

Bauer, Thomas

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Do Immigrants Reduce Natives' Wages?

Evidence from Germany*

Thomas Bauer
(SELAPO, University of Munich)

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Abstract

This paper investigates the effects of immigration on the wages of native workers in Germany. The analysis differentiates native and foreign workers according to their occupational status. The estimation of a translog production using 1990 cross section data reveals mixed results regarding the production relationship between different native and foreign groups. However, the effects of immigration on the wages of natives are numerically very small. Separability tests show that the use of an aggregate index for foreign labor and the treatment of natives and foreigners as similar inputs is not appropriate.

JEL Classification: J23, J61

Keywords: immigration, substitutability, separability, wages

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Correspondence to.

Thomas Bauer
SELAPO, University of Munich
Ludwigstr. 28/RG
80539 München
Germany
E-Mail: thomas.bauer@selapo.vwl.uni-muenchen.de

1. Introduction and Review of the Literature

At the center of the debate on immigration policy in Germany has been the fear that immigrants might have negative effects on the earnings of native employees. The empirical investigation of the substitutability of natives by foreigners is critical in evaluating the validity of these concerns. Starting with the analysis of Grossman (1982) a multitude of empirical studies of the labor market effects of immigration have been done for the United States. A survey of these studies is given by Borjas (1994). Typically these studies have applied the theory of labor demand with multiple factor inputs (see Hamermesh, 1993). This has been done by estimating a production function for the elasticities of substitution between immigrants and natives, which allows computation of the effect of foreigners on other factor prices. Most of these studies could not support the hypothesis that native Americans are strongly and adversely affected by immigration (Borjas, 1994).

Compared to the United States the empirical evidence for the German labor market is relatively rare. DeNew and Zimmermann (1994) and Haisken-DeNew and Zimmermann (1995) have employed a reduced form model of a labor market by estimating a standard wage equation with German panel data. In this reduced form model it is assumed that wages are determined by human capital and job characteristics, industry affiliation and the overall share of the foreigners in the industry in which the native individual works. The sign of the estimated coefficient of this foreigner-share variable determines whether immigrants are complements or substitutes to natives. DeNew and Zimmermann (1994) have found significant substitutional effects of immigration for native blue collar workers and complementarity effects for native white collar workers with less than 20 years of labor market experience. According to their estimates, a 1%-point increase in the employment of migrants leads to a decrease of the wages of native blue collar workers by 5.3% and to an increase of the wages of low-experienced white collar workers by about 3.5%.

Using the same framework and data set but disaggregating the foreigner industry share by regions, Haisken-DeNew and Zimmermann (1995) have found significantly different effects than in their 1994 study. Overall, the estimates exhibit a complementarity effect of immigration.

Looking at different occupational groups Haisken-DeNew and Zimmermann (1995) have found no significant wage effects of immigration on native white collar workers, but a significant positive wage effect on native blue-collar workers with more than 20 years of labor market experience. Using a similar specification as DeNew and Zimmermann (1994) but a different data set, Pischke and Velling (1994) have found positive but predominantly insignificant wage effects of migration. However, all of these studies have used only one aggregate index to describe foreign labor as a input factor for production. Therefore, it is implicitly assumed that the foreigners form a homogenous group. One objective of this study is to test whether this assumption is sensible or whether foreigners should be disaggregated into several different groups.

Gang and Rivera-Batiz (1994) featured the use of a production technology to estimate the labor market effects of immigration. Differently to the existing literature, the authors have not considered immigrants and native-born as separate production inputs. Rather, Gang and Rivera-Batiz (1994) have suggested that the labor market impact of immigrants is related to the specific skills they bring to the labor market of the receiving country. The authors have used three steps to evaluate the factor price elasticities between natives and immigrants. In the first two steps they have estimated factor price elasticities differentiating the inputs education, low-skilled labor and experience using a translog production function. In the third step the authors have calculated composite elasticities of complementarity between natives and immigrants using the average qualification of both labor groups regarding the three human capital inputs.

Based on 6 waves (1986-1989) of the Eurobarometer, the results of Gang and Rivera-Batiz (1994) imply small substitution effects of immigrants from the guestworker recruitment countries (Turkey, Portugal, Spain and Italia). The highest negative effect is estimated for the case of a 1% inflow of Turks which would lower the wages of Germans by about 0.11%. It has to be noted that the results of Gang and Rivera-Batiz (1994) crucially depend on the assumed characteristics of the immigrants with regard to their human capital endowment. Using the average characteristics of German immigrants as reported by Licht and Steiner (1992) instead of the average characteristics of the immigrants in the Eurobarometer most of the calculated elasticities even change their sign.

