_i \ell_i^S + \theta_i \hat{\ell}_i^{M_j} \tag{37}$$

with $i = L, H, L+H$. If the estimated labour demand correspond to the true demand, the regression has no constant ($\beta_i = 0$) an the estimated parameters are $\varepsilon_i = 1$ and $\theta_i = -1$, respectively. If they are different, a constant could be necessary ($\beta_i \neq 0$) and for the parameters we only know $1 \geq \varepsilon_i > 0$ and $0 > \theta_i \geq -1$. The parameter ε_i is probably different from one, because θ_i and ε_i are connected through the covariance. Therefore, if θ_i is biased ε_i is biased two.[12] We estimate this model (model 9) with OLS.

Model 9 (M9): Equation (37) with $i = L, H, L+H$

Table 4: Unemployment estimates with the estimated labour demand of the models 1-8

M9	M1	M2	M3	M4	M5	M6	M7	M8
β_L	-12156,0	-27117,3	-13842,8	-27612,8	-7798,61	-26525,7	-10519,2	-20219,5
	(-3,05)	(-5,07)	(-3,73)	(-4,58)	(-1,76)	(-5,49)	(-2,51)	(-5,34)
β_H	-39,1426	262,048	-111,572	279,414	58,3667	273,771	-40,2801	268,790
	(-0,86)	(3,05)	(-2,92)	(2,76)	(0,99)	(3,22)	(-0,87)	(2,06)
β_{L+H}	-4872,2	-12000,8	-6420,93	-13298,3	-2487,23	-10956,3	-4552,60	-5428,03
	(-2,63)	(-8,94)	(-3,99)	(-8,57)	(-1,14)	(-8,60)	(-2,39)	(-2,60)
ε_L	0,9257	1,3525	0,9868	1,3524	0,7670	1,3437	0,8662	1,1581
	(8,84)	(4,58)	(9,64)	(4,21)	(6,64)	(4,92)	(8,03)	(7,06)
ε_H	0,1574	0,1133	0,1645	0,1069	0,1450	0,1153	0,1560	0,0924
	(6,06)	(9,47)	(5,36)	(9,06)	(6,97)	(9,65)	(5,93)	(8,48)
ε_{L+H}	0,5429	0,7470	0,5887	0,7828	0,4718	0,7155	0,5325	0,5248
	(10,43)	(6,67)	(9,65)	(6,23)	(10,87)	(7,07)	(10,55)	(8,76)
θ_L	-0,3753	-0,1568	-0,1579	-0,0580	-0,3773	-0,1674	-0,1443	-0,1071
	(-3,40)	(-1,55)	(-3,23)	(-1,45)	(-4,03)	(-1,64)	(-3,62)	(-2,16)
θ_H	-0,1286	-0,1554	-0,0503	-0,0599	-0,1255	-0,1400	-0,0452	-0,0451
	(-3,98)	(-5,27)	(-3,58)	(-4,64)	(-4,40)	(-5,47)	(-3,86)	(-3,49)
θ_{L+H}	-0,3379	-0,2927	-0,1416	-0,1201	-0,3282	-0,2821	-0,1258	-0,1195
	(-4,08)	(-3,22)	(-3,89)	(-3,12)	(-4,44)	(-3,29)	(-4,11)	(-3,40)

Numbers in parenthesis are t-statistics based on Newey-West HAC standard errors.

The parameters ε_L and ε_H are better estimated in the NNTP models, since they are closer to one. For θ_L we can also identify better estimates with NNTP, but θ_H seems not to be affected by different specifications of technical progress. The latter indicates, that the high skilled unemployment is not affected negatively by technical progress, but the low skilled unemployment is strong negative affected.

Table 5: Coefficients of determination and Durbin – Watson statistics of the unemployment estimates

M9		M1	M2	M3	M4	M5	M6	M7	M8
U_L	R^2	0,700	0,511	0,692	0,500	0,730	0,522	0,711	0,573
	$\overline{R}^2$	0,662	0,450	0,653	0,437	0,696	0,462	0,675	0,520
	DW	0,581	0,548	0,585	0,545	0,580	0,550	0,580	0,538

[12] For a discussion of this problem see for example Greene (1997).

U_H	R^2	0,838	0,864	0,827	0,848	0,847	0,867	0,834	0,815
	$\overline{R}^2$	0,818	0,847	0,805	0,830	0,828	0,851	0,814	0,792
	DW	0,693	0,698	0,681	0,654	0,699	0,714	0,685	0,580
U	R^2	0,766	0,719	0,759	0,716	0,779	0,720	0,766	0,699
	$\overline{R}^2$	0,736	0,684	0,729	0,681	0,751	0,686	0,737	0,661
	DW	0,594	0,593	0,596	0,598	0,595	0,588	0,593	0,528

R^2 is the coefficient of determination, $\overline{R}^2$ is the adjusted coefficient of determination, and DW is the Durbin-Watson d statistic.

