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ACCIDENTS AT WORK IN ITALY: AN EMPIRICAL ANALYSIS AT THE REGIONAL LEVEL

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Accidents at work in Italy:

an empirical analysis at the regional level

Abstract

This work proposes an analysis of occupational accidents in Italy at the regional level. To this end, INAIL and ISTAT data are used for the period 2010-2019 to apply different econometric estimation techniques (pooled OLS model, fixed effects model and random effects model) and to better consider regional specificities. As will be seen in the course of the work, in most of the estimates, the results show statistically significant correlations between some economic variables and the regional social context (GDP per capita, level of education, unemployment, fragility of the local labour market and level of crime in the region) and the accident phenomenon alternatively defined with different indicators. Therefore, the analysis seemingly confirms the relevance of the regional dimension, which should also be considered for possible policy interventions.

JEL Classification: J21, J28
Keywords: occupational accidents, business cycle, Italian regions, panel data

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1. Introduction

Occupational safety and health (OSH) is a fundamental aspect of workers' well-being. For this reason, attention to this issue has been strongly refocused in recent years at the political, economic, and social levels, resulting in a wide and interdisciplinary literature (Tullini, 2017; Delogu, 2018; Sclip, 2019; Conti, 2016; Alessandrini et al. 2017; Pascucci and Delogu, 2020; De Sario et al. 2021). Economic analyses have mainly focused on identifying the determinants of the workplace accidents, highlighting significant correlations between their frequency and a set of "exogenous variables" relating to socioeconomic and institutional factors, the environment and work organisation, the characteristics of firms and the sector of economic activity in which they operate. Results suggest howwork accidents may be characterised by a certain degree of territorial heterogeneity. On average, Eurostat data show that the accident rate in the European Union (percentage of nonfatal accidents in relation to those in employment) is 1.46 percent in 2020, with a ranking that has a wide range of variations in the indicator across countries. Higher proportions of workplace accidents are found in France (2.9 percent), Denmark (2.6 percent), Portugal (2.3 percent), Spain (2 percent) and Slovenia (1.8 percent) versus countries with the lowest levels of the same indicator (Romania 0.07 percent, Bulgaria 0.08 percent, Greece 0.11 percent, Latvia 0.22 percent and Lithuania 0.32 percent). With reference to Italy, the percentage of (nonfatal) accidents at work was 1.4 percent in 2020, but the marked territorial differences in income, labour market characteristics, human capital and productive structure make it interesting to deepen the analysis at the territorial level.

Therefore, this work proposes an analysis of occupational accidents in Italy at the regional level and follows the strand of international literature that delineates workplace accidents as a complex and multidimensional phenomenon (Laflamme, 1990; Fabiano et al., 2004; Cornelissen et al., 2017, Castaldo et al. 2022) but differs from it in the regional perspective of analysis.

To this end, INAIL and ISTAT data for the period 2010-2019 are analyzed using a set of econometric estimation techniques (pooled OLS model, fixed effects model and random effects model) to assess the relevance of regional specificities. As will be seen in the course of the work, in most of the estimates, the results show statistically significant correlations between some economic variables and the regional social context (GDP per capita, level of education, unemployment, fragility of the local labour market and level of crime in the region) and the accident phenomenon is alternatively defined with different indicators. Therefore, the analysis seemingly confirms the relevance of the regional dimension, which should also be considered for possible policy interventions. The INAIL policy for OSH implemented through the ISI calls[1] seems to fit into this framework (Salberini and Signorini, 2020). The publication for calls at the national level is in fact accompanied by a decentralised distribution of funds based on regional public notices published through the publication of individual notices for each region and autonomous province; these regions are left in charge of operationally

[1] For a full analysis of the policy measure, see Ragazzi (2020).

managing the execution of the procedure because of the complete and detailed information on the local territorial reality.

The work is structured as follows. After introducing a literature review in Section 2, Section 3 describes the data and variables used in the analysis. Section 4 describes the econometric methodology and the estimation results. Finally, Section 5 contains concluding remarks.