A second problem of the study of Gang and Rivera-Batiz (1994), which will be addressed in this study, can be found in the assumption that immigrants and natives of the same sex and with a similar human capital endowment are identical factor inputs. Due to social and cultural differences it could be possible that otherwise identical foreigners and natives should be treated as different factor inputs.

The main objective of this paper is to give further evidence on the production relationship between foreigners and natives using German cross-section data for 1990. Different to the existing German literature on this issue the paper follows the bulk of the literature in the U.S. by estimating an aggregate production function and treating immigrants and natives as different factor inputs. Furthermore, the production function will be tested for separability to determine whether there exists an aggregate index for foreign labor and whether immigrants and natives of the same occupational status must be treated differently. The next section presents the empirical model and describes the data set used in this study. Section III discusses the estimates of the impact of different groups of immigrants on the wages of natives and the results of the separability tests. Section IV concludes.

II. Empirical Model and Data Set

To determine the production relationship between natives and foreigners I will follow the work of Grossman (1982) by assuming that the production technology is characterized by a translog production function (see Christensen, Jorgenson and Lau, 1971):

$$(1) \quad \ln Y = \ln \alpha_0 + \sum_i \gamma_i \ln X_i + \frac{1}{2} \sum_i \sum_j \gamma_{ij} \ln X_i \ln X_j, \text{ for } i, j = 1, \dots, n,$$

where Y is the quantity produced, X_i is the quantity of input i , and γ_i and γ_{ij} are technology coefficients to be estimated. The use of a production function instead of a cost function is justified

by the assumption that the input quantities, not input prices, are fixed. Since cross-section data is used for the empirical analysis it is plausible to assume that there is no factor mobility which in turn implies that all inputs are approximately fixed. A detailed discussion of the assumptions needed to justify the use of production function and a cost function can be found in Hamermesh (1993).

Assuming competitive factor markets one can derive that

$$(2) \quad \frac{\partial \ln Y}{\partial \ln X_i} = \frac{P_i X_i}{Y} = s_i,$$

where P_i is the price of factor i and s_i is the relative share of income accruing to factor i . Partial logarithmic differentiation of the production function (1) and use of equation (2) gives the following system of factor share equations:

$$(3) \quad s_i = \alpha_i + \gamma_{ii} \ln X_i + \sum_j \gamma_{ij} \ln X_j, \text{ for } i, j = 1, \dots, n.$$

Demand theory requires symmetry, so that $\gamma_{ij} = \gamma_{ji}$. I also impose homogeneity, $\sum \alpha_i = 1$. To implement this share equation system empirically, a random disturbance term is added to each share equation. It is assumed that the resulting disturbance vector is multivariate normally distributed with mean vector zero and constant covariance matrix Ω^* . Since the factor shares s_i add up to 1, only $n - 1$ of the n factor share equations in (3) are linearly independent. This problem is solved by deleting one of the share equations. To make sure that the choice of the omitted share equation has no impact on the estimation results the remaining $n - 1$ equations have been estimated using the iterative Zellner's seemingly unrelated regression technique (IZEF). The technology parameters of the omitted parameters could be calculated using the restrictions that

$\sum_i \gamma_{ij} = \sum_j \gamma_{ij} = \sum_i \sum_j \gamma_{ij} = 0$ which follows from the assumption of linear homogeneity, $\sum \alpha_i = 1$, symmetry $\gamma_{ij} = \gamma_{ji}$, and from $\sum s_i = 1$.