Table 5 supports the findings of table 4. With NNTP the explained variation of the low skilled is far better and of the whole unemployment slight better. Again the high skilled unemployment is not effected by technical progress concerning the quality. The residuals indicate autocorrelation. To make the parameters statistics more reliable we use Newey-West autocorrelation and heteroscedasticity consistent variances.

Finally, the question which model is the correct specification, can only be answered with the separability tests. Therefore linear and non – linear separability tests and some restriction tests concerning the technological progress are applied to M1. The results (not reported) confirm with a significance level of 0,01 that neither one production factor is weak separable nor is technological progress.[13] That applies to both linear and non – linear separability. The results are supported by the DW-statistics in table 3. The more factors are neglected, the lower are the DW-statistic. This indicates a specification bias. For the technological progress we test HNTP against NNTP. For this we combine equation (26) with (27). Again the results are unambiguous. M1 is the solely correct specification.

All in all this shows impressively that the West – German unemployment problem is for the most part a problem of a permanent increasing skill gap of the low skilled. The results of the cost function and unemployment estimates indicate, that specifications with NNTP are superior. This is especially true for the low skilled. This allows two conclusions. First, the labour demand can be explained by prices and NNTP. Second, for the demand of low skilled labour technological progress plays a more important part than for the high skilled.

13 All test results based on the Wald Test.

5. Discussion of elasticities and biased technical change

Now we investigate, if every factor of M1 have a significant bias concerning technical change. Technically spoken, equation (27) is not zero but a part of the equation could be. The results (not reported) do not support the idea that for example, energy and material do not have a significant biased technical progress, but capital and labour do. The conclusion is, that there is a complex bias between all production factors. Before we report the technological progress as explained in equation (23), we test two further considerations. First, it is absolutely unlikely that the two kinds of labour have the same bias. Second, it is again unlikely that capital and high skilled have the same bias. This fulfils the requirement of Hamermesh (1996, 352), *"Studies applying Type c methods to a variety of sets of aggregate time series data that allow the disaggregation of labor by skill category and that test for possible nonneutrality of technical change across types of labor are needed."* [14]

Table 6: Bias of technological change in model 1

Year	1976	1979	1982	1985	1988	1991	1994
φ_M	0,027	0,026	0,027	0,027	0,026	0,026	0,026
φ_K	0,025	0,026	0,029	0,026	0,025	0,024	0,024
φ_L	-0,106	-0,110	-0,106	-0,115	-0,122	-0,128	-0,131
φ_H	0,168	0,155	0,135	0,133	0,131	0,128	0,120
φ_E	-0,098	-0,098	-0,077	-0,075	-0,103	-0,109	-0,115

Table 6 shows the bias of technological change of each input. As one could expect, the bias for the low skilled is negative and increasing. The bias of the high skilled is positive but decreasing. Additionally, material and capital have a stable factor using and energy an unstable and comparatively high factor saving bias. Hence, the results indicate a SBTC, again.

Table 7 shows Allen – Uzawa, cross price, and Morishima elasticities of the relevant inputs capital, low and high skilled concerning M1. If we apply the complementarity conditions we receive the result, that only five conditions and none of the strong conditions are satisfied. On the basis of these results we must reject the hypothesis of CSC. This confirm the supposition of Hamermesh (1996, 352) concerning the CSC. *"The evidence is far too sparse, though, to infer whether this conventional interpretation is correct, or whether instead it is produced by technical change that augments different types of labor at different rates."*

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14 Type c methods are translog models.