2. Workplace accidents: a literature review

Numerous studies have analysed the determinants of workplace accidents and occupational diseases, contributing to a literature that today seems to suggest that occupational safety and health (OSH) is a complex and multidimensional phenomenon, a combination of determinants ranging from individual and workplace-related factors to socioeconomic and institutional characteristics (Laflamme, 1990; Fabiano et al., 2004; Cornelissen et al., 2017). From this perspective, the occurrence of a workplace accident results from the interaction of a multitude of elements that increase or decrease the probability of of the event. Their understanding is crucial for both firms in the prevention phase and policy-makers in the design and implementation phase of a policy (Micheli et al., 2018).

First, the characteristics of the production system influence the frequency of workplace accidents. The size composition of firms in the country is considered a variable that can have an impact on OSH levels (Fabiano et al., 2004). In Italy, for example, small and medium-sized firms have on average, a higher accident rate with worse consequences due to the scarcity of human, economic and technological resources (Micheli et al., 2018). Moreover, this evidence is not only relative to the Italian territory but can be generalised: it is widely recognised in the literature that given the same sector—and therefore the same sources of risk—SMEs generally face the same types of health and safety problems as larger firms but they have lower capacity to deal with these problems from different points of view (Frick and Walters, 1998; Antonsson et al., 2002). First, economic resources: usually, smaller firms have greater economic needs and therefore encounter greater economic obstacles to carrying out activities that ensure adequate levels of OSH (Dorman, 2000; Champoux and Brun, 2001; Hasle and Limborg, 2006; Nordlöf et al., 2017). Second, regarding capabilities in terms of OSH knowledge and culture, there is, in fact, a difference between SMEs and large firms regarding the decision latitude of strategic choices, which has a nonnegligible impact on OSH levels. As pointed out by several authors (Eakin and MacEachen, 1998; Eakin, 2010; Walters et al., 2018), in most SMEs, the owner and manager roles coincide (Walters and Wadsworth, 2016). Such owner-managers organizational structure generally lacks specific occupational safety training and expertise (Antonsson, 2002), and their decision-making activity is multitasking and is framed within a short-term horizon that is often characterised by high external uncertainty (Hasle et al., 2012). In this framework, the quality of the working environment may not be a priority. This often leads SME owner-managers to consider the accident risk as an unavoidable part of the job and therefore ineliminable, underestimating the accident risk, with a personalisation of the accident to the worker and a ”deresponsibility” of the employer in terms of ensuring good levels of OSH (Walters et al., 2018).

A further strand of literature focuses instead on the impact of the business cycle on accident

frequency: it has been shown that in the sector with the largest number of employees, namely, manufacturing, accident rates increase significantly during upturns and decrease during recessions (Ruhm, 2000; Asfaw, 2011). This pro-cyclical trend in accidents has been further generalised and deepened, leading to the conclusion that these cyclical fluctuations in accident rates are linked to unemployment trends. In particular, this can be attributed, in the first place, to the worsening of working conditions due to the increase in the intensive and extensive margin (Lilley et al., 2002; Dembe et al., 2005; Folkard & Lombardi, 2006; Lindroos et al., 2008), which traditionally occur at the same time as an increase in unemployment. Moreover, it appears that the threat of unemployment has a disciplinary effect on those who work: the fear of being unemployed induces the worker to demand fewer protections regarding the working environment (Blank et al., 1996). According to Robinson (1988), on the other hand, the relationship found between the increase in unemployment and the increase in the frequency of accidents can be attributed to the decrease in the number of people employed - and thus the decrease in the number of workers exposed to the accident event - in addition to the decrease in union power - and thus in the possibility of contracting more OSH requests. Boone & Van Ours (2006) analyse the cyclical fluctuation of occupational accidents by distinguishing between fatal and nonfatal accidents in 16 OECD countries, showing that fatal accidents, in contrast to nonfatal accidents, do not exhibit a pro-cyclical pattern. The authors then test the underreporting theory, according to which this difference in cyclicality is due to workers' (non)reporting behaviour rather than to elements strictly related to occupational safety. In fact, while fatal accidents are always reported, nonfatal accidents do not always emerge because reporting an accident could affect a worker's reputation by increasing the likelihood of being fired, which, in the presence of high unemployment rates, leads to significant losses due to the difficulty of reemployment and re-entering the labour market (Boone & Van Ours, 2006).

