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Risk self-perception and occupational accidents

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ABSTRACT

Introduction: This study analyzes the relationship between measures of occupational accidents and workers' perception of risk in the workplace using nationally representative data on workers' characteristics and a complete record of occupational accidents. *Methods*: Regression analyzes addressing both the ordinal nature of the dependent variable and causality were conducted to control for different sociodemographic factors influencing workers' perceptions of occupational risks. Special attention was paid to the risk level of the worker's workgroup, existence of family responsibilities, organizational safety culture, and measures of accident rates. *Results*: Individuals showed different perceptions of risk based on their personal and work characteristics. Significant associations were observed between each variable of interest and risk perception. Overall, the results remain robust across specifications addressing both simultaneity and ordinality. *Conclusions*: Employees' "reading" of hazards was not fully aligned with objective information on occupational accidents but depended on individual characteristics. Having family responsibilities or being unionized increased workers' risk perception, whereas belonging to a workgroup with higher accident rates reduced it. *Practical applications*: Knowing how workers perceive risk and how this perception deviates from statistical information on accidents are essential for management to accurately design safety measures. In this regard, specific characteristics such as age, having dependents in the family, or the typology of the workers' workgroup should be taken into account. Greater knowledge of preventive measures will improve the way workers perceive risk, and ultimately contribute to reducing the likelihood of occupational accidents.

1. Introduction

In recent decades, there have been numerous changes in the composition of the workforce owing to factors such as outsourcing and globalization of the economy, the development of automatization and digitalization of productive processes, and a range of demographic issues such as the increase in women's participation and migratory movements. The consequences of these changes on occupational health and safety have been studied from a multidisciplinary perspective (Pouliakas & Theodossiou, 2013). Advances in occupational health and safety have been key factors in improving workers' conditions, especially in the most hazardous occupations. However, occupational injuries and accidents remain serious safety concerns worldwide (Laske et al., 2022).

Within this framework, several studies have focused on the differences between the actual (or objective) risk a worker faces in the workplace and the subjective risk an individual perceives while at work (Sjöberg, 2000; Kouabenan, 2009; Viscusi, 1979). Although objective measures of risk capture the extent to which individuals are exposed to dangers at work (injuries, accidents, and diseases), risk perception refers to individual subjective assessments of the risks inherent in each work environment (i.e., the likelihood of such undesired consequences occurring).

As an approximation of objective risk, this study uses the statistical/expected value of experiencing an accident and its severity in the workplace. This was calculated as an "incidence index," a ratio of the number of accidents every 100,000 workers. We recognize that although this accident rate is not a perfect construct for objective or real risk, it serves as a starting point for studying the relationship between the probability of an accident occurring and the workers' perceptions regarding its occurrence. Perceived risk is subjective and varies among workers (Xia et al., 2017). Subjective evaluations of risk can be influenced by beliefs about the risk, such as its probability of occurrence and the nature and severity of its consequences, as well as other aspects external to the worker, such as whether the risk is voluntary or imposed, natural or technological. Additionally, risk perception may be affected

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by individual or social psychological variables (age, sex, experience, education, personality, motivation, values, etc.), cognitive variables (knowledge, amount of information available, and expertise), evaluations of personal exposure, and the ability to cope with risk (perception of one's skills, precautions taken, control efforts, etc.). Finally, risk perception is also influenced by cultural, political, or strategic variables unique to the organization (organizational culture, safety policy, social norms, etc.).[1]

Differences between objective risk and perceived risk have frequently been elucidated in the difference between "rational" risk perception and "emotional" risk perception (Xia et al., 2017).[2] From a rational perspective, workers are likely to perceive risk by deliberately calculating the level of risk. However, such a rational approach is usually only possessed by experts in a particular field, while laypeople tend to perceive risk based on emotions; that is, they perceive risk through direct and intuitive judgment, which is influenced by diverse factors, such as the characteristics of risk, personal variables, and cultural and socioeconomic backgrounds (Kouabenan, 2009). Despite their complexity, emotional perceptions of risk are usually well assessed by asking about an individual's perception of risk, that is, the worker's direct and intuitive feelings of a specific risk (Rundmo, 1996; Slovic et al., 1979, 2004; Xia et al., 2017).

When workers' perceptions of risk deviate significantly from objective risk, workers may not accurately evaluate the related risks in the workplace (Loewenstein et al., 2001; Micic, 2016, Ibrahim et al., 2022). Because risk perception is subjective, workers' distinct behaviors when facing similar risks result from different "readings" of the risk (Salmon & Stanton, 2013; Naderpour et al., 2014). As claimed by Gegax et al. (1991), the average accident rates (computed for industrial or occupational categories) may not reflect workers' perceptions of risk and may not apply to workers whose risks differ from the average. Therefore, the information regarding the accident rates and the way workers perceive risk at work may not completely align, and several factors cause risk perceptions to differ across workers. In a review by Leoni (2010), one of the findings was that people tend to overestimate small risks and underestimate large risks, or that individuals tend to claim to be less at risk than their peers. Such illusory beliefs may lead to substantial differences in risk perceptions among experts, managers, and laypeople (or workers in general).[3] Nevertheless, injury data are expected to significantly influence emotional (subjective) risk perceptions (Leoni, 2010; Ibrahim et al., 2022).

The objective of this study was to analyze the relationship between the risk perceived by workers in the workplace and the incident rate of fatal accidents associated with the job they perform. In doing so, we control for an ample set of personal and job-related characteristics, such as age, educational level, family, hours worked, firm size, tenure, occupation, sector, type of contract, and other job-related factors (Hakes & Viscusi, 2004; Ibrahim et al., 2022).[4] Among these variables, we placed special emphasis on testing the following hypotheses concerning how worker's workgroup, family responsibilities, and safety culture are related to self-perceived risk (see Fig. 1):

Hypothesis 1 (H1). *Worker's self-perception of risk is influenced by the worker's workgroup*. Members of workgroups that are highly exposed to risks perceive a given risk as less dangerous than members of workgroups that are rarely exposed to risks (Christian et al., 2009; Liang et al., 2018).

Hypothesis 2 (H2). *Worker's perception of risk is influenced by the personal and family situation*. Risk aversion is greater when there are more family responsibilities (DeLeire & Levy, 2004).

