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IMMIGRANT LABOR AND WORKPLACE SAFETY

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ABSTRACT

Immigrant Labor and Workplace Safety*

Using standard as well as recently developed univariate and bivariate count data models, this paper analyzes the determinants of workplace accidents using a firm data set for Germany. Given the tight system of public workplace safety regulation, introduced partly as early as in 1869, and the important role of foreign labor in manufacturing, the focus is on the impact of work organization and interdependence between native and foreign workers. The empirical results indicate that there are no significant differences between natives and foreign workers regarding technological determinants of workplace accidents. However, the employment of guestworkers has a strong positive effect on the job safety of natives. The estimates imply that a 1 percent increase in the employment of guestworkers is associated with a 0.4 percent decrease of severe accidents of natives.

JEL Classification: C25, C35, J28, L60
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1. INTRODUCTION

The determinants and consequences of workplace safety have been an important issue in the IO literature since the end of the 1960s.[1] Various theoretical and empirical studies have been inspired by the introduction of workplace safety regulations in the U.S., notably the Coal Mine Health and Safety Act (CMHSA) of 1969, and the Occupational Safety and Health Act (OSHA) of 1970. The theoretical literature mainly focus on the justification of government interventions on the market for workplace safety. In a world of perfect markets and complete information the presence of wage differentials for risky jobs implies that public regulation of occupational safety is unnecessary, since risk premiums in dangerous occupations guarantees the compensation of workers in the case of an accident and induce the socially optimal effort needed to reduce job hazards (see Thaler and Rosen, 1976).

However, in incomplete markets or with incomplete information nonoptimal situations can occur. Assuming that workers are not well informed about safety standards in different firms, the outcomes on the market for workplace safety is inefficient, which justifies mandatory insurance and the enforcement of safety standards.[2] Taking into account that firms and workers can influence the probability of workplace accidents as well as the possibility of moral hazard problems with regard to workers' and firms' precaution, Lanoie (1991) shows that nonoptimal levels of safety investments of workers and firms may occur. However, this does not necessarily mean that safety investments are inefficiently low. Lanoie's (1991) model further shows that regulatory safety policies may not be welfare-improving. To summarize, the theoretical literature on workplace safety obtains different

1 See Viscusi (1993) for an overview.

2 See Oi (1974), Diamond (1977), Carmichael (1986), and Lanoie (1990). In a model where workers systematically underestimate risk, Rea (1981) shows that mandatory insurance and saftey regulation may reduce the level of safety.

results regarding the necessity and the effects of state regulations depending on the specific assumptions of the respective theoretical model.

Empirical work on workplace accidents have mainly concentrated on the effect of CMHSA and OSHA regulations on the frequency and severity of workplace injuries, the relationship between workers' compensation and job safety, as well as the impact of unionization. The empirical evidence for the consequences of government safety regulation and workers' compensation benefits is mixed. Whereas Viscusi (1986), McCaffrey (1983) and Lanoie (1992) found no or little impact of government safety regulations, the empirical results of Gray and Jones (1991a, 1991b) indicate that there is a significant positive influence of OSHA inspections on workplace safety. Chelius (1982) and Neumann and Nelson (1982) conclude that high compensation benefits result in less serious injuries since employers invest more in safety. Higher compensation benefits, however, are positively correlated with slighter injuries since employees behave less careful. Ruser's (1991, 1993) results, on the other hand, indicate that increased workers' benefits lead to more lost workdays and to more severe accidents at work.

In this paper we adopt a new perspective and analyze the empirical causes of workplace accidents of blue collar workers, focusing on the interdependence between native and foreign employees. So far, the role of immigrant labor in the problem of workplace safety has not been addressed in a substantial way. Based on the results of previous studies that race and regional origin play a significant role as determinants of workplace injuries in the U.S. (Worral and Butler, 1983; Bartel and Thomas, 1985; Graham and Shakow, 1990; Hamermesh, 1997), we use a unique micro data set of manufacturing establishments in Germany in order to investigate the question whether immigrant labor has a special, more risky part in industrial production. We further address the question, whether the availability of cheap foreign labor for risky jobs has a positive impact on the job security of natives by opening them the opportunity to be promoted to more secure jobs or a negative effect through decreasing incentives of firms to invest in injury prevention. The empirical analysis of this paper includes the development and application of a new bivariate count data model.

The paper is organized as follows: The next section provides some basic background information of the German system of workplace security regulation and workers' participation, which constitute the framework of our analysis. A short description of the German immigration experience further enables us to develop some hypotheses why immigrant labor could be treated differently in actual work organization and risk distribution than native labor. Section 3 describes the data set used in the empirical analysis, and the hypothesized relationships between workplace accidents and the independent variables. Section 4 provides details about the econometric count data models with which this data set is analyzed. The estimation results are presented in Section 5. Finally, the empirical results are summarized in Section 6.

2. Foreign Labor and Workplace Safety

One topic which has not been addressed in a substantial way so far, is the role of immigrant labor for workplace safety. Although some empirical results for the U.S. indicate that non-white and Southern employees have a higher risk of a work injury (e.g. Worrall and Butler, 1983; Butler and Worrall, 1983; Bartel and Thomas, 1985; and Graham and Shakow, 1990), standard theory gives only an indirect hint by discussing the possibility of race-related discrimination in wages and compensation (e.g. Chelius, 1974). Graham and Shakow (1990) ascribe higher job risks and lower compensating wage differentials to non-whites as a result of labor market segmentation in a "primary" and a (worse) "secondary" segment. Hamermesh (1997) has found no empirical evidence for such a segmented labor market for native whites, Hispanics and immigrants in the U.S. However, he confirms the observation that African-Americans tend to work in jobs of significantly lower quality than the other groups. Apart from racial discrimination issues, the performance of foreign laborers in workplace safety is of special interest if it comes to the question whether immigrant labor, especially if projected as temporary, is used for particularly risky activities in industrial production.