Labour market characteristics are also decisive in influencing OSH levels. Kirschenbaum et al. (2000) suggest that the propensity to be injured is more directly influenced by organisational factors and work relationships than by personal factors and human error: according to the authors, the type of contract and the interaction between longer working hours and level of pay are crucial factors that significantly influence the occurrence of injuries. The importance of the fragility of the job position is also highlighted by Fabiano et al. (2008) and Sánchez et al. (2011), who show that temporary workers not only have a higher frequency of accidents, but such accidents also occur with greater severity. Furthermore, there is a broad consensus that the sector of economic activity also plays a decisive role in occupational accident risk levels: this is confirmed by the fact that the differences found in terms of accident frequency between economic sectors persist even when controlling for contextual differences between clusters of countries (Lenaerts et al., 2020). The sectoral perspective is especially important when studying risks related to the physical environment (Leigh, 1989; Maiti and Bhattacherjee, 1999; Maiti et al., 2001; Maiti et al., 2004; Haslam et al., 2005; Khanzode et al., 2011), which depend on the type of activity performed, the production process, the materials used, the equipment typically employed in an industry, and the activities performed during the work activity (Parent-Thirion et al. 2012; Walters and Wadsworth, 2016, Lenaerts et al., 2020). Intersectoral differences are also crucial in terms of occupational structure, which places certain groups in a particularly vulnerable position. Indeed, sectors dominated by *blue-collar* occupations, such as construction, agriculture, industry, and transport, typically have less safe physical environments; in contrast, sectors dominated by *white-*

collar occupations, such as financial services, education and public administration, benefit from safer physical environments (Lenaerts et al., 2020). Thus, while sectors dominated by the so-called *white collar workers*, with a higher level of education and generally higher labour income, are subject to OSH risks that are more related to psychological factors (such as stress and anxiety), the so-called *blue collar workers*, with lower pay and less education, are subject to a higher risk of physical injuries (Dorman, 2000; European Commission, 2008).

Finally, a further category of possible determinants of accident frequency is that of institutional characteristics. In particular, the hypothesis is that a higher level of crime and deviations from the law also lead to lower compliance with existing OSH regulations with a consequent increase in the likelihood of accidents (Lindroos et al., 2008). Indeed, it is well known in the literature that the propensity for OSH regulatory compliance, as well as the adoption of good organisational and managerial practices, ensure better performance in terms of accident frequency (Antonsson et al., 2002; Walters and Wadsworth, 2016; Mohammadfam et al., 2017). Among institutional determinants, the adoption of appropriate organisational models also plays an important role (Shannon et al., 1996; Vassie et al., 2000; Kogi, 2002; Parent-Thirion et al., 2012; Ipsen et al., 2015). Organised work, in fact, operates at different levels to make workplaces safer (Walters et al., 2005) since the characteristics and choices regarding the organisation of work, both at a technical and human level, determine the general context in which tasks will be performed (Laflamme, 1990). In particular, certain aspects of process organisation, working methods and the organisation of the work itself - such as working hours or soft tools such as task rotation, teamwork and worker involvement - are elements that determine the physical environment in which the task is carried out and are a managerial responsibility that decisively impacts the level of workers' exposure to the risk of injury (Parent-Thirion et al., 2012; Irastorza et al., 2016). This is even more relevant in light of the evidence that even if safer machinery is implemented, a lower incidence of accidents is not guaranteed unless accompanied by appropriate organisational models (Walters et al., 2005). In fact, interventions in the physical environment are not necessarily predictive of causal effects per se; the actual outcome of an investment varies depending on the intervention, the context, and the interaction between these factors and may generate positive, negative, expected, or unexpected effects (Pedersen et al., 2012). In particular, the main factors that could influence the effectiveness of an intervention and may lead to an unexpected outcome - which should therefore be considered - are the organisation of work and the tasks performed, information, training, worker commitment, leadership, management involvement in safety, safety culture and worker attitude (Micheli et al., 2018).