Hypothesis 3 (H3). *Safety culture can make workers more informed and aware of workplace hazards*. More information entails greater knowledge of job characteristics, measures taken to reduce risks, and compliance with these measures (Gegax et al., 1991; Christian et al., 2009). This leads to increased awareness of the risks associated with the workplace (more adequate risk perception), greater knowledge of prevention measures, and consequently, a decreased likelihood of accidents.

A noteworthy contribution of this study is the use of nationally representative data. These data were obtained from a survey that simultaneously provides information on several individual characteristics, including risk perception at the individual level. This comes at the cost of using somewhat aged data as the survey ceased in 2010. Since then, no other survey has provided information on the perceived risk and individual (personal and labor-related) characteristics of workers.[5] In addition to the survey, information was obtained from other sources, particularly from statistical analysis from the complete register of occupational accidents in Spain for each year of the sample. The second relevant novelty of this study is that it addresses the question of endogeneity raised by the bidirectional causality between risk perception and some of the explanatory variables. This study uses appropriate econometric tools to address the simultaneity bias problem.

2. Materials and methods

2.1. Dataset

Data on workers' perceived risk in the workplace, as well as other variables expressing the personal characteristics of individuals and their jobs, are provided by the Quality of Life at Work Survey (QLWS). It is an annual survey based on individuals aged 16 years and older residing in households and is nationally representative. Owing to data availability, information was selected only for the period of 2007–2010.[6] The data comprised a repeated cross-sectional sample collecting substantial information on the social relationships, situations, attitudes, and values of workers in the workplace, as well as personal and job characteristic variables, including certain workplace environmental conditions. The variable indicating the risk perceived by the worker ranges from 0 (low) to 10 (very high) and is obtained from the response to the question: *"Indicate the level of risk or dangerous situations you perceive in your current job."* The remaining variables are listed in Table 1. To select a more homogeneous sample, only male employees working more than 30 h per week were included in the study; the final sample comprised 13,096 individuals.[7]

Data on accidents in Spain are from the Occupational Accident Statistics (EAT, *Encuesta de Accidentes de Trabajo*). This database provides

[1] See Kouabenan (2009) and the references cited therein for a more detailed description of the role of beliefs in accidents.

[2] This line of reasoning follows that of "anticipated" vs. "anticipatory" emotions (see Loewenstein et al., 2001). Similar arguments are posed in Epstein (1994), Slovic et al., (2004) and Weber et al. (2002).

[3] Biased risk perceptions may originate in unrealistically positive self-evaluations, unrealistic optimism, or in the illusion of invulnerability (Taylor and Brown, 1994; Hakes and Viscusi, 2004; Kouabenan, 2009).

[4] There is no information in our databases on workplace hazards. In the empirical part of the paper, we employ the variables of occupation, industry, and firm size as proxies for differences in workplace risk.

[5] Note that, since 1995, there has not been any relevant change in Spanish legislation regarding health and safety at work.

[6] Our sample is constructed by pooling the last four consecutive available waves, from 2007 to 2010. The sample can extend backward, but not forward, since the survey ceased in 2010. Extending the sample backwards is not advisable, because the questionnaire was revised after 2004, the survey was not carried out in 2005, and in 2006, information was not present for some of our variables of interest.

[7] A common finding is that men and women judge risks differently, with men generally perceiving lower risks than women (Gustafson, 1998). For an explicit treatment of gender differences in risk, see DeLeire and Levy (2004) and Leoni (2010).

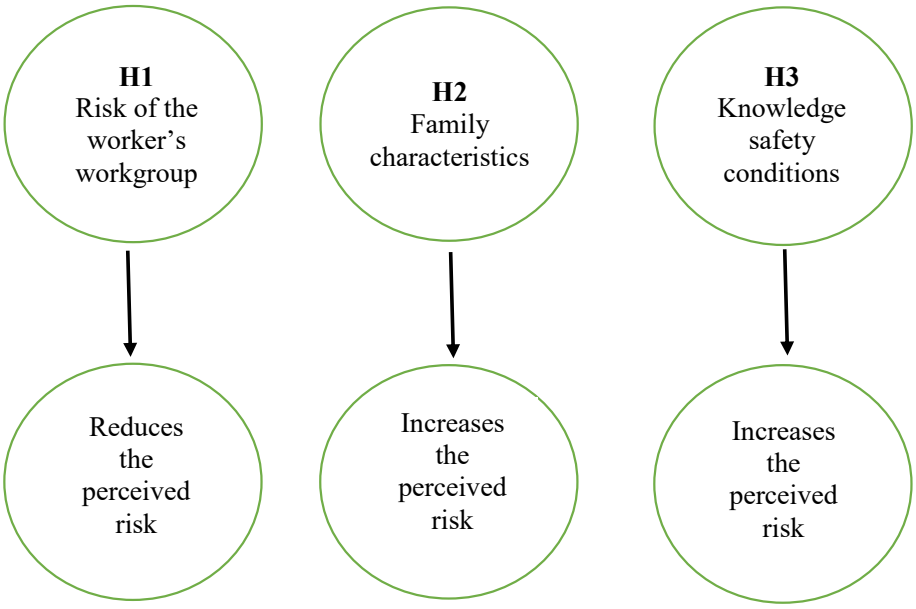

Fig. 1. Hypotheses to test.

annual data on work-related accidents that have been reported in the administrative records authorized for this purpose.[8] It collects statistical information on the causes and circumstances according to which accidents have occurred at work to contribute to the improvement of knowledge about the prevention of occupational hazards. Disaggregate information was extracted from the microdata of the reported accidents to determine incidence rates. They express the number of accidents per 100,000 workers and are calculated by dividing the number of accidents by the number of workers and then dividing it by 100,000. Information on the number of workers was obtained from a Spanish Labor Force Survey. Because accidents differ considerably between industries, occupations, and personal and labor characteristics, we constructed as many incidence rates of accidents as possible to capture the likelihood of an occupational accident for a worker with specific characteristics. Thus, the incidence rates were computed by combining 10 occupational categories, that is, four industries, four age ranges, two types of contracts, four seniority ranges, and four years, thereby producing 5,120 different values. The incidence rate was assigned to each of the 13,096 individuals based on their characteristics. Incidence rates were computed for fatal accidents only, as these are absolutely objective, free from the claims reporting bias (Ruser & Butler, 2009: Martín-Román & Moral, 2017), and capture the highest level of risk in the workplace.[9]

2.2. Descriptive analysis

Table 1 presents the definitions and mean values of relevant variables. The data show that the average risk of fatal accidents during the years in question was 8.45 per 100,000 workers, while the average perceived risk was 4.19 (this is valued between 0 and 10). Note that these variables measure two different aspects of risk and are not directly comparable.