Especially in Germany, where immigration was perceived as temporary, at least during the guestworker-regime of the 1960s and early 1970s, it is interesting to see whether foreign workers show a different pattern of job risk than natives. In the late 60's and early 70's, the German labor market experienced an increasing shortage of unskilled labor. To satisfy this excess demand for unskilled labor, Germany actively recruited foreign guestworkers from south European countries.[3] These guestworkers were mainly hired for low-quality jobs in the manufacturing sector, for which German firms could not hire enough natives. Persistently different risk patterns for foreigners and natives, if controlled for job and technology characteristics as well as for experience, could therefore indicate basically different strategies of management and work organization on firm level for workers of different origin. Following the argument of Dustmann (1993), immigrants may have less incentives to invest in injury prevention skills than natives because they stay in Germany only temporarily and therefore the pay-off period for any investment in such skills is shorter. Our first objective is thus to identify the determinants of workplace accidents for foreigners and natives, and to check whether there are significant differences.

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[3] For a detailed description of the German migration policy and immigration experience in this time period see Schmidt and Zimmermann (1992) and Zimmermann (1995). Bauer and Zimmermann (1997) and Bauer et. al. (1998) give a detailed description of the organization and enforcement of the recruitment of guestworkers.

The German system of workplace safety regulations, however, is very dense and surveillance of firms is tight.[4] Enforcement of those regulations and their updates is the task of Labor Inspection Offices (*Gewerbeaufsichtsämter*) at the State level, of Employers' Liability Insurance Associations (*Berufsgenossenschaften*, ELIA) at the local level, and, finally, of company medical officers, occupational safety engineers and technicians on the firm level. Each firm with more than 20 employees has to have an occupational safety commissioner. Furthermore, the safety commissioners have to cooperate with the work council, the elected representative body of the workers in all firms with more than 5 full-time employees.[5] Especially in firms with more than 20 full-time employees, the work council, which is usually dominated by the trade unions, has an important influence on all firm matters concerning social affairs, including work organization and workplace safety.

The effectiveness of the legal control system is illustrated by the following numbers: In 1975, the year which is relevant for our data set, there were 2,532 employees in the state and local inspection offices, and 300,195 occupational safety commissioners in 103,668 firms in Germany. 493,070 inspections in 307,420 (non-agricultural) firms resulted in 7,994 sanctions by the Labor Inspection offices and 4,263 by Employers' Liability Insurance Associations. Sanctions range from warnings and ad hoc orders to fines and law suits (German Federal Government, 1976). In view of the dense regulation system and the tight enforcement of these regulations, it seems reasonable to

4 Already the Conduct of Commercial and Industrial Activities Act (*Gewerbeordnung*) of 1869 introduced workplace safety regulations, followed by relevant parts of a whole range of laws like the Imperial Insurance Act (*Reichsversicherungsordnung*, 1911), the Radiation Protection Act (*Strahlenschutzverordnung*, 1965), the Dangerous Materials Act (*Verordnung über gefährliche Arbeitsstoffe*, 1971), Work Protection Act (*Arbeitssicherungsgesetz*, 1973), or the Workplace Regulations Act (*Arbeitsstättenordnung*, 1975).

5 The right of workers to constitute a work council and the rights of this council are regulated in the Law on Labor Relations at the Workplace (*Betriebsverfassungsgesetz*, 1972). Note that until 1971 guestworkers needed the agreement of the employer if he wanted to candidate for the work council.

hypothesize that at least in the field of technologically provided workplace safety foreigners should not be discriminated against.

Lower investments in the safety of immigrant workers by the firm will therefore be most likely in the field of work organization, where the work council takes part in management decision-making. In the economic literature on union "voice" (Freeman, 1980; Freeman and Medoff, 1984) it has been argued that unions provide workers with a forum in which to express dissatisfaction. According to this framework, the opportunity to express dissatisfaction with job conditions using the union as a "voice" reduces voluntary employee turnover and increase job tenure, training, productivity and workplace safety. Since German unions are organized on industry, district and national levels instead of the firm level, it is plausible to look at the work council instead of unionization of establishment. The representation of guestworkers in the work council empowers them with increased "voice" and may give rise to increased complaints about guestworker specific job risks or racial differences in work organization.[6] Thus, representation of guestworkes in the work council may result in a lower number of work-related accidents for this group of workers. Due to the democratic structure of the work council, increasing attention on guestworker-specific job risks through foreign members of the work council may not necessarily have negative effects on the job security of natives.

The second objective of this paper is to analyze whether there are interactions between the job risks of native and foreign workers. From empirical studies on the labor market effects of immigration, we know that foreign labor tends to serve as a buffer for native employment, with foreign workers being the first to lose their jobs in times of economic stagnation and the last being re-employed in boom periods (e.g. Zimmermann, 1995; Bauer und Zimmermann, 1997). A similar problem might

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6 See Heywood (1992) for an analysis whether unions influence the pattern of racial treatment.

occur at the micro level, where firms may ascribe especially risky activities to immigrant workers and promoting natives to more secure jobs. One the other hand, one could argue that the availability of cheap labor for risky jobs might decrease the incentive for German firms to invest in injury prevention. Therefore, *a priori* the effect of guestworkers on job security of natives is ambiguous.

3. DATA

The data set used to evaluate the determinants of workplace safety in German manufacturing was collected in 1976. For the questions we address in this paper, this data set is extremely valuable despite its age: It is the only data set available for the firm level which provides information on workplace accidents, and it was collected at the peak of foreign employment in Germany in the mid-seventies. The firms in the data set had at least 200 employed persons, or a capital stock of at least DM 500,000, or annual revenues of at least DM 5 million in 1975. After eliminating all observations with missing values to at least one of the used variables, a final sample of 922 observations remain for estimation. Descriptive statistics of the variables appear in Table 1.