3. Data and Variables

The database was constructed by referring to INAIL microdata from two distinct sources: a first set of data broken down by PAT (Territorial Insurance Position) and by year, which contains information on workplace accident phenomena, and a second set of data containing information on firms insured with the Institute. After aggregating the tables provided by the Institute into a single database illustrating the national situation, the data needed to measure the variables of interest at the regional scale for the period 2010-2019 were selected. The dataset obtained was expanded by including additional variables

constructed from ISTAT data on fair and sustainable welfare (BES).

Starting from this framework, indicators were constructed to represent different dimensions of the accident phenomenon, which, in this work, constitute the dependent variables alternatively used in the econometric model. Specifically, in addition to the accident risk, defined as the number of employees who suffered physical and/or psychological damage because of accidents at work, more representative indicators of the consequences of workplace accidents were also considered, both in terms of days of absence from work and in economic-financial terms considering the amount of compensation paid. These quantities are observed on an annual basis and are measured in relation to the number of employees, where the latter are measured as full-time equivalents.

Table 1 provides an overview of the dependent variables included in the analysis, giving a brief description of each one and illustrating the source of the data and the unit of measurement used.

Table 1. Dependent variables

Variable	Description	Source	Unit of measurement
Accident risk *(Inf_Dip)*	Number of accidents at work per number of full-time equivalent employees.	INAIL	Ratio*100
Injury severity *(Gra_Dip)*	Number of serious[2] accidents at work per number of full-time equivalent employees.	INAIL	Ratio*100
Days of absence *(Gg_Dip)*	Number of days of absence from work per number of full-time equivalent employees.	INAIL	Ratio
Social costs *(Ind_Dip)*	Amount of compensation paid out per number of full-time equivalent employees.	INAIL	Ratio

The independent variables, on the other hand, are classified into three groups. The first group analyses information on the dynamics of the labour market, with reference to irregularly employed and low-paid employees. These are, for different reasons, "fragile" categories of workers, who may therefore be more exposed to accident risks. According to the European Commission (2008), in fact, growing job insecurity is generally accompanied by deteriorating working conditions, reduced possibilities of combining work with other private and social responsibilities, and increasing inadequacy of social security systems to cope with more heterogeneous and uncertain individual work histories. ISTAT

[2] Defined as accidents involving a number of days of absence from work of 30 or more.

defines the employed as nonregular when work positions are carried out without compliance with the applicable tax-contribution regulations. This leads the statistical units to not be directly observable at firms, institutions, and administrative sources, so the data presented here are the result of an estimation process and are considered in relation to the total number of employed persons. Low paid employees are, on the other hand, defined in percentage terms as the ratio of employees with an hourly wage of less than 2/3 of the median wage to total employees.

The second group of independent variables illustrates aspects related to the organisation of production processes and the business cycle, focusing on the number of large firms present in the area and the unemployment rate. As widely highlighted in the literature (Antonsson, 2002; Fabiano et al., 2004; Nordlöf et al., 2017; Micheli et al., 2018), in fact, a greater presence of large firms is expected to represent a factor that decreases the occurrence of the accident phenomenon, as well as a higher unemployment rate (Lilley et al., 2002; Dembe et al., 2005; Folkard & Lombardi 2006; Lindroos et al., 2008). Given the regional dimension of the analysis, firms are defined as "large" when they employ a workforce equal to the equivalent of 100 full-time employees, and the value is expressed as a share per thousand firms. Although this value deviates from the standard definitions of statistical offices, this definition was chosen as an adaptation to a regional context that, especially in smaller regions, is characterised by SMEs. Unemployment, on the other hand, is expressed as the number of active persons not in employment (aged 15 years and over).