Table 1
Definition and mean of variables.

Variable	Definition	Mean
Self-perceived risk	Subjective risk. Range from 0 to 10	4.19
Incidence rate	Incidence rate (per 100,000 workers) of fatal accident	8.45
Dependents	1: Children or dependent adults in the household: 0, no.	0.36
Union	1: The worker is unionized. 0: Otherwise	0.23
Age	Age	41.89
$Age^2/100$	Age squared divided by 100	18.68
Compulsory education	Highest education attained: Compulsory education	0.45
Secondary education	Highest education attained: Secondary non-compulsory education	0.33
Higher education	Highest education attained: Tertiary education	0.22
Nationality	1: Spanish. 0: Otherwise	0.68
Tenure	Tenure in the current job (in years)	11.23
Over-education	1: Worker is over-educated (education level above that required in the job). 0: Otherwise	0.15
First job	1: Worker is in the first job. 0: Otherwise	0.21
Permanent contract	1: Worker is in a permanent job. 0: Otherwise	0.81
Hours worked	Average number of worked hours per week	42.11
Firmsize < 11	Firms less 11 workers	0.22
Firmsize 11–50	Firms between 11 and 50 workers	0.27
Firmsize 51–250	Firms between 51 and 250 workers	0.17
Firmsize > 250	Firms more 250 workers	0.34
Agriculture	1: Work in the primary sector. 0: Otherwise	0.04
Manufacturing	1: Work in the manufacturing sector. 0: Otherwise	0.24
Construction	1: Work in the construction sector. 0: Otherwise	0.18
Services	1: Work in the services sector. 0: Otherwise	0.54
Skilled, non-manual	1: Worker in skilled, non-manual occupation. 0 Otherwise	0.29
Unskilled, non-manual	1: Worker in unskilled, non-manual occupation. 0 Otherwise	0.16
Skilled, manual	1: Worker in skilled-manual occupation. 0 Otherwise	0.28
Unskilled, manual	1: Worker in unskilled-manual occupation. 0 Otherwise	0.26

Note: Paid employees working 30 h or more (except the military).

Table 2 displays the mean incidence rates of fatal accidents and the perceived risk for different groups of workers. The construction sector was the most dangerous and was perceived as such by workers, while the service sector showed the lowest values for both risk variables. In

[8] In the event of an occupational accident, the firm is obliged to notify the accident and report some of its characteristics both to the insurance company (the public national health and safety system or a private company) and to the Spanish Ministry of Labor. Since 2003, this communication has been carried out telematically.

[9] The accident notification indicates the place and the company where the accident occurred. The sector to which the accident is attached corresponds to the company where the accident occurred, regardless of the contractual status of the worker (hired by the company, subcontracted or working for a temporary employment agency).

agriculture, the incidence rate was higher than that in manufacturing and services, while workers' perceptions were similar to those of services and lower than those of manufacturing workers. By occupation, unskilled-manual workers showed the highest rate of fatal accidents, however, skilled manual workers perceived more risk than unskilled manual workers. Incidence rates and perceived risk were lower among the more educated, who were closely related to skilled non-manual occupations. This finding is consistent with the idea that low-skilled jobs tend to be more dangerous than high-skilled jobs.

Temporary workers had a much higher incidence rate than permanent workers; however, the differences in risk perception were unclear. By seniority, workers with less tenure had higher incidence rates, but did not perceive more risk than those with more tenure. The incidence rate of workers with dependents (children or adults) was approximately the same as that of workers without dependents; however, the risk perception was higher for the former. Union workers had lower incidence rates, however, their risk perception was higher than that of non-union workers. From this first piece of evidence, it can be deduced that incidence rates and subjective risk are not synchronous; in some cases, they are inversely related, as in the case of age or seniority. In summary, certain distortions can be observed between workers' perceptions of risk and the incidence rates.

3. Methodology

3.1. The benchmark model

The empirical analysis derived from the previous discussion assumes that perceived risk is associated with incidence rates, reflecting both the likelihood and severity of an accident. We used standard analysis regressions of self-perceived risk (PR) on a set of controls as shown in Eq. (1).

$$PR_{it} = \alpha + \lambda_t + \beta_0 X_{it} + \beta_1 Y_{it} + \beta_2 HW_{it} + \gamma_0 IR_{it} + \varepsilon_{it} \quad (1)$$

where the self-reported risk perception of individual i in year t depends on yearly dummies (λ_t), vectors of individual sociodemographic (X_{it}) and job characteristics (Y_{it}), individual hours worked (HW_{it}), and incidence rates (IR_{it}). The parameters α, λ_t, β_0, β_1, β_2, and γ_0 must be estimated, and ε_{it} denotes the error term. The dependent variable, *PR*, was measured on a scale from 0 to 10. *HW* was included as a specific variable because it can show reverse causality, as discussed below.[10]

This basic model is expanded to test each of the three hypotheses as follows:

$$Equation\,(1) + \gamma_1 IR^r_{it} \quad (2)$$

where IR^r_{it} indicates the incidence rate of the work group (defined as a group of the same sex, age range, and educational level);

$$Equation\,(1) + \gamma_2 F_{it} \quad (3)$$

where F_{it} is a variable that captures family characteristics; and

$$Equation\,(1) + \gamma_3 UM_{it} \quad (4)$$

where UM_{it} is a dummy variable indicating that the individual belongs to a union.

We tested H2 by proxying for the family variable with a dummy variable indicating whether an individual has young children or dependent adults at home. To assess H3, the binary variable indicating whether the individual was a union or a non-union worker was used as a proxy for safety conditions. Belonging to a union may make workers more aware of the level of risk and provide a more accurate perception of risks that are closer to the likelihood of an accident.