As dependent variables we use the number of accidents of native and foreign blue collar workers in 1975. The data set further enables us to distinguish between less severe accidents which results with up to 3 days of work absence and severe accidents with more than 3 days of absence. Absence of more than three days has to be reported by the firm to the *Berufsgenossenschaften* (ELIAs). In our data, there are on average 0.05 less severe accidents per native worker and 0.07 less severe accidents per foreign worker. These numbers indicate that the unconditional probability of less severe accidents is not significantly different between natives and foreigners. However, with regard to severe accidents it appears that foreigners face higher job risks, since the average number of severe accidents per foreign worker is 0.15 whereas it is only 0.10 for natives. It is also interesting that the number of severe accidents is higher than the number of less severe accidents for both, foreigners and natives. This indicates some measurement problems in the case of less severe accidents, which have not to be reported to the ELIA.[7]

As explanatory variables we use industry dummies on a 2-digit level to control for safety differences between industries. It can be further expected that firms with interdependent production processes (e.g., assembly line or process production) are more likely to experience lost production time when an injury occurs and should therefore result in a higher incentive to invest in workplace safety. The existing literature often assumes that these firms are more capital intensive and uses measures for capital intensity as a proxy of the firm-specific production technology (Curington, 1986). The data set used in this study provides us with very detailed information on the production processes used in a particular firm, i.e. whether the firm produces using single production, small series, middle series, large series, whether the firm uses an assembly line and whether the firm has process production. Using this information we constructed a variable which is increasing with the interdependence of the used production process.[8] The number of accidents may further be influenced by the organization of the working processes. It could be expected that firms with shift working show higher injury rates, since shift workers often work in the night and do not have a stable work schedule. In order to control for this we used the share of workers in a firm who are employed as shift workers.

Usually, firms and workers can influence the probability of workplace accidents. Depending on the extent that a worker's precaution cannot be observed by a firm, moral hazard problems may

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7 See Eisenberg and McDonald (1988) for a discussion of the problems of recording injuries in the workplace by firms and their reporting to official institutions.

8 The final variable takes the following values: single production=1, small series=2, middle series=3, large series=3, assembly line=4, production street=5, process production=6.

arise which lead to nonoptimal levels of precaution from firms and workers (Lanoie, 1991). The efficiency wage literature shows that such moral hazard problems can be solved by effort-dependent wages. In the case of workplace accidents it could be expected that workers who get a piecework rate or premium payments should have an higher incentive to invest in self-protection activities since they normally experience higher income losses through work absence than workers who get a fixed time payment. However, it may be the case that workers underestimate the job risk. In this case workers with piecework or premium payments may be less cautious than workers with a time payment since they can increase their income by working faster and taking less care of their security. To study the effects of the payment structure on workplace safety, we include the share of workers who get a piecework and premium payment, respectively.

To control for the size of the group at risk in a particular firm, we use the logarithm of the number of blue collar native workers and the number of blue collar foreign workers as a scaling factor in the respective equations for the two groups. The share of foreign workers on all workers in a firm is the central variable of interest to analyze whether the employment of guestworkers has a negative or positive effect on the job security of natives. It is often hypothesized that injury rates are negatively related to the experience and formal education of the work force. Therefore, we include the total number of skilled workers as percentage of all blue collar workers in the firm as a proxy for the ability of the work force to acquire injury avoiding skills. Furthermore, we use the share of workers hired in the year previous to the survey, since new workers are unfamiliar with the work equipment and procedures specific to the particular firm and therefore may be involved in a disproportionate share of accidents. Given the German system of democracy on the firm level, as described in the last section, one can expect that the work council will be more interested in the security of foreign workers if one or more guestworkers are members of this council. To take account of these potentially important effect we included a dummy variables which indicates whether there are foreign members in the work.

4. Bivariate Count Data Models

In recent years, count data models have become quite popular in discrete data econometrics.[9] In the field of workplace safety, however, only Gray and Jones (1991a) and Ruser (1991, 1993) have already applied such models. While Gray and Jones (1991a) use fixed effects Poisson and NEGBIN models to investigate the significance of OSHA rules for a data set of U.S. manufacturing plants between 1972 and 1983, Ruser (1991, 1993) analyzes another U.S. firm data set for 1979 to 1984 by applying NEGBIN and QGPMLE techniques as well as a mixed NEGBIN-multinomial model. None of those studies uses a bi- or multivariate approach which we do in order to model the interaction of workplace accidents of foreigners and natives. The basic idea of such an approach is the following: From our consideration above, it seems sensible to distinguish between four types of workplace accidents, depending on the origin of the workers involved and the severity of the accident. This results in a firm's job risk record being described by four count variables (number of less severe and severe accidents of natives and foreigners, respectively). One could proceed modeling these variables separately, and estimate an adequate model for each kind of observations. This, however, is problematic since the counts can be expected to be closely related representing a competing risk of accidents for a firm. Taking this interdependence into account may increase the efficiency of the

9 For an overview of some basic modelling techniques for count data see Winkelmann and Zimmermann (1995). A review of the literature on bivariate and multivariate count models is given by Cameron and Johansson (1996) and Cameron and Trivedi (1998), respectively.

estimation. We tested for this interdependence by using a test proposed by Cameron and Trivedi (1993).

The technical starting point of our empirical analysis are univariate models. As point of departure we apply a standard Poisson model. This basic model has the familiar form[10]:

$$P(Y = y|x) = e^{-l} l^{y} \frac{1}{y!} \tag{1}$$

where $E(Y|x) = V(Y|x) = l = e^{b'x}$. x is a vector of covariates and ß a vector of coefficients to be estimated. The main limitation of the Poisson regression model is its requirement of an equal mean and variance of Y which results from the assumptions that (i) the events of Y occur randomly over time and (ii) the full amount of individual heterogeneity is captured by the regression. If these assumptions are violated, the Poisson regression model leads to consistent but inefficient parameter estimates. In the case of unobserved heterogeneity or a positive correlation between the events overdispersion (the variance exceeds the mean) can occur, whereas negative contagion causes underdispersion. In most economic applications of count data models overdispersion can be observed.