The assumption of fixed quantities requires the use of Hicksian elasticities of complementarity instead of the better known Allan elasticities of substitution. A discussion of the relationship between these two elasticities is given by Sato and Koizumi (1973). The Hicksian elasticity of complementarity measures the effect on the relative price of factor i of a change in the relative quantity of factor j , holding constant the marginal costs and the quantities of other factors. It can be shown that under the translog production technology, the Hicksian elasticities of complementarity are given by (see Hamermesh, 1993):

$$(4) \quad c_{ij} = \begin{cases} \frac{\gamma_{ij} + s_i s_j}{s_i s_j}, & \text{for } i \neq j, \\ \frac{\gamma_{ii} + s_i^2 - s_i}{s_i^2}, & \text{for } i = j. \end{cases}$$

Factors i and j are substitutes (complements) if c_{ij} is negative (positive). Finally, the elasticity of factor price, which measures the percentage change of the price of factor i due to a one-percent increase in the supply of factor j , is given by (see Hamermesh, 1993):

$$(5) \quad \frac{\partial \ln P_i}{\partial \ln X_j} = \theta_{ij} = s_j c_{ij}.$$

Since the elasticities are non-linear functions of the estimated parameters γ_{ij} and the shares themselves are functions of these parameters, there are severe problems in calculating the standard errors for the elasticities without reverting to Monte Carlo simulations. Therefore, I will refer to the estimated standard errors of the technology coefficients γ_{ij} as an approximation of the standard errors of the elasticities.

The factor share equations (3) are estimated using a cross-section of the *German Labor*

Force Survey from 1990. The *German Labor Force Survey* is a 1% sample of all German employees paying social security contributions and has been collected by the German Labor Office since 1973. A detailed description of the data set is given by Bender et al. (1996). The analysis is restricted to full-time working male individuals of 17 years or older who are not apprentices. From this cross-section data I have calculated the number of individuals working in each out of 93 industries for the following six subgroups: native and foreign low-skilled blue collar workers, native and foreign high-skilled blue collar workers and native and foreign white collar workers. Since in some industries no foreign workers are observed, the available number of observations is reduced to 62 industries. The factor shares s_i for each subgroup are calculated as the sum of the gross daily wages of that subgroup in a particular industry divided by the sum of the wages of all subgroups in the respective industry.

It is not possible to obtain capital stock data for all industries used in this analysis. Hence, strong separability between the capital stock and all other inputs must be assumed. If this assumption is inappropriate, the resulting cross-price elasticities of demand for the factors are overestimated and the own-price elasticities of demand are underestimated (see Berndt, 1980). Note also, that the described restrictions on the used sample assumes that females, part-time workers and apprentices are fully separable from the factors taken into consideration in the following empirical analysis. The descriptive statistics of the variables are shown in [Table 1](#). They show that most of the natives are high skilled blue collar workers followed by white collar workers. Contrary to the natives, foreign workers are mostly low-skilled blue collar workers followed by high skilled blue collar workers. Only a small number of foreigners are employed as white collar workers.

III. Estimation Results

A. Substitutability between Natives and Foreigners

The estimated coefficients of the share equations (3) are shown in [Table 2](#). For estimation the factor share equation for white collar natives was deleted. [Table 2](#) shows that there exists no significant

production relationship between low skilled blue collar native and foreign workers ($\gamma_{UN,UF}$), native low skilled blue collar workers and foreign high skilled blue collar workers ($\gamma_{UN,SF}$), and foreign low skilled blue collar workers and foreign white collar workers ($\gamma_{UF,WF}$). Thus, immigration seems to have no effect on those natives for which the concerns of large negative wage effects are greatest. The estimates of the translog coefficients are used to calculate the Hicksian elasticities of complementarity (c_{ij}) and the elasticities of factor price (θ_{ij}). The results of this calculation are presented in Table 3.A.

Table 3.A shows that all own-elasticities have the expected negative sign. Several findings with regard to the cross-elasticities are worth stressing. First, most of the immigrant groups are complements to natives. The only exception are white collar immigrants who have a negative impact on the wages of low skilled blue collar and white collar natives and foreign low skilled blue collar workers who are substitutes to high skilled blue collar natives. However, the surprising results regarding the wage effects of white collar immigrants should be interpreted carefully since many data cells of this group include only small numbers. Summarizing, white collar natives always benefit from immigration whereas the largest native group, high skilled native workers, benefit only from the immigration of high skilled blue collar and white collar foreign workers. Compared to the existing empirical studies for Germany these results are more in line with those of Haisken-DeNew and Zimmermann (1995) and Pischke and Velling (1994) who found overwhelming complementarity effects of immigration. Despite the insignificant coefficient $\gamma_{UN,SF}$ the calculated Hicksian elasticities of complementarity indicate that low skilled blue collar and high skilled blue collar workers are substitutionary inputs. On the other hand, white collar natives are complements to all groups of low and high skilled blue collar workers. These results are consistent with the expectation that “like” inputs are more substitutable than “unlike” inputs.