It is frequently claimed that unionized workers' representative participation in British firms is associated with lower levels of injury, as they tend to be better informed than those who are not so organized (Bryson, 2004; Nichols et al., 2007; Robinson & Smallman, 2013). In Spain, however, there is a free-rider effect that discourages union membership, because the *erga omnes* clause extends what is agreed upon in collective bargaining to all workers in all companies included in the scope of the collective agreement, regardless of whether they are union workers or not.[11] Consequently, unionization in Spain is strongly associated with deep involvement in different aspects of labor relations, including safety at work. While prevention delegates, those elected from among the workers of a company, adopt a merely scientific-technical role as a defensive strategy and only try to reduce minor accidents, union members are more proactive and involved in identifying risks that can lead to all types of accidents, including serious and fatal ones (Payá-Castilblanque, 2020; Walters & Wadsworth, 2020).

In this framework, we approximate the knowledge of the company's safety culture by the fact that the worker is unionized (information provided in our database) while the presence of prevention delegates can be captured by the size of the company, because their number increases with the number of workers. In any case, these prevention delegates are generally considered less effective than union representation in improving occupational health (Nichols et al., 2007; Walters & Wadsworth, 2020).

3.2. Addressing endogeneity

The cross-sectional nature of the data and the presence of certain independent variables raise the problem of dealing with possible endogeneity in the estimation of the regression equations. Specifically, simultaneity due to reverse causality led us to focus on two variables: working hours and union membership. We hypothesize that these pairs

Table 2
Means of fatal accident and self-perceived risk by group of workers.

Variable	Risk of fatal accident (per 100,000 workers)	Self-perceived risk (0, no risk-10 highest risk)
Overall	8.45	4.19
Agriculture	10.89	3.80
Manufacturing	8.42	4.51
Construction	14.17	5.32
Services	6.46	3.71
Skilled, non-manual	2.83	2.83
Unskilled, non-manual	4.90	3.81
Skilled, manual	11.68	5.12
Unskilled, manual	13.48	4.96
Age 16–25	8.46	4.27
Age 25–40	6.38	4.39
Age 41–55	9.53	4.21
Age > 55	10.91	3.60
Compulsory education	11.65	4.75
Secondary education	7.44	4.27
Higher education	3.49	2.93
Fixed-term contract	13.17	4.63
Permanent contract	7.37	4.09
Tenure < 1 year	18.40	4.31
Tenure 1–5 years	9.84	4.32
Tenure 6–15 years	7.58	4.32
Tenure > 15 years	5.53	4.04
Dependents in the household	8.47	4.51
No dependents in the household	8.47	4.17
Unionized worker	7.38	4.79
Non-unionized worker	8.79	4.02

[10] Existing literature agrees that a higher number of accidents is associated with working longer hours (Dembe et al., 2005; Salminen, 2004; Yamauchi et al., 2019).

[11] We also note that in Spain, less than 20% of the total workers are unionized, whereas close to 80% of the total workers are covered by a collective bargaining agreements.

of variables may be bidirectionally related. Regarding working hours, although working for more/lesser hours may influence risk perception, the opposite is also true. Self-perceived risk may influence the hours worked, provided that the worker has some room for maneuver in choosing the number of hours or the length of the working day; for example, the worker may accept/refuse to accept to work overtime or to change the type of contract (full-time or part-time). As for union membership, it may be that people who are particularly concerned about safety at work are more likely to join unions and not necessarily that being unionized alone provides workers with a better understanding of occupational hazards.

To account for the likely endogeneity in the estimation, we can proceed in two ways, depending on whether the dependent variable is considered as cardinal or ordinal. When risk perception is assumed to be cardinal, the first approach involves the use of a standard Instrumental Variable-estimation to control for endogeneity. It attempts to instrument the hours worked and union membership to obtain consistent estimates through 2SLS (or GMM); furthermore, tests for the exogeneity of the regressors and validity of instruments can be routinely used. To aid in identifying the effects of interest, a set of exclusion restrictions were formulated. Assumptions need to be made about the variables that affect working hours and union membership, however, conditional on these variables, they have no residual impact on job satisfaction.[12]

Specifically, the exclusion restrictions can be modelled as follows:

$$HW_{it} = \alpha + \lambda_t + \beta_0 X_{it} + \beta_1 Y_{it} + \beta_2 HW*_{it} + \gamma_0 IR_{it} + v_{it} \quad (5)$$

$$UM_{it} = \alpha' + \lambda'_t + \beta'_0 X_{it} + \beta'_1 Y_{it} + \beta'_2 UM*_{it} + \gamma'_0 IR_{it} + \varepsilon_{it} \quad (6)$$

where X_{it}, Y_{it} and IR_{it} are the same explanatory variables as in Eq. (1), and $HW*_{it}$ and $UM*_{it}$ represent the instruments of these variables. The fitted values for *HW* and *UM* obtained from these equations were introduced in the estimation of Eqs. (1), (2), (3) and (4).

This two-step method can only be viewed as an approximation of the correct estimator when the dependent variable is ordered (e.g., Van de Ven & Van Praag, 1981; Bryson et al., 2004). A more efficient approach would be to consider the ordered and discrete nature of Risk Perception. This second alternative takes advantage of the simultaneous estimation of different equations by allowing the unobserved individual components of such equations to be jointly distributed. More precisely, the second approach consists of a joint estimation of the equations of interest [Eqs. (1) to (4)] using an ordered probit, together with selection equations [Eqs. (5) and (6)]. The simultaneous estimation of these equations is included in the general class of multiple-equation models with discrete endogenous variables (Heckman, 1978, 1979). Following Roodman (2011), we model risk perception and potential endogenous regressors as a system of equations, estimated using a simulated maximum likelihood method from multivariate normal distribution functions resembling the Geweke-Hajivassiliou-Keane (GHK) simulator.

The joint modeling of the equations allows for the error terms to be correlated across equations, and thereby, for any endogeneity in the modeled equations, so that the endogeneity is corrected by way of error correlation estimates (Roodman, 2011). Additionally, the cross-equation correlations of the estimated errors (ρ) perform as a test of the endogeneity of the regressors; when ρ is significantly different from zero, the exogeneity is rejected. The latter approach considers the ordered nature of dependent variables and the possible lack of strong or valid instruments.

[12] The choice of the variables that act as instruments is described in Section 4.2.