To overcome these problems, more general models have been developed which allows for overdispersion. In these models the Poisson parameter ? itself is treated as a random parameter. Within this framework we use a compound count process (Winkelmann und Zimmermann, 1995). Let

$$\overline{\lambda} = e^{b'X+e} = e^{b'X} u \tag{2}$$

10 Indices for observations are ommitted to facilitate reading.

where the error u captures unobserved heterogeneity and is assumed to be uncorrelated with the explanatory variables. Setting $E(u)=1$, $\bar{\lambda}$ is a random variable with mean $E(\tilde{\lambda})=\lambda$ and variance $V(\tilde{\lambda})=\lambda^2\sigma_u^2$. Since $\tilde{\lambda}$ cannot be observed, conditioning is not possible, and the marginal distribution for Y is obtained by integrating the joint distribution over $\tilde{\lambda}$:

$$f(Y)=\int f(y|\tilde{\lambda})g(\tilde{\lambda})d\tilde{\lambda}. \tag{3}$$

A specific parametric distribution has to be assumed to integrate (3). Assuming a gamma distribution for u with $E(u)=1$ and $V(u)=\sigma_u^2=ny^{-1}$, it can be shown that $\tilde{\lambda}$ is also gamma distributed with mean $E(\tilde{\lambda})=\lambda$ and variance $V(\tilde{\lambda})=ny^{-1}\lambda^2$. Integration of (3) then leads to the following negative binomial distributed probability function for *Y*:

$$P(Y=y|\lambda,ny)=\frac{\Gamma(y+ny)}{\Gamma(y+1)\Gamma(ny)}\left(\frac{ny}{ny+\lambda}\right)^{ny}\left(\frac{\lambda}{ny+\lambda}\right)^{\lambda}, \tag{4}$$

where $E(Y|\lambda,ny)=\lambda_x=e^{\beta'x}$, and $V(Y|\lambda,ny)=\lambda(1+ny^{-1}\lambda)$.

This technique was first used by Hausman et al. (1984) who applied it in modelling panel data.[11] In principle, other distributions than gamma could be assumed for ?. The problem is to obtain a closed expression for the probabilities and therefore for the likelihood function. If this is not a necessary objective one could also use normal or lognormal distributions, as introduced by Preston (1948).

[11] A recent application of these models is provided by Geil et al. (1997). Cameron and Trivedi (1986) examined various different specifications for cross sectional count models. According to their methodology, the model presented here is called NEGBIN II.

If the problem under consideration involves dependent counts for the endogenous variables, joint estimation of these equations is desirable. In order to obtain a multi- or bivariate model, several different approaches are possible. Among those approaches the most popular method has been the so-called trivariate reduction method or seemingly unrelated Poisson regression model (SUPREME). This method uses the property that any sum of Poisson variables is also Poisson distributed. A formal analysis can be found in Johnson and Kotz (1972). Applications are provided in Gourieroux, Monfort and Trognon (1984), Jung and Winkelmann (1993) and King (1989).

For the bivariate case the trivariate reduction method assumes the existence of two Poisson distributed count variables (Y_i) which are the sums of an equation-specific Poisson variable (Y_i^*) and a cross-equation count (U), where the latter links both equations together:

$$\begin{aligned} Y_1 &= Y_1^* + U \\ Y_2 &= Y_2^* + U. \end{aligned} \tag{5}$$

Using the characteristic that any sum of Poisson distributed random variables is also Poisson distributed, it is possible to derive a probability function which can be estimated using maximum likelihood. Within this general framework two different approaches can be derived, depending on whether the mean of the linking count is parametrized or treated as a constant. The main limitation of the trivariate reduction method is similar to that of the univariate Poisson model, namely the implicit assumption of equal means and variances. A violation of this assumption (over - and underdispersion) leads to consistent but inefficient estimates of the parameter vector ß. Similar to the NEGBIN model described above one solution to this problem is to treat the parameters of the bivariate Poisson model as a gamma distributed random variable. However, this proceeding leads to severe computational problems which have not been solved so far (see Jung and Winkelmann, 1993).

Differently to the bivariate models discussed so far, this paper makes use of the compounding technique described above. In order to apply this technique for the derivation of a multinomial model based on Poisson, one has to assume a multinomial distribution for the Poisson parameters. Similar to the approach for univariate models, a possible multivariate model can be formulated as:

$$P(Y_i = y_i | \tilde{\lambda}_i) = e^{-\tilde{\lambda}_i} \tilde{\lambda}_i^y \frac{1}{y!}, \quad i = 1,\ 2,\ \ldots, N \tag{6}$$

where

$$\tilde{\lambda}_i = e^{\beta_i ' x_i + \varepsilon} = \lambda_i u, \quad u \sim \gamma(1, ny). \tag{7}$$

For the bivariate case (i = 2), integration of the resulting joint distribution for Y_i over $\tilde{\lambda}_i$ leads to the following probability function:

$$P\left(Y_1 = y_1, Y_2 = y_2 | x_1, x_2\right) = \frac{\Gamma\left(y_1 + y_2 + ny\right)}{\Gamma\left(y_1 + 1\right)\Gamma\left(y_2 + 1\right)\Gamma\left(ny\right)} \left(\frac{ny}{ny + \lambda_1 + \lambda_2}\right)^{ny} \times \left(\frac{\lambda_1}{ny + \lambda_1 + \lambda_2}\right)^{y_1} \left(\frac{\lambda_2}{ny + \lambda_1 + \lambda_2}\right)^{y_2} \tag{8}$$

This model can be thought of as a bi- or multivariate Poisson model.[12]

Following the approach of Hausman et al. (1984) the univariate NEGBIN model can also be extended to a multivariate setting. We start with two Poisson count variables Y_1 and Y_2 and their

12 This model was first derived by Marshall and Olkin (1990) who called it a bivariate NEGBIN because of the NEGBIN marginals.

parameters $?_1$ and $?_2$. Now these $?_i$ differ in a fundamental way from the ? of the last model since it is only assumed that they are outcomes of the same distribution whereas the $?_i$ of the multivariate Poisson model are assumed to be outcomes of the same draw. In particular, the random term u from equation (7) is assumed to be gamma distributed with parameters d which generates the NEGBIN model with a parameter that varies across i. Then it is assumed that $d = \delta/(1+\delta)$ is beta distributed with parameters a and b to take into account the possibility of a correlation of the different counts. Given this modification the multivariate version of the NEGBIN model can be formulated as:

$$P(Y_i = y_i | \tilde{\lambda}_i) = e^{-\tilde{\lambda}_i} \tilde{\lambda}_i^{y} \frac{1}{y!}, \tag{9}$$

where $\tilde{\lambda}_i \sim \gamma(\lambda_i, \delta),\ d = \frac{\delta}{\delta+1} \sim \beta(a, b),$ for i = 1, 2.