Greater insight into the native wage effects of immigration can be gained by looking at the calculated elasticities of factor prices reported in Table 3.B. Inspection of the elasticities shows that the impact of migrants on the wages of all native labor groups is negligible. For example, with a cross-elasticity of 0.01967 the highest positive effect is found for the earnings of white collar

natives with respect to the quantity of low skilled blue collar foreigners. This result implies that a 10% increase in the supply of low skilled blue collar foreigners increases the earnings of white collar natives by less 0.20%, translating to a DM 0.31 increase for the average daily wage of native white collar workers of DM 153.26. The estimated negative effects are also very small. If evaluated at the average daily wage of the respective native group a 10% inflow of white collar immigrants reduces the daily wage of low skilled blue collar workers by about 0.21% (DM 0.21) and that of white collar natives by 0.08% (DM 0.12), and a 10% increase in the supply of low skilled blue collar foreigners decreases the wages of high skilled blue collar natives by 0.08% (DM 0.09). These elasticities reveal that some immigrant groups compete with some native groups, but the impact of this effect is numerically unimportant. With the exception of the results of DeNew and Zimmermann (1994), who have found relatively large wage effects, these findings are in line with the existing German evidence.

However, Table 3 reveals a sizeable effect of immigrants on the wages of their own group. The elasticities within the immigrant groups are much larger than the cross-elasticities between natives and foreigners and in most cases are also larger than the respective elasticities within the native groups. For example, a 10% increase of low skilled blue collar immigrants reduces the daily wages of low skilled blue collar workers by 2.55% (DM 2.57); a 10% increase in the number of high skilled blue collar immigrants reduces the daily wage of the same group by 0.71% (DM 0.81); and a 10% inflow of white collar foreigners reduces the wage of white collar immigrants by 1.78% (DM 2.71). With respect to the cross-elasticities the highest negative effect is estimated to be a reduction of the wages of high skilled blue collar immigrants by 1.00% (DM 1.15) in the case of a 10% increase in the supply of low skilled blue collar foreigners. The highest positive impact is released by a 10% inflow of high skilled blue collar immigrants which increases the wages of white collar immigrants by 1.78% (DM 2.71). It is interesting that similar results, namely relatively large impacts of immigrants on the determination of their own wages when compared to their effect on natives, are obtained in the U.S. (Borjas, 1987). It is possible that these results are driven by outliers if the immigrants are concentrated in relatively few industries. However, restricting the analysis to industries with relatively large numbers of immigrants does not have major impacts on

the estimation results.

B. Functional Separability

An important step in the examination of the production relationship between natives and immigrants is a test for functional separability of the inputs. Such a test determines the possibility for aggregation of inputs, since the acceptance of a separability restriction implies the existence of some aggregate index of a subset of the inputs. Based on this test one can decide whether the use of an aggregate index of foreign labor as in DeNew and Zimmermann (1994), Haisken-DeNew and Zimmermann (1995) and Pischke and Velling (1994) is sufficient or if a more detailed grouping of the immigrants is useful. In addition, it is possible to test whether natives and immigrants of the same occupational status should be treated as different factor inputs or if they must be treated in a common way. Note, however, that this test is only an approximate test of the assumption of Gang and Rivera-Batiz (1994) since the analysis in this paper does not directly control for the human capital endowment of the different groups. Despite the importance of these separability tests the use of different groupings of natives and foreigners were assumed a priori in all existing studies of the wage effects of immigration.

Approximate tests for varying degrees of separability have been derived by Denny and Fuss (1977). They have suggested a nested sequential testing procedure starting with the least restrictive form of weak separability. According to Denny and Fuss (1977) the following additional conditions must hold for weak separability of the inputs $k \in (t+1, \dots, n)$ from the inputs $i, j \in (1, \dots, t)$:

$$(6) \quad \ln Y = F[G(\ln X_1, \dots, \ln X_t), \ln X_{t+1}, \dots, \ln X_n] \text{ if } \frac{\alpha_i}{\alpha_j} = \frac{\gamma_{ik}}{\gamma_{jk}} \quad \forall i, j, k,$$

where the α 's and γ 's are the estimated parameters. Whenever this first separability hypothesis cannot be rejected, the testing sequence proceeds to strong separability. Therefore, the second step of the test procedure tests, whether the translog function is a quadratic approximation to an arbitrary logarithmic partially strong separable function of the form

$$(7) \quad \ln Y = G(\ln X_1, \dots, \ln X_t) + H(\ln X_{t+1}, \dots, \ln X_n) \text{ if } \gamma_{ik} = \gamma_{jk} = 0 \quad \forall i, j, k.$$