4. Results[13]

4.1. Not dealing with endogeneity

4.1.1. OLS estimation

Table 3 presents the results of estimating the relationship between each of the personal and job characteristics and self-perceived risk at work for the selected sample of employees using OLS. Model (1) corresponds to the basic specifications in Eq. (1), whereas Models (2)–(4) refer to the equations used to test the three hypotheses. At this stage, the bias associated with potential endogeneity was not addressed; therefore, causality was not investigated and the coefficients should be interpreted as only partial correlations. The incidence rate was highly significant and positively correlated with risk perception. The coefficients of personal and job-related characteristics reveal a consistent picture across all regressions, retaining the expected sign and magnitude.

Certain patterns were identified by focusing on the parameters common to all specifications. Age variables exhibit an inverted-U shape, indicating that in the early years, risk perception increases with incidence rates up to the age of 35 years and then declines.[14] The inclusion of the incidence rate of fatal accidents shapes the typically-found monotonic positive influence of age on risk perception (Salminen, 2004; Bravo et al., 2020). Higher education was associated with lower risk perception, with foreign workers perceiving less risk, *ceteris paribus*, compared to native Spanish workers. Regarding work-related variables, the self-perceived risk increases with tenure, hours worked, and firm size; it is higher for overeducated workers but lower for those at their first jobs. With respect to activity branches, workers in the construction sector perceived the highest risk, followed by manufacturing and services and the primary sector. Manual workers perceived more risk, while skilled nonmanual workers perceived the least risk. Surprisingly, the type of contract was not statistically significant.

Considering the variables of interest, the incidence rate of fatal accidents was positively and significantly associated with the perception of risk in the workplace, with an estimated coefficient that hardly changed when additional variables (allowing for the hypotheses tested) were included (see row 1 in Table 3). The first important result is clear: with other variables being equal, subjective risk moves in tandem with the incidence rates. The estimated elasticity of the relationship is low: if the incidence rate doubles at the mean value (changes from 8.5 to 17 fatal accidents for every 100,000 workers), risk perception increases from 4.19 to 4.25. However, this somewhat weak relationship was expected because the incidence rate refers to fatal accidents, whereas perceived risk may also include risks other than fatalities, such as injuries or diseases. Our choice of the incidence of fatal accidents as a proxy for objective risk is based on the following: first, it is the most objective measure one can find, and second, this type of accident is the one that workers can undoubtedly consider as the true risk in the workplace.

Regarding the first hypothesis, it was observed that when the incidence rate of the worker's workgroup (computed as the average for workers in their age group and educational level) was included, perceived risk was reduced. The higher the incidence rate of the group, the lower the worker's perceived risk compared with the other groups where the incidence rate is lower. Looking at the second hypothesis, and as anticipated in the descriptive analysis, workers with family responsibilities seem to be more risk averse. Finally, union membership increased the perception of risk. The simple argument is that the union provides workers with greater knowledge of job characteristics, including information on accident rates.

[13] All estimated results obtained from statistical package StataSE© 14.

[14] The age at which Risk Perception reaches a maximum is computed as follows $MaxAge=(50*\delta_1)/(-\delta_2)$ where δ_1 is the coefficient associated with *Age* and δ_2 is the coefficient associated with $(Age)^2/100$.

Table 3
Linear OLS estimates for the relationships among risk perception and regressors.

	Model (1)		Model (2)		Model (3)		Model (4)	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE.
Incidence rate (*IR*)	0.007***	0.002	0.008***	0.002	0.007***	0.002	0.007***	0.002
Incidence rate worker workgroup (IR^r)			−0.065**	0.026				
Dependents					0.410***	0.111		
Union							0.802***	0.067
Age	0.119***	0.018	0.127***	0.018	0.119***	0.018	0.104***	0.018
$Age^2/100$	−0.173***	0.021	−0.173***	0.021	−0.175***	0.021	−0.156***	0.021
Secondary education	−0.051	0.069	−0.306**	0.123	−0.051	0.069	−0.081	0.068
Higher education	−0.500***	0.098	−1.021***	0.229	−0.493***	0.098	−0.493***	0.097
Nationality	0.318***	0.106	0.332***	0.106	0.309***	0.106	0.264**	0.106
Tenure	0.014***	0.004	0.014***	0.004	0.014***	0.004	0.009***	0.004
Over-education	0.248***	0.076	0.252***	0.076	0.245***	0.076	0.205***	0.076
First job	−0.166**	0.070	−0.158**	0.070	−0.166**	0.070	−0.140**	0.069
Permanent contract	0.031	0.076	0.032	0.076	0.035	0.076	0.005	0.076
Hours worked	0.043***	0.004	0.043***	0.004	0.043***	0.004	0.047***	0.004
Firmsize 11–50	0.357***	0.079	0.357***	0.079	0.354***	0.079	0.316***	0.078
Firmsize 51–250	0.457***	0.088	0.458***	0.088	0.455***	0.088	0.363***	0.088
Firmsize > 250	0.826***	0.078	0.824***	0.078	0.821***	0.078	0.649***	0.079
Manufacturing	0.886***	0.154	0.885***	0.154	0.890***	0.154	0.826***	0.153
Construction	1.536***	0.154	1.531***	0.154	1.542***	0.154	1.513***	0.153
Services	0.817***	0.151	0.818***	0.151	0.821***	0.151	0.745***	0.151
Unskilled, non-manual	0.794***	0.094	0.805***	0.094	0.793***	0.094	0.720***	0.093
Skilled, manual	1.934***	0.098	1.937***	0.098	1.934***	0.098	1.860***	0.097
Unskilled, manual	1.859***	0.096	1.860***	0.096	1.859***	0.096	1.769***	0.096
Year dummy	Yes		Yes		Yes		Yes	
Regional dummy	Yes		Yes		Yes		Yes	
Corrected R^2	0.13		0.13		0.13		0.14	
Observations	13,096		13,096		13,096		13,096	

Note: *p < 0.1; ** p < 0.05; *** p < 0.01.