Conditional only on the exogenous variables we obtain the following expression for the probability function in the bivariate case:

$$\begin{aligned} P(Y_1 = y_1, Y_2 = y_2 | x_1, x_2, a, b) = {} & \frac{\Gamma(a+b)}{\Gamma(a)\Gamma(b)} \frac{\Gamma(y_1+\lambda_1)}{\Gamma(y_1+1)\Gamma(\lambda_1)} \frac{\Gamma(y_2+\lambda_2)}{\Gamma(y_2+1)\Gamma(\lambda_2)} \\ & \times \frac{\Gamma(a+\lambda_1+\lambda_2)\Gamma(b+\lambda_1+\lambda_2)}{\Gamma(a+\lambda_1+\lambda_2+b+\lambda_1+\lambda_2)}, \end{aligned} \tag{10}$$

where $\lambda_i = e^{\beta_i' x_i}$ for i = 1, 2.

This bivariate NEGBIN model is more flexible than its Poisson counterpart because the correlation is now achieved by assuming that the compounders $?_i$ have the same distribution for one unit. This is not as hard as to assume that a random effect has the identical impact on different counts like it is done in the bivariate Poisson model.

5. ESTIMATION RESULTS

We have estimated successively univariate Poisson and NEGBIN models for workplace accidents of foreigners and natives as well as their bivariate Poisson and NEGBIN counterparts. We have further distinguished less severe and severe accidents according to the categories of up to three days of absence and more than three days of absence, respectively. However, to justify the application of bivariate models a significant interdependence between the counts under investigation must exist. A general framework for testing the assumption of zero interdependence in bivariate and multivariate settings has been developed by Cameron and Trivedi (1993). Using results from the theory of series expansions for joint distributions in terms of marginal distributions and their related orthonormal polynomials they derive a conditional moment test which is based on the covariance between pairs of orthonormal polynomials. This test procedure is very general because it copes with any form of interdependence. Since only marginals are used, it is not necessary to specify a specific model of interdependence to test against it .

We use the test procedure of Cameron and Trivedi (1993) to test the Poisson and NEGBIN approaches against their correlated counterparts (see Table 2). The relevant test statistic τ^2_{nm} is asymptotically $\chi^2(1)$ distributed.[13] For approximate independence, all four test statistics in any row of Table 2 are required to be small. The tests reveal that for both, foreigners and natives, less severe and severe accidents seem to be uncorrelated. However, zero interdependence between foreigners and natives can be rejected in all cases. A likelihood ratio test of the bivariate NEGBIN model against the bivariate Poisson resulted in refusal of the bivariate Poisson model for both, less severe as well as

13 The test statistic is based on Cameron and Trivedi (1993), p. 32, equation (2.9).

the severe accidents. Therefore, the following discussion of the estimation results concentrates on the bivariate NEGBIN model.

Table 3 shows the estimation results for the bivariate NEGBIN model.[14] In the case of less severe accidents, significantly different industry effects appear for natives and foreigners. Whereas natives have a higher probability of less severe accident in the metal industry if compared to the reference industry of chemicals and chemical products, and a lower probability in the textile industry, foreigners have a significantly higher inhury risk in the metal industry and the machinery and transport industry. For both, natives and foreigners, a marginaly significant effect is found in the pulp, paper and printing industry. The impact of the production technology, is insignificant for natives as well as for foreigners. The finding that the choice of production technology has no significant effects on less severe accidents is in line with the hypothesis that the German system of safety regulations prevents discrimination with regard to the technological risks of the workplace. Similar to the effect of the production process, shift working has no significant impact on less severe accidents. The results in Table 3 further indicate that payment schedules do not influence less severe accidents.

With regard to the interaction between natives and foreigners it appears that the share of foreign workers in a firm has no statistically significant effect for both, natives and foreigners. New hirings and foreign work council members do not affect less accidents either. Only the share of skilled foreign workers increases the number of less severe accidents of foreigners on a statistically significant level.

The estimation results for severe accidents are provided in the fourth and fifth row of Table 3. Some interesting differences between less severe and severe accidents appear. First, the estimated

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14 The estimation results for all models, the univariate and bivariate Poisson and NEGBIN models for both types of accidents, are given in the Appendix-Tables 1 and 2.

industry effects indicate that over industries there exists a higher variance of the number of accidents of foreigners than for natives. Only in the textile industry and the electronics industry foreigners do not have a significantly higher risk propensity than in the referency industry of chemicals and chemical products. In rubber and plastic products and in the textile industry native workers face a statistically significant lower and in the metal industry and the machinery and transport industry a statistically significant higher job risk if compared to the reference group.

With regard to the variable controlling for the production process in a firm it appears that the probability of having a severe accidents increases with the interdependence of the production process for foreigners only. In spite of the dense system of workplace safety regulations in Germany, which has been described in section 2, this result indicates that foreigners face higher technological workplace risks than natives. Shift working has a statistically significant positive effect on severe accidents of natives and foreigners where the difference between the two coefficients is not statistically significant. These results support our hypothesis that foreigners and natives face similar workplace risks occuring from the field of work organization. Similar to the case of less severe accidents, piecework rates seem not to affect severe accidents. The coefficients for premium payment, however, are significantly positive on the 10% level for natives and foreigners with the difference between the two coefficients not being statistically significant. This result indicates, that workers receiving premium payments which depend on their effort behave less cautious against severe accidents than workers with a pure time payment scheme.