The resulting Wald-test-statistics for the most interesting factor combinations are presented in Table 4. The first three rows of Table 4 show that the existence of an aggregate index could not be accepted neither for native and foreign low skilled blue collar workers, nor for native and foreign skilled blue collar workers, nor for native and foreign white collar workers. These results indicate that natives and immigrants with the same occupational status can not be treated as similar inputs. Regarding the separability of immigrants the test shows that only skilled blue collar immigrants and white collar immigrants can be treated as an aggregate. However, logarithmic partially strong separability of this combination could be rejected on a 1% significance level. The last row of Table 4 further shows that foreigners as a group are not separable from natives. According to these findings the use of an aggregate index for foreign labor is inappropriate and could lead to unreliable estimates of the parameters describing substitution between the labor subaggregates.

IV. Summary and Conclusions

Based on a translog production function this study investigates the substitutability of natives and foreigners using German cross-section data for 1990. The analysis differentiates between low skilled blue collar, high skilled blue collar and white collar native and foreign workers. Unfortunately, due to a lack of data the role of capital as a input factor could not be taken into consideration. Therefore, the analysis of this paper holds only for the assumption of full separability between capital and all other factor inputs. The empirical results show that white collar immigrants are substitutes to low skilled blue collar and white collar natives. High skilled blue collar natives tend to be adversely affected by the increase in the supply of low skilled blue collar immigrants. Between all other native and foreign groups a complementary relationship could be revealed. Moreover, all wage effects of immigration are calculated to be numerically very small. Despite the use of a different methodology and a different data set these findings confirms most of the existing

evidence for Germany. The results indicate that the fears of great negative effects of immigration on the wages of natives lacks an empirical basis. Rather, most of the native labor groups can expect benefits in terms of higher earnings from immigration. Tests for the separability characteristics of the used translog production function confirm the hypothesis that, under the assumptions made, the aggregation of foreigners into a single group may not always be sufficient. Furthermore, these separability tests show that natives and foreigners with the same occupational status are not separable. These findings imply the possibility that in this respect most of the existing studies on the wage effects of immigration in Germany may report biased results.

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Table 1: Descriptive Statistics

Variable	Natives		Foreigners	
	Mean	Standard Deviation	Mean	Standard Deviation
<i>Number of Employees:</i>				
Low-Skilled Blue Collar	298.11	411.62	70.24	93.00
High-Skilled Blue Collar	516.56	804.51	45.10	94.04
White Collar	461.50	954.21	17.31	34.39
<i>Income Shares:</i>				
Low-Skilled Blue Collar	0.1950	0.11	0.0545	0.05
High-Skilled Blue Collar	0.3172	0.18	0.0256	0.02
White Collar	0.3874	0.23	0.0203	0.03

Table 2: Technology Parameters (γ_{ij}) for the Translog Production Function

Coefficient	Value	t-Value
α_{UN}	0,22069 [†]	8,91
α_{UF}	0,13854 [†]	9,35
α_{SN}	0,15461 [†]	5,41
α_{SF}	0,07580 [†]	10,37
α_{WN}^1	0,29448 [†]	9,92
α_{WF}	0,11588 [†]	10,26
$\gamma_{UN,UN}$	0,13482 [†]	17,08
$\gamma_{UN,UF}$	-0,00388	-0,96
$\gamma_{UN,SN}$	-0,06320 [†]	-11,32
$\gamma_{UN,SF}$	-0,00211	-1,01
$\gamma_{UN,WN}$	-0,06140 [†]	-11,00
$\gamma_{UN,WF}$	-0,00801 [†]	-2,78
$\gamma_{UF,UF}$	0,03761 [†]	11,30
$\gamma_{UF,SN}$	-0,01993 [†]	-6,24
$\gamma_{UF,SF}$	-0,00397 [†]	-2,43
$\gamma_{UF,WN}$	-0,01349 [†]	-3,87
$\gamma_{UF,WF}$	-0,00182	-0,95
$\gamma_{SN,SN}$	0,19426 [†]	29,20
$\gamma_{SN,SF}$	-0,00785 [†]	-4,08
$\gamma_{SN,WN}$	-0,08739 [†]	-15,89
$\gamma_{SN,WF}$	-0,00557 [†]	-2,44
$\gamma_{SF,SF}$	0,02314 [†]	12,99
$\gamma_{SF,WN}$	-0,00979 [†]	-5,53
$\gamma_{SF,WF}$	0,00309 [†]	2,57
$\gamma_{WN,WN}^1$	0,18304 [†]	28,73
$\gamma_{WN,WF}$	-0,01097 [†]	-3,58
$\gamma_{WF,WF}$	0,01628 [†]	7,43
Log-Likelihood	-738,129	