4.1.2. OP estimation

The next step in the estimation strategy is an ordered probit model that considers the ordinal nature of PR. Up till now in this study, we considered that problems of endogeneity were not at place and that OP estimation can be applied, regardless of endogeneity. The upper part of Table 4 lists the marginal effects corresponding to a high accident risk perception for the specifications under consideration. Specifically, in our case, the marginal effects indicate the change in the predicted probability of a perception of risk greater than seven, given a change of one unit in each individual dependent variable and holding all other variables at their means. For dichotomous variables, the marginal effect indicates a change from zero to one. Only the results corresponding to the variables of interest are shown (other control variables offer results similar to those observed in the previous estimate). Although the marginal effects are not directly comparable with the estimated coefficients of the regression in Model (1), the evidence provided shows qualitatively coincident results, confirming that assuming either cardinality or ordinality in subjective values has little effect on the empirical qualitative results.[15] The results again show that more risk is perceived when the incidence rate is higher, when there are dependents in the worker's household, or when the worker belongs to a union, whereas less risk is perceived when the incidence rate of the worker's workgroup is higher.

4.2. Dealing with endogeneity

4.2.1. 2SLS estimation

In the following sections, we address endogeneity using two alternative methods. The second block in Table 4 offers 2SLS estimates of Eqs. (1) to (4), where hours worked and union membership are instrumented, as expressed in Eqs. (5) and (6), and their fitted values are introduced in the main equations.[16] The Standard Wu-Hausman test rejected the exogeneity of both variables. At this point, risk perception was considered cardinal.

The selection of appropriate instruments was investigated. Regarding the instrument for hours worked, and following Cornelissen et al. (2011), we tried different alternatives constructed as sample averages across different groups (industry, occupation, region, etc.) and tested for their appropriateness. The constructed variables are expected to correlate with the actual number of hours worked; however, there is no reason to think that this indirectly influences individual worker risk perception. After several attempts, the average number of hours worked by industry, occupation, and type of working day was the instrument selected for hours worked, because it provided the highest values for R^2 and Shea's partial R^2, which were obtained in the first-stage regression (5) of the potentially endogenous variable of hours worked on the different set of exogenous instruments.

For union membership, the establishment age or an indicator of whether a workplace belongs to a multi-establishment firm or is a standalone workplace was not available in our database. Among the set of possible instruments, the one that produced the best results in terms of R^2 and Shea's partial R^2 on the regression of membership variables on exogenous instruments was the worker's evaluation of their knowledge of union activity. This subjective variable ranged from 0 (no knowledge) to 10 (full knowledge). This was expected to be somewhat correlated with union membership but not at all with self-perceived risk in the workplace. As in the case of working hours, this hypothesis was corroborated because there was little evidence of the weakness of such instruments.[17]

The estimated coefficients for the incidence rates are still positive

[15] Ferrer-i-Carbonell and Frijters (2004) produced evidence that assuming either ordinality or cardinality of happiness scores had little effect on the qualitative empirical results. As a result, OLS estimation is more often used than ordered probit or logit models, because of the straightforward interpretation of the coefficients.

[16] Note that only in Equation (4) both hours worked and union membership are simultaneously introduced. In Equations (1) to (3) only the variable hours worked appears as a regressor.

[17] Results are not shown but are available upon request.

Table 4
Ordered probit. IV and GHK estimations.

Ordered Probit: marginal effect of high perceived risk (between 7 and 10)								
	dy/dx	SE	dy/dx	SE	dy/dx	SE	dy/dx	SE.
Incidence rate (*IR*)	0.001***	0.0003	0.001***	0.0003	0.001***	0.0003	0.001***	0.0003
Incidence rate worker workgroup (IR^r)			−0.007**	0.003				
Dependents					0.051***	0.015		
Unionised							0.102***	0.001
Log Likelihood	−13005.8		−13003.9		−13000.2		−12943.7	
Instrumental Variable estimates (2SLS) for the relationships among risk perception and regressors								
	Coef	SE	Coef	SE	Coef	SE	Coef	SE
Incidence rate (*IR*)	0.005**	0.002	0.006**	0.002	0.005**	0.002	0.005**	0.002
Incidence rate worker workgroup (IR^r)			−0.044*	0.027				
Dependents					0.405***	0.117		
Unionized							0.549***	0.23
R^2	0.04		0.04		0.04		0.04	
Wu-Hausman endogeneity test								
H0: Hours worked: exogenous	66.912	0.000	66.976	0.000	66.581	0.000	80.704	0.000
H0: Union: exogenous							10.345	0.000
Participation equation (weak instrument test). Shea's partial R^2								
Average hours worked	0.302	0.342	0.321	0.353	0.325	0.354	0.324	0.35
Union							0.1011	0.114
GHK simultaneous estimates (MLE) for the relationships among risk perception and regressors								
	Coef	SE	Coef	SE	Coef	SE	Coef	SE
Incidence rate (*IR*)	0.002**	0.001	0.002**	0.001	0.002**	0.001	0.002**	0.001
Incidence rate worker workgroup (IR^r)			−0.017*	0.01				
Dependents					0.145***	0.043		
Union							0.47***	0.059
ρ_{12}	−0.012***	0.005	−0.322***	0.043	−0.042***	0.005	−0.335***	0.041
ρ_{13}							−0.291***	0.04
ρ_{23}							0.125**	0.062
Log Likelihood	−54815.7		−54790.2		−54810		−60125.8	

Note: dy/dx. Marginal effect on self-perceived risk greater than 7 as a consequence of a one-unit increase in the corresponding independent variable and holding all other variables at their means.
*p < 0.1; ** p < 0.05; *** p < 0.01. Rest of controls as in Table 3.

and statistically significant, but somewhat lower than those obtained in Table 3, indicating that the influence on perceived risk with the double direction of causality is not as high as that when considering only one-way causality. Similar behavior was observed for the coefficients testing the three hypotheses, confirming the results and conclusions discussed above.

4.2.2. ML estimation

To ensure robustness in our results when considering the issue of endogeneity, we now consider the ordered nature of risk perception and estimate the systems of equations using conditional simulated likelihood (Roodman, 2011). We do so by allowing for the possibility that in Eqs. (1) to (3), unobserved heterogeneity in perceived risk may be correlated with the process by which individuals choose the number of hours worked. Eq. (4) allows for the joint determination of perceived risk, hours worked, and union membership. The systems are not fully recursive because the variables of hours worked and union membership enter the equation explaining risk perception; however, the reverse does not apply. The estimated results are presented at the bottom of Table 4. In Models (1) to (3), hours worked is taken as the only endogenous variable, while Model (4) also allows for the endogeneity of union membership.