An increasing share of guestworkers in a firm is associated with less severe accidents for natives without affecting the foreigners themselves. According to the estimated coefficients a 1 percent increase in the employment share of foreigners is associated with a 0.4 percent decrease of severe accidents of natives. For the average firm, this means that the employment of ten more foreigners decreases the number of natives' severe accidents from 30.0 to 28.8. The skill level of the work force and the number of new hirings increase the number of severe accidents for both groups of workers. Again, both effects are not statistically significant across the two groups. Finally, the highly significant positive coefficient of the incidence of foreign work council members on the number of severe accidents for both, natives and foreigners, confirm the important role of guestworkers' representation in the work council. However, in the German case it seems that foreigners in the work council vote against safety investments which is in the interest of foreigners if such investments are connected with lower wages and if the foreigners expect to stay in Germany only temporary.

6. CONCLUSIONS

Our paper aimed at identifying the determinants of workplace accidents in Germany with its tight public control system of workplace safety. We analyzed whether there are significant differences between natives and foreigners with regard to less severe and severe accidents and placed special attention to the interaction of native and foreign labor. The analysis has been performed by applying improved bivariate count data models on an unique micro data set of manufacturing establishments in Germany.

The estimation results show that less severe workplace depend mainly on the particular industry a worker is employed. The production technology, payment schedules and work organization show are not able to explain the incidence of less severe accidents. Furthermore, there are no significant differences between foreigners and natives. These results indicate that the dense system of workplace safety regulations in Germany is effective in reducing less severe accidents. However, due to the possibility of large errors in the measurement of less severe accidents these results have to be interpreted carefully.

Differently to less severe accidents, severe workplace injuries are influenced by the production technology and the work organization in a firm. The effects of these variables show that foreigners face higher risks in terms of technological safety whereas there are no differences between natives and foreigners regarding workplace risks due to work organization. Concerning the relationship between foreign and native labor we found strong evidence that guestworker employment has a positive effect on the workplace safety of natives. The empirical results imply that a 1 percent increase of the employment of guestworkers decreases severe accidents of natives by 0.4 percent without having a statistically significant effect on less severe accidents of natives. In general, the results suggest that guestworkers primarily are employed in risky activities and that the availability of foreign labor for risky jobs disclosed native workers the opportunity to be promoted to more secure jobs.

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Table 1: Descriptive Statistics

Variable	Mean (S.D.)	Variable	Mean (S.D.)
Rubber and Plastic Products	0.068 (0.25)	Workers: Foreigners (in % of all workers)	0.239 (0.16)
Construction, Material	0.056 (0.23)	Skilled Workers (in % of all workers)	0.332 (0.23)
Basic Metals, Metal Products	0.114 (0.32)	Piecework Rate (in % of all workers)	0.219 (0.26)
Machinery, Equipment, Transport	0.261 (0.44)	Premium Payment (in % of all workers)	0.144 (0.27)
Electronics, Precision Instruments	0.175 (0.38)	Hirings (in % of all workers)	0.135 (0.17)
Pulp, Paper, Printing	0.107 (0.31)	Foreign Superior	0.240 (0.43)
Leather, Textiles, Waering Apparel	0.092 (0.29)	Foreign Work Council Members	0.277 (0.45)
Food and Luxury	0.074 (0.26)	Less Severe Accidents: Natives	15.638 (65.74)
Production Process	3.594 (1.95)	Less Severe Accidents: Foreigners	6.015 (25.24)
Shift Working	0.515 (0.50)	Severe Accidents: Natives	30.010 (66.50)
ln (Native Workers)	4.943 (1.10)	Severe Accidents: Foreigners	14.060 (34.20)
ln (Foreign Workers)	3.548 (1.34)		
Observations			922

Table 2: Tests of Independence

Table 2a: Test of Independence for the Poisson Model

Test statistic t^2_{nm}	$t^2_{1,1}$	$t^2_{1,2}$	$t^2_{2,1}$	$t^2_{2,2}$
Foreigners with less than 4 vs. more than 3 days of absence	2.647	0.002	0.029	6.361
Germans with less than 4 vs. more than 3 days of absence	0.459	0.187	0.917	3.436
Foreigners vs. Germans with less than 4 days of absence	11.359	1.044	0.948	4.208
Foreigners vs. Germans with more than 3 days of absence	15.271	0.018	0.136	4.573

Table 2b: Test of Independence for the Negbin Model

Test statistic t^2_{nm}	$t^2_{1,1}$	$t^2_{1,2}$	$t^2_{2,1}$	$t^2_{2,2}$
Foreigners with less than 4 vs. more than 3 days of absence	4.122	2.55	0.814	1.364
Germans with less than 4 vs. more than 3 days of absence	1.361	0.673	0.961	0.016
Foreigners vs. Germans with less than 4 days of absence	10.337	2.041	1.488	1.255
Foreigners vs. Germans with more than 3 days of absence	14.793	0.243	4.081	0.19

For independence it is required that all four test statistics are small. They are asymptotically $?^2(1)$-distributed.