*: IZEF-Estimations of Equation (3). U: low skilled blue collar workers; S: High skilled blue collar workers; W: White collar workers; N: Natives; F: Foreigners. †: significant different from 0 on a 5% significance level. Number of Observations: 372. The factor share equation for native white collar workers was deleted for estimation.

¹: This coefficients have been estimated using the following restrictions: $\sum \alpha_i = 1$ and $\sum_i \gamma_{ij} = 0$.

Table 3: Hicksian Elasticities of Complementarity (c_{ij}) and Factor Price Elasticities (θ_{ij})***A. Hicksian Elasticities of Complementarity (c_{ij})**

	UN	UF	SN	SF	WN	WF
UN	-0.58264 [†]	0.63450	-0.02183 [†]	0.57764	0.18717 [†]	-1.02423 [†]
UF	-	-4.68774 [†]	-0.15280 [†]	-1.84318 [†]	0.36097 [†]	-0.64740
SN	-	-	-0.22188 [†]	0.03286 [†]	0.28888 [†]	0.13459 [†]
SF	-	-	-	-2.75977 [†]	0.01293 [†]	6.95059 [†]
WN	-	-	-	-	-0.39454 [†]	-1.02423 [†]
WF	-	-	-	-	-	-8.74787 [†]

B. Elasticities of Factor Price (θ_{ij})**With respect to the Quantity of:**

The Change of the Wage of:	UN	UF	SN	SF	WN	WF
UN	-0.11362 [†]	0.03458	-0.00692 [†]	0.01479	0.07251 [†]	-0.02079 [†]
UF	0.12373	-0.25548 [†]	-0.04847 [†]	-0.04719 [†]	0.13984 [†]	-0.01314
SN	-0.00426 [†]	-0.00833 [†]	-0.07038 [†]	0.00084 [†]	0.11191 [†]	0.00273 [†]
SF	0.11264	-0.10045 [†]	0.01042 [†]	-0.07065 [†]	0.00501 [†]	0.14110 [†]
WN	0.03650 [†]	0.01967 [†]	0.09163 [†]	0.00033 [†]	-0.14012 [†]	-0.00801 [†]
WF	-0.19972 [†]	-0.03528	0.04269 [†]	0.17794 [†]	-0.15285 [†]	-0.17758 [†]

*: U: low skilled blue collar workers; S: High skilled blue collar workers; W: White collar workers; N: Natives; F: Foreigners. The calculated elasticities are based on the estimated technology coefficients in Table 2. See equation (4) for the calculation of the Hicksian elasticities of complementarity and equation (5) for the calculation of the elasticities of factor prices. A [†] denotes a statistical significant technology parameter in Table 2.

Table 4: Wald-Tests for Separability*

Factorcombination	Weak Separability		Partial Strong Separability	
	Wald-Statistic	Restrictions	Wald-Statistic	Restrictions
(UN, UF) - SN, SF, WN, WF	30,19	4	-	-
(SN, SF) - UN, UF, WN, WF	41,66	4	-	-
(WN, WF) - UN, UF, SN, SF	44,18	4	-	-
(UF, SF) - UN, SN, WN, WF	15,55	4	-	-
(UF, WF) - UN, SN, SF, WN	15,21	4	-	-
(SF, WF) - UN, UF, SN, WN	3,54	4	206,78	8
(UF, SF, WF) - UN, SN, WN	302,07	9	-	-

*: U: low skilled blue collar workers; S: High skilled blue collar workers; W: White collar workers; N: Natives; F: Foreigners. See text for a description of the testing procedure. Critical Values: $\chi^2_4(0,01) = 13,28$; $\chi^2_8(0,01) = 20,09$; $\chi^2_9(0,01) = 21,67$.