The estimated correlation between the error terms of risk perception and hours worked equation, ρ_{12}, is statistically significant in all models, showing a negative sign in all specifications. Significance confirms the endogeneity of hours worked, whereas a negative sign indicates that unaccounted factors that tend to increase the number of hours worked, also tend to reduce risk perceptions. A similar finding was observed for union membership. The estimated correlation between the error terms of the perceived risk and the membership equation, ρ_{13}, is statistically significant and negative, showing that unobserved characteristics favoring union membership led to lower risk perception. Finally, there is an unaccounted-for correlation between the errors of the hours worked and membership equations, with ρ_{23} being statistically significant at the 5 % level, supporting the idea that both variables are positively related, such that unobserved characteristics favoring union membership led to longer hours worked.

Focusing on the variables of interest, the estimated coefficients again have the same sign as in the previous estimates, although their values are further reduced. This pattern is similar to both that observed in Table 3 and in the second block in Table 4, suggesting that the evidence in favor of the three hypotheses tested is robust, although their influence on the perception of risk is not as high as was initially estimated.

5. Discussion

This study explored the relationship between the subjective risk perception of employees and an approximation of the objective risk based on the incidence rate of fatal accidents in the workplace. A stepwise procedure that considers both the ordered nature of risk perception and the possibility of biases arising from simultaneity between risk perception and some of the explanatory variables was followed. Most of the results are common, and therefore robust, to any specification used in the regression. A summary of these results is presented in Table 5.

First, we found that perceived risk and incidence rates are significantly correlated; a greater incidence rate positively affects subjective risk perception once an ample set of personal and job-related characteristics is controlled for. This confirms that personal and organizational variables influence "emotional" risk perception, but the two measures of risk do not exactly reflect the same phenomenon. Second, a few hypotheses were tested to show that the worker's workgroup, family responsibilities, and safety environment were all related to self-perceived risk in the workplace. Finally, when considering simultaneity in some decisions and in risk perception, the influence of the incidence rate on

Table 5
Summary of estimated results.

Cardinality	Causality	
	No causality	Causality
Cardinal	*OLS (Table 3)*	*2SLS (Table 4, 2nd panel)*
	IR 0.007***	IR 0.005**
	H1 IR^r −0.065**	H1 IR^r −0.044*
	H2 F 0.410***	H2 F 0.405***
	H3 UM 0.802***	H3 UM 0.549***
Ordinal	*OP (Table 4, 1st panel)*	*MLE (Table 4, 3rd panel)*
	IR 0.001***	IR 0.002**
	H1 IR^r −0.007**	H1 IR^r −0.017*
	H2 F 0.051***	H2 F_{it} 0.145***
	H3 UM 0.102***	H3 UM_{it} 0.470***

Notes: IR: incidence rate; IR^r: worker's workgroup incidence rate; F: family responsibilities; UM: union worker. H1, H2, H3: hypotheses 1, 2 and 3, respectively. In OP estimation the results are marginal effects and they are not directly comparable with the coefficients of the other cases. *p < 0.1; ** p < 0.05; *** p < 0.01.

risk perception is reduced, but is still significantly positive, and the three hypotheses continue to be accepted.

5.1. Practical application

This study was based on the fact that risk perception is subjective and distinct from observed or objective risk (Slovic et al., 1979; Loewenstein et al., 2001). While objective statistical data on accidents are usually unknown to employees, they often have an intuitive and non-analytical judgment of risk, commonly referred to as emotional risk perception (Xia et al., 2017). The notion of risk can be addressed by directly asking workers about their feelings (Rundmo, 1996; Slovic et al., 2004). This perception can be further shaped if workers are properly informed and trained. In this way, they can acquire more knowledge about the risks inherent in the workplace so that the perception of risks is closer to the statistical data on occupational accidents. To investigate the relationship between both measures of risk, we considered an ample set of personal and organizational characteristics that influence risk perception (Kouabenan, 2009; Xia et al., 2017; Ibrahim et al., 2022). Understanding how employees perceive risk and how this perception deviates from objective statistical data may be helpful in accurately designing procedures to increase information and avoid accidents.

The results in Table 3 are described in detail to specify how risk perception varies across personal and job characteristics, confirming that protective safety measures must consider the distinctive features of workers. Our investigation can also serve to enhance the influence of additional factors that the literature suggests may influence risk perception, such as workers' workgroup behavior (Liang et al., 2018), the occupational group (Leoni, 2010), the safety environment (Christian et al., 2009; Xia et al., 2020), the hours worked (Greubel & Nachreiner, 2013) or family responsibilities (Deleire & Levy, 2004; Grazier & Sloane, 2008). In this sense, closeness in age, sex, educational level, or occupation may influence how workers perceive risk compared to other workers with very different characteristics. Analogously, a good safety environment is essential for accident prevention, requiring more informed employees, especially via the role played by unions or union delegates because the presence of prevention delegates may not be as effective in stimulating risk prevention (Walters & Wadsworth, 2020). The results also reveal the importance of family responsibilities. If parents are more risk averse than non-parents, the latter may face riskier tasks, and safety prevention should focus more on these workers.

Overall, this study makes it clear that risk perception deviates significantly from statistical, objective accident information, suggesting that employees' "reading" of risk differs significantly depending on various individual characteristics. When implementing preventive measures, the company management must seek a better perception of workplace risks. While an overall risk management policy should prevail in the workplace, specific characteristics, such as those aforementioned, need to be addressed.

5.2. Strengths and limitations

The first strength of this study is the use of a nationally representative dataset from a survey to measure risk perception at the individual level, which simultaneously provided information on a range of individual characteristics. This information was complemented by statistics from the entire registry of occupational accidents in Spain for each year of the sample.

The second strength of this study is its careful treatment of the issue of simultaneity between certain explanatory variables and the dependent variable of risk perception. Two-way causality may mask the final relationships between these variables. To disentangle these dual causations, simultaneity was addressed by instrumental variable estimation using 2SLS or MLE. Using appropriate instruments, the causality of hours worked and unionization was isolated, ensuring that the final effect was free of reverse causality. Once simultaneity was controlled for, the coefficients of the variables of interest decrease in magnitude but remain statistically significant. In other words, part of the initial influence of incidence rates on risk perception was due to reverse causality.