Table 3: Workplace Accidents: Results of the bivariate NEGBIN-Model

	Accidents with less than 4 days of absence		Accidents with more than 3 days of absence	
	Natives	**Foreigners**	**Natives**	**Foreigners**
Constant	-2.275††	-2.561††	-1.297††	-1.769††
	(0.420)	(0.347)	(0.212)	(0.183)
Rubber and Plastic Products	-0.368	0.069	-0.302†	0.296†
	(0.313)	(0.336)	(0.142)	(0.155)
Construction, Material	-0.120	-0.142	0.078	0.329††
	(0.321)	(0.305)	(0.144)	(0.153)
Basic Metals, Metal Products	0.513†	0.741††	0.372††	0.850††
	(0.278)	(0.294)	(0.129)	(0.133)
Machinery, Equipment, Transport	0.393	0.666††	0.221†	0.559††
	(0.272)	(0.283)	(0.122)	(0.129)
Electronics, Precision Instruments	-0.193	-0.132	-0.173	0.105
	(0.275)	(0.285)	(0.121)	(0.129)
Pulp, Paper, Printing	-0.525†	-0.578†	0.015	0.359††
	(0.304)	(0.326)	(0.138)	(0.153)
Leather, Textiles, Waering Apparel	-0.634††	-0.344	-0.701††	-0.004
	(0.310)	(0.322)	(0.134)	(0.153)
Food and Luxury	0.183	0.309	-0.082	0.261†
	(0.323)	(0.339)	(0.139)	(0.148)
Production Process	-0.038	0.0003	0.013	0.029††
	(0.031)	(0.029)	(0.015)	(0.015)
Shift Working	0.019	0.084	0.247††	0.212††
	(0.130)	(0.130)	(0.056)	(0.064)
Piecework Rate	0.411†	0.382	-0.019	-0.012
	(0.226)	(0.235)	(0.102)	(0.116)
Premium Payment	0.034	0.232	0.148†	0.185†
	(0.204)	(0.210)	(0.086)	(0.100)
ln (Native Workers)	0.786††	-	0.736††	-
	(0.054)		(0.024)	
ln (Foreign Workers)	-	0.724††	-	0.765††
		(0.052)		(0.027)
Share of Foreign Workers	-0.069	0.164	-0.404††	-0.214
	(0.456)	(0.413)	(0.194)	(0.207)
Skilled Worker	0.362	0.768††	0.423††	0.485††
	(0.275)	(0.295)	(0.135)	(0.155)
Hirings	0.207	0.248	0.853††	0.725††
	(0.383)	(0.393)	(0.121)	(0.147)
Foreign Work Council Members	-0.085	0.149	0.163††	0.220††
	(0.139)	(0.144)	(0.060)	(0.066)
?		-		-
a		1.682††		6.957††
		(0.120)		(0.423)
b		0.812††		6.150††
		(0.056)		(0.441)
Log-likelihood		-3890.3		-5876.4

*: Standard errors in parentheses. Observations: 922. Reference industry: Chemicals and chemical products.
††: statistically significant at least at the 5%-level. †: statistically significant at least at the 10%-level.

Appendix Table 1: Workplace Accidents with less than 4 Days of Absence*

	Poisson		**NEGBIN**		**Bivariate Poisson**		**Bivariate NEGBIN**	
	Natives	**Foreigner**	**Natives**	**Foreigner**	**Natives**	**Foreigner**	**Natives**	**Foreigner**
Constant	-3.414††	-3.465††	-4.494††	-3.654††	-4.215††	-3.857††	-2.275††	-2.561††
	(0.081)	(0.115)	(0.422)	(0.410)	(0.409)	(0.350)	(0.420)	(0.347)
Rubber and Plastic Products	0.071	0.485††	0.013	-0.345	-0.468	0.208	-0.368	0.069
	(0.070)	(0.104)	(0.313)	(0.377)	(0.320)	(0.329)	(0.313)	(0.336)
Construction, Material	0.927††	0.584††	0.313	-0.206	0.061	-0.053	-0.120	-0.142
	(0.062)	(0.106)	(0.326)	(0.406)	(0.336)	(0.348)	(0.321)	(0.305)
Basic Metals, Metal Products	1.251††	1.283††	0.996††	0.943††	0.806††	0.958††	0.513†	0.741††
	(0.054)	(0.082)	(0.286)	(0.338)	(0.295)	(0.302)	(0.278)	(0.294)
Machinery, Equipment, Transport	1.005††	0.954††	0.896††	0.454	0.628††	0.673††	0.393	0.666††
	(0.055)	(0.085)	(0.269)	(0.326)	(0.279)	(0.288)	(0.272)	(0.283)
Electronics, Precision Instruments	0.644††	0.219††	0.384	0.239	0.218	0.129	-0.193	-0.132
	(0.058)	(0.090)	(0.271)	(0.327)	(0.280)	(0.290)	(0.275)	(0.285)
Pulp, Paper, Printing	-0.568††	-0.517††	-0.361	-0.815††	-0.577†	-0.619†	-0.525†	-0.578†
	(0.088)	(0.128)	(0.297)	(0.366)	(0.306)	(0.322)	(0.304)	(0.326)
Leather, Textiles, Waering Apparel	-0.500††	-0.450††	-0.392	-0.403	-0.642††	-0.320	-0.634††	-0.344
	(0.082)	(0.123)	(0.304)	(0.363)	(0.313)	(0.328)	(0.310)	(0.322)
Food and Luxury	0.501††	0.502††	0.250	0.200	0.086	0.055	0.183	0.309
	(0.074)	(0.104)	(0.308)	(0.365)	(0.314)	(0.325)	(0.323)	(0.339)
Production Process	-0.025††	0.015†	0.040	0.005	0.017	0.047	-0.038	0.0003
	(0.005)	(0.008)	(0.029)	(0.036)	(0.030)	(0.030)	(0.031)	(0.029)
Shift Working	0.165††	-0.027	0.148	0.177	0.202	0.099	0.019	0.084
	(0.024)	(0.038)	(0.124)	(0.143)	(0.123)	(0.126)	(0.130)	(0.130)
Piecework Rate	0.572††	0.097	0.370	0.229	0.391†	0.227	0.411†	0.382
	(0.042)	(0.066)	(0.232)	(0.270)	(0.234)	(0.240)	(0.226)	(0.235)
Premium Payment	-0.041	-0.248††	0.111	0.191	0.063	0.247	0.034	0.232
	(0.045)	(0.066)	(0.210)	(0.234)	(0.208)	(0.214)	(0.204)	(0.210)
ln (Native Workers)	0.926††	-	1.070††	-	1.059††	-	0.786††	-
	(0.009)		(0.060)		(0.053)		(0.054)	
ln (Foreign Workers)	-	0.935††	-	1.019††	-	1.015††	-	0.724††
		(0.014)		(0.065)		(0.051)		(0.052)
Share of Foreign Workers	-1.291††	-0.625††	-0.223	-0.798††	0.051	-0.699††	-0.069	0.164
	(0.098)	(0.114)	(0.443)	(0.447)	(0.427)	(0.403)	(0.456)	(0.413)
Skilled Worker	-0.302††	0.880††	0.514†	1.544††	0.626††	1.407††	0.362	0.768††
	(0.052)	(0.085)	(0.278)	(0.332)	(0.281)	(0.291)	(0.275)	(0.295)
Hirings	0.307††	0.249††	0.004	0.003	-0.111	0.124	0.207	0.248
	(0.081)	(0.112)	(0.360)	(0.370)	(0.347)	(0.351)	(0.383)	(0.393)
Foreign Work Council Members	0.171††	0.420††	-0.126	-0.100	-0.255†	-0.044	-0.085	0.149
	(0.022)	(0.036)	(0.150)	(0.167)	(0.147)	(0.149)	(0.139)	(0.144)
?	-	-	2.074††	2.438††	2.208††		-	
			(0.119)	(0.171)	(0.120)			
a	-	-	-	-	-		1.682††	
							(0.120)	
b	-	-	-	-	-		0.812††	
							(0.056)	
Log-likelihood	-13189.7	-5409.9	-2446.9	-1721.8	-4188.3		-3890.3	

*: Standard errors in parentheses. Obeservations: 922. Reference industry: Chemicals and chemical products.