Table 7: Elasticities of model 1

Year	1976	1979	1982	1985	1988	1991	1994
σ_{KL}	0,968	0,966	0,963	0,965	0,964	0,963	0,962
	(1196,1)	(1151,2)	(1109,1)	(1063,8)	(1021,8)	(980,6)	(939,1)
σ_{KH}	1,077	1,074	1,072	1,062	1,059	1,057	1,053
	(35,47)	(37,29)	(39,12)	(40,68)	(42,54)	(44,45)	(46,28)
σ_{LH}	0,287	0,317	0,429	0,390	0,362	0,344	0,372
	(1,12)	(1,25)	(1,71)	(1,57)	(1,46)	(1,39)	(1,50)
η_{KL}	0,212	0,204	0,212	0,195	0,184	0,175	0,171
	(114,32)	(110,90)	(115,98)	(107,48)	(101,97)	(97,76)	(96,39)
η_{LK}	0,101	0,098	0,087	0,100	0,103	0,105	0,106
	(116,28)	(108,56)	(93,70)	(103,36)	(103,42)	(101,43)	(98,18)
η_{KH}	0,068	0,073	0,084	0,084	0,085	0,087	0,092
	(34,19)	(37,12)	(42,83)	(43,50)	(44,38)	(45,53)	(48,72)
η_{HK}	0,113	0,109	0,097	0,110	0,114	0,115	0,116
	(35,72)	(36,04)	(33,59)	(39,53)	(42,59)	(45,05)	(46,89)
η_{LH}	0,018	0,022	0,033	0,031	0,029	0,028	0,033
	(1,08)	(1,25)	(1,88)	(1,68)	(1,52)	(1,42)	(1,58)
η_{HL}	0,063	0,067	0,095	0,079	0,069	0,062	0,066
	(1,11)	(1,24)	(1,82)	(1,58)	(1,44)	(1,36)	(1,49)
μ_{KL}	0,992	0,992	0,992	0,992	0,992	0,992	0,992
	(4081,0)	(4821,7)	(5874,6)	(7707,5)	(11751,0)	(26126,8)	(89272,3)
μ_{LK}	0,955	0,954	0,955	0,952	0,950	0,948	0,947
	(81,35)	(78,11)	(75,22)	(72,09)	(68,94)	(65,86)	(62,93)
μ_{KH}	1,004	1,003	1,002	1,002	1,002	1,002	1,002
	(490,95)	(524,61)	(559,41)	(596,17)	(633,60)	(673,43)	(713,92)
μ_{HK}	0,813	0,827	0,851	0,853	0,855	0,858	0,867
	(11,98)	(12,78)	(13,74)	(14,38)	(15,01)	(15,67)	(16,45)
μ_{LH}	0,806	0,817	0,837	0,836	0,835	0,835	0,842
	(18,68)	(20,33)	(22,38)	(24,03)	(25,86)	(27,97)	(30,55)
μ_{HL}	0,763	0,776	0,801	0,799	0,799	0,799	0,807
	(14,37)	(15,70)	(17,40)	(18,68)	(20,10)	(21,75)	(23,81)

Numbers in parenthesis are asymptotic t-statistics.

So far one can only conclude that the SBTC, which provides a good explanation for the development of (un)employment, stands possibly in conflict with the CSC. For that reason we review all estimated models and the reported studies for an overlooked connection.

A first interesting finding is, that if we apply the complementarity conditions on the hypothesis labour – labour complementarity and capital – labour substitutability ($KL > LH$ and $KH > LH$), in both cases all nine conditions are satisfied.[15] That means, that low and high skilled labour are strong complements but both are substitutes for capital. If we test this hypothesis on the reported studies in table one, we get the surprising results that FM82 and B84 satisfy both cases, too (but the authors do not mention that). Indeed, they fulfil all eight conditions an have therefore estimated a strong complementarity between blue and white collar labour and substitutability between labour and capital.[16] In P91 we found with eight satisfied conditions a support of the second labour – labour complementarity ($KH > LH$). Obviously these hypothesis need not be a contradiction to the CSC, since FM82 support the CSC nearly as good.[17] To test the robustness of these results concerning M1, all three hypothesis will be tested on the other seven models, too.

Table 8: Results of the complementarity condition test on the complementarity hypothesis

	CSC	LLC(KL)	LLC(KH)
M1	5 nsc	8 bsc	8 bsc
M2	5 nsc	8 bsc	8 bsc
M3	8 bsc	7 ssc	2 nsc
M4	6 fsc	2 nsc	0 nsc
M5	5 nsc	8 bsc	8 bsc
M6	5 nsc	8 bsc	8 bsc
M7	7 fsc	7 ssc	6 ssc
M8	8 bsc	8 bsc	7 fsc

CSC capital – skill complementarity; LLC(KL) labour complementarity and capital low skilled substitutability; LLC(KH) labour complementarity and capital high skilled substitutability, nsc no strong condition, fsc first strong condition, ssc second strong condition, bsc both strong conditions.

In table 8 the results of all hypothesis tests of complementarity are shown. For example, 5 nsc (M1 and CSC) means, that the Hypothesis is five times satisfied (three times rejected) and satisfies no strong condition. We can draw the following conclusions. First, separating the results in models with HNTP and NNTP, we can ascertain that there is no significant difference concerning the complementarity hypothesis. Second, the two labour – labour complementarities exist in the bulk of the models relative robust of the specification.

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15 This idea goes back to Griliches, too. However, to our knowledge this hypothesis has never been examined so fare. Concerning the equations 9 – 16 that means for $KL > LH$ that $i = L, j = K, o = H$ and for $KH > LH$ that $i = H, j = K, o = L$.

16 In FM82 they are from condition one to four strong absolute complements, and in B84 they are for all conditions strong absolute complements.