This study has certain limitations that mostly arise from data availability. First, the data used to test the proposed hypotheses were cross-sectional. Longitudinal information would help to identify the possible causal relationship for more variables influencing risk perception, for which it is difficult to find appropriate instruments. Second, variables capturing workplace hazards are lacking; therefore, we proxied these with dummies for occupation, industry, and firm size. Third, the inclusion of other missing variables that may be correlated with risk perception—such as those related to cultural and political factors, to the organization's strategic policy (social norms, group pressures, safety, etc.), to the risk itself (nature, familiarity of the employee, etc.), and to forces linked to psychological and cognitive traits—would be useful in our analysis.

Finally, the last QLWS wave was in 2010. Since then, no national survey of a similar scope has provided information on individual risk perceptions in the workplace in Spain. Despite this, a review of recent literature on the Spanish case suggests that our study on the (dis) alignment between accident rate and risk perception remains interesting. It should be borne in mind that, since the approval of the Law on Occupational Risk Prevention (LPRL, *Ley de Prevención de Riesgos Laborales*) in 1995, there have been no dramatic changes in the legislation on Occupational Safety and Health (OSH). Its enactment represented a major change from previous regulations by promoting effective and real compliance with the OSH obligations of Directive 89/391/EEC. It proposes a culture of prevention that promotes safety and health education at all levels (Sesé et al., 2002).

The evolution of occupational accidents from 1990 to the present has been characterized by a generalized reduction in serious and fatal accidents, however, there has been a marked procyclical behavior in minor and hard-to-diagnose accidents, that is, an increase in accident rates has occurred during expansion and a reduction in recessions (Martín-Román & Moral, 2017; De la Fuente et al., 2014). The first explanation for this procyclicality of accidents is based on moral hazard issues due to individuals taking more risks ex-ante (the so-called Peltzman effect, 1975) or claims reporting bias (Rose & Butler, 2009).[18] The second reason is the low commitment of companies to OSH, as management focuses mainly on formal rather than effective compliance with prevention obligations, and on the low encouragement of workers' participation in

[18] Martin-Roman and Moral (2017) provide evidence on supporting this argument for the situation right after the setup of the Law on Occupational Risk Prevention (LPRL) in 1995 in Spain.

risk prevention activities (Arocena and Núñez, 2009; Fernandez-Muñiz et al., 2018). Although the obligation to have prevention delegates in companies with more than 50 workers (also recommended for companies with more than six workers), has helped to reduce the accident rate to some extent, it has not achieved more ambitious objectives (Ollé-Espluga et al., 2015; Payá-Castilblanque, 2020). Work inspections have recently been advocated as a way to promote OHS intervention (Lafuente & Abad, 2021).

The general impression is that the reduction of occupational accidents remains an important issue for policymakers and that our findings and the proposals derived from them are applicable today. In particular, there is a need for greater involvement of workers in requesting management to implement OSH measures, for which the role of trade unions as providers of awareness and risk perception seems indisputable.

5.3. Recommendations for future research

Apart from making more data available, a couple of factors could improve this research in the short run. First, more affordable ways to expand this study would be to consider alternative definitions of risk, not only by considering the severity of accidents but also whether they are computed for specific groups. Regarding the use of rates of fatal accidents, Gegax et al. (1991) pointed out that the weak relationship between statistical measures of risk and perceived risk could be due to the fact that risk perception does not necessarily refer to the likelihood of suffering a fatal accident, but only to a "normal" (or less lethal) accident. Second, a more comprehensive analysis of the set of relationships among all variables and how they are interconnected would also strengthen our study. These two avenues can be explored further in future studies.

One important concern is that a better understanding of how employees perceive risk is necessary to encourage safer behavior (Arezes & Miguel, 2008; Gyekye, 2006), although this link between risk perception and protective behavior has been challenged (Rundmo, 2001; Kouabenan et al., 2015). These and other recent studies (Oah et al., 2018; Xia et al., 2020) have argued that perceptions of workplace risk may result in job hindrances or challenges. Accordingly, a greater awareness of risks may lead workers to require sustained physical and/or mental resources, causing stress or strain for employees and preventing them from following adequate or appropriate safety behaviors. This study did not explore this possibility; however, it may become a future line of research.

6. Conclusion

Subjective risk perception, identified as emotional risk perception, is significantly related to the objective/statistical risk of accidents, identified as rational risk, once a broad set of personal and occupational characteristics are controlled for. The considerable variation in worker's characteristics leads to a marked heterogeneity in risk perception: the "reading" of a risk differs for individuals, depending on their own characteristics. For example, older workers perceive less risk and are more likely to experience accidents than younger workers. Similarly, workers with family responsibilities or unionized workers suffer fewer accidents and perceive higher risks in the workplace.

The results of all the analyses are robust, as the estimated coefficients are essentially the same, although the importance of incidence rates was substantially reduced as simultaneity was addressed. In addition, three elements were found to influence the relationship between incidence rates and subjective risk: the worker's workgroup, family issues, and the organization's safety culture (approximated by unionization). While the positive association between incidence rates and perceived risk does not vary a lot across different specifications, being unionized or having dependents positively affected risk perception. Moreover, the higher the incidence rate in a given group of workers, the lower was the perception of risk for a worker belonging to that group.

Given that the three hypotheses raised in this study were confirmed, it allowed us to provide guidelines to improve risk perception and the effectiveness of risk prevention training for workers. We advise providing statistics on incidence rates with the highest possible level of disaggregation, so that the workers, especially prevention representatives, have a more precise knowledge of the risks inherent to both the job and the characteristics of the worker. Thus, it is possible to provide specific information on occupational hazards for workers of different ages, educational levels, and other characteristics.

It is more difficult to design specific measures for those who do not have dependents or belong to a trade union. Therefore, it is necessary to insist on a greater commitment on the part of company management, prevention representatives, and the workers themselves to develop mechanisms that allow greater knowledge of both potential risks in the workplace and of prevention activities, beyond the strictly legal ones, to overcome the evaluations of work inspections. As indicated by Paya-Castilblanque (2020) and Walters and Wadsworth (2020), the mere allocation of prevention delegates may not be sufficient; all workers in the firm should be informed of their allocation (Ollé-Espluga et al., 2015).

Some proposals have been made on a more general scale and they aim to reduce accident rates in Spain; these include the implementation of safety management systems such as OHSAS 18001 or economic instruments that encourage a company's good OSH performance (lower insurance premiums or tax deductions) and penalize those companies that have poor occupational risk management (see Fernández-Muñiz et al., 2018).

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