Appendix Table 2: Workplace Accidents with more than 3 Days of Absence*

	Poisson		NEGBIN		Bivariate Poisson		Bivariate NEGBIN	
	Natives	**Foreigner**	**Natives**	**Foreigner**	**Natives**	**Foreigner**	**Natives**	**Foreigner**
Constant	-1.990††	-2.493††	-2.186††	-2.003††	-1.864††	-2.330††	-1.297††	-1.769††
	(0.051)	(0.073)	(0.180)	(0.170)	(0.164)	(0.150)	(0.212)	(0.183)
Rubber and Plastic Products	-0.015	0.861††	-0.005	0.133	-0.221†	0.532††	-0.302†	0.296†
	(0.038)	(0.060)	(0.135)	(0.155)	(0.126)	(0.136)	(0.142)	(0.155)
Construction, Material	0.238††	0.651††	0.143	0.259	0.101	0.406††	0.078	0.329††
	(0.035)	(0.065)	(0.138)	(0.163)	(0.129)	(0.141)	(0.144)	(0.153)
Basic Metals, Metal Products	0.233††	0.969††	0.405††	0.732††	0.377††	0.868††	0.372††	0.850††
	(0.029)	(0.052)	(0.122)	(0.140)	(0.113)	(0.122)	(0.129)	(0.133)
Machinery, Equipment, Transport	0.177††	0.681††	0.320††	0.387††	0.260††	0.581††	0.221†	0.559††
	(0.029)	(0.054)	(0.117)	(0.135)	(0.108)	(0.119)	(0.122)	(0.129)
Electronics, Precision Instruments	-0.235††	0.257††	-0.003	0.202	-0.054	0.309††	-0.173	0.105
	(0.032)	(0.056)	(0.116)	(0.135)	(0.108)	(0.119)	(0.121)	(0.129)
Pulp, Paper, Printing	-0.025	0.551††	0.064	0.188	-0.018	0.345††	0.015	0.359††
	(0.036)	(0.061)	(0.123)	(0.144)	(0.115)	(0.127)	(0.138)	(0.153)
Leather, Textiles, Waering Apparel	-0.682††	0.358††	-0.510††	-0.044	-0.608††	0.089	-0.701††	-0.004
	(0.043)	(0.062)	(0.130)	(0.148)	(0.121)	(0.131)	(0.134)	(0.153)
Food and Luxury	-0.021	0.500††	-0.030	0.136	-0.089	0.303††	-0.082	0.261†
	(0.039)	(0.064)	(0.131)	(0.152)	(0.122)	(0.134)	(0.139)	(0.148)
Production Process	0.004	0.039††	0.015	0.030††	0.014	0.036††	0.013	0.029††
	(0.003)	(0.001)	(0.013)	(0.015)	(0.012)	(0.013)	(0.015)	(0.015)
Shift Working	0.153††	0.120††	0.193††	0.162††	0.215††	0.193††	0.247††	0.212††
	(0.017)	(0.024)	(0.053)	(0.059)	(0.050)	(0.053)	(0.056)	(0.064)
Piecework Rate	0.139††	0.183††	-0.082	-0.057	-0.073	-0.014	-0.019	-0.012
	(0.029)	(0.042)	(0.098)	(0.111)	(0.092)	(0.098)	(0.102)	(0.116)
Premium Payment	0.297††	0.241††	0.194††	0.229††	0.220††	0.226††	0.148†	0.185†
	(0.027)	(0.037)	(0.089)	(0.098)	(0.083)	(0.088)	(0.086)	(0.100)
ln (Native Workers)	0.859††	-	0.876††	-	0.826††	-	0.736††	-
	(0.006)		(0.025)		(0.022)		(0.024)	
Ln (Foreign Workers)	-	0.888††	-	0.846††	-	0.879††	-	0.765††
		(0.009)		(0.026)		(0.023)		(0.027)
Share of Foreign Workers	-0.343††	-0.530††	-0.015	-0.456††	-0.163	-0.431††	-0.404††	-0.214
	(0.063)	(0.071)	(0.190)	(0.202)	(0.176)	(0.180)	(0.194)	(0.207)
Skilled Worker	0.552††	0.751††	0.427††	0.785††	0.470††	0.646††	0.423††	0.485††
	(0.038)	(0.056)	(0.127)	(0.144)	(0.119)	(0.128)	(0.135)	(0.155)
Hirings	1.200††	0.913††	1.007††	0.964††	1.056††	0.920††	0.853††	0.725††
	(0.042)	(0.054)	(0.154)	(0.159)	(0.143)	(0.149)	(0.121)	(0.147)
Foreign Work Council Members	0.137††	0.160††	0.138††	0.189††	0.171††	0.192††	0.163††	0.220††
	(0.016)	(0.022)	(0.060)	(0.064)	(0.056)	(0.058)	(0.060)	(0.066)
?	-	-	0.372††	0.372††	0.331††		-	
			(0.021)	(0.024)	(0.018)			
a	-	-	-	-	-		6.957††	
							(0.423)	
b	-	-	-	-	-		6.150††	
							(0.441)	
Log-likelihood	-6674.5	-4230.1	-3334.4	-2608.8	-6109		-5876.4	

*: Standard errors in parentheses. Obeservations: 922. Reference industry: Chemicals and chemical products.