17 We found a strong energy – skill complementarity hypothesis (ESC) in BM79, however, the authors do not mention that. Note that BM79 found a capital – energy complementarity (CEC) in their study. The difference to our finding

Third, CSC is supported only in the models without material and seems to be independent of the specification of technological progress. Since the cost share of material is above 50% this is an immense specification error because material is not weak separable. Only one reported study take material into account. It is BM79 which do not support the CSC.

The latter point has two interesting consequences. Certainly, the finding of Frondel and Schmidt (2001), that the CSC will be weaker with an increasing number of inputs and hence decreasing cost shares, is possibly one important point. But this does not explain the second point. The specification of NNTP has a far-reaching implication because in all four specifications no negative cross price elasticity is found. Whereas in the HNTP specifications three of four cases contain some negative cross price elasticities. Since technology is not a cost share the idea of Frondel and Schmidt is not applicable here. If we look again at table two, we can observe that the more factors are included the lower are the parameters. The same is true for the implementation of NNTP. Since M1 is not separable all other models are misspecified. As we pointed out above this is supported by the DW-statistics. Strictly speaking the other models have a specification bias owing to omitted variables. The consequences are increasing parameters and especially for the insignificant parameters a change in the sign. These effects of the specification bias can explain the cost share argument of Frondel and Schmidt, but not vice versa.

Two decisive effects result from this parameter behaviour. On the one hand, some of the signs change and on the other hand, since not every parameter decreases with the same rate, the order of magnitude between the parameters change. Both effects are important for any complementarity hypothesis, because the order of magnitude of the γ-parameters could change. We call these effects of the specification bias on the parameters the γ-effect.

Concerning the results in table 2 this means that if the cost shares of capital and high skilled are roughly equal (like in this study), we can reject the CSC if $\gamma_{KL} < \gamma_{KH}$. But if (like in M3, M4, M7 and M8) $\gamma_{KL} > \gamma_{LH}$ we get the exact opposite result concerning the hypothesis and accept the CSC. Therefore it is important that these parameters are statistically significant. For all three complementarity hypothesis we need the parameters γ_{KL}, γ_{KH} and γ_{LH} respectively. In M1 all three are significant.[18]

is, that we have a hypothesis of an relation between three factors and not only between two factors. That means, the CEC looks only a the sign, but we look beyond that at the relative ratio.

18 The reported studies do not give much information about statistical significance. Only BC74 reports all standard errors which indicate statistically significance. All others studies give no or incomplete information.

To sum up it can be said the following on the basis of model one. Capital has no complement relation to any other factor and the CSC can't be verified. The used production technology is skill biased. If we use the complementarity conditions the two types of labour are complements refer to the elasticities of capital and labour. For the low skilled we have two effects. First, the low skilled price rises faster than every other price. This lead to a relative high substitution of labour. Second, the direction of the production technology was affected by this price expectation and perhaps by globalisation effects (a shift in the output – market conditions). The reason for this supposition is the relative high negative influence of NNTP for the low skilled labour demand. This all indicates both a complex substitution process between all production factors on account of changing relative factor prices and a complex factor bias. Both effects hurt the unskilled (un)employed for the most part.

6. Conclusion

This paper has shown that the CSC is more a myth than reality. Based on a critical review on the model specification the CSC is not significantly detectable. One gain of the study is the distinction between skilled and unskilled labour rather than between blue and white collar workers which is usually used. Furthermore it is the first study that combines the implicit estimated skill specific labour demand with the skill specific unemployment. The main findings of this paper are the following:

- On the basis of the complementarity conditions we cannot unambiguously support the existence of the CSC in the reported studies. Rather it seems that the CSC results from a cost function that is misspecified in terms of neglected factor prices.
- A further application of the complementarity conditions lead to the results that the two types of labour are complements refer to the elasticities of capital and labour.
- If separability is considered, we must rejected the CSC and accept a LLC instead.
- Beyond that, we found a SBTC which seems to be relative unaffected by functional specifications concerning the neglected factor prices.
- If factor prices and/or NNTP are omitted the estimated cost shares have a specification bias which we call the γ-effect. As a consequence, both the sign of statistical insignificant parameters and the order of magnitude of them could change. This could lead to quite different interpretations of both the substitution and the complementarity effects.

- All specifications with NNTP have exclusive positive cross price elasticities, unlike the HNTP specifications.
- If we use the implicit estimated skill specific labour demand to explain the development of high and low skilled unemployment, the models with NNTP are superior.
- The growing low skilled gap is explained by factor prices and technical progress. Both effects and especially the latter hurts the unskilled (un)employed for the most part.
- Concerning the translog cost function there is no doubt that the choice of the (right) specification has a decisive meaning for the results and has to be done very carefully.

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