Finally, the third group of variables included in the analysis represents some relevant characteristics of the economic system. With reference to regional contexts, following the skill-effect hypothesis, according to which workers with more education are at lower risk of physical environment-related injuries (Haslam et al., 2005; Khanzode et al., 2011; Parent-Thirion et al. 2012; Walters and Wadsworth, 2016; Lenaerts et al., 2020), the relevance to the spread of secondary education was considered, measured by reference to the number of individuals aged 15-64 who have completed at least upper secondary school (qualification no less than Isced[3]). Finally, in light of the relevance of the quality of institutions, with particular reference to compliance with regulatory provisions (Lindroos et al.,2008; Pedersen et al. 2012; Irastorza et al., 2016; Micheli et al., 2018), the degree of legality and the level of economic well-being in the territory were considered, used as proxies for OSH compliance, measured with reference to the two covariates "voluntary homicides", calculated as the number of voluntary homicides consumed per 10,000 inhabitants, and GDP per capita, expressed as gross domestic product at market prices per resident (chain-linked values with reference year 2015). Table 2 presents an overview of the independent variables included in the analysis, providing, for each of them, a brief description and illustrating the source of the data and the unit of measurement used.

[3] International Classification of Education

Table 2. Independent variable

Variable	Description	Source	Unit of measurement
Nonregular employed (ONR)	Jobs performed without complying with tax-contribution regulations per total number of employees	Istat	Percentage
Low paid employees (DBP)	Employees with an hourly wage below 2/3 of the median hourly wage out of total employees	Istat	Percentage
Large Firms (Az)	Firms with at least 100 employees (full-time equivalent) on total number of firms	Inail	Percentage
Unemployment (DIS)	Unemployment rate per population aged 15 and over	Istat	Percentage
Secondary Education (DIP)	Persons older than 15 years who have completed at least secondary school	Istat	Thousand
Crime CR	Number of voluntary homicides committed per 10,000 inhabitants.	Istat	Ratio
GDP pro-capita (GDPpc)	Gross Domestic Product at market prices (chain-linked volumes with reference year 2015) per inhabitant	Istat	Euro/10.000

Table 3 presents the main descriptive statistics for the dependent variables. The rate of accidents at work ranges from a minimum of 1.02 to a maximum of approximately 4.50 accidents per hundred employees. On average, the index takes a value of 2.44, and this value is not significantly different from the median value. More specifically, the degree of skewness of the distribution is relatively low, and the kurtosis is very close to that of a normal distribution. Finally, the coefficient of variation is 0.279.

The rate of serious accidents at work varies from a minimum of 4.16 to a maximum of approximately 15.67 serious accidents per thousand employees. On average, the index takes a value of 8.79, and this value is not significantly different from the median value. The degree of skewness of the distribution is relatively low, and the negative sign of the kurtosis indicates a slight platykurtic trend in the

distribution. Finally, the coefficient of variation is 0.277.

Table 3. A brief description of the dependent variables.

	Min.	Median	Mean	Max	asymmetry	kurtosis	CV
Inf_Dip	1.020	2.438	2.437	4.498	0.31	-0.02	0.279
Gra_Dip	4.156	8.924	8.788	15.662	0.12	-0.65	0.277
Gg_Dip	0.4182	0.9386	0.9146	14.645	-0.11	-0.67	0.251
Ind_Dip	18.39	36.53	35.83	53.43	-0.33	-0.58	0.210

Table 4 presents the main descriptive statistics for the independent variables. Regarding the first group of independent variables, the number of nonregular employees varies from a low of 7.40 percent to a high of 32.20 percent of the registered jobs. On average, the index assumes a value of 13.07 percent and a median value of 11.55 percent. Since the median value is lower than the mean value, it is not surprising that the degree of skewness of the distribution is slightly positive. Finally, the kurtosis coefficient indicates a slightly platykurtic distribution, and the coefficient of variation is 0.3129.

The number of employees with low pay varies from a low of 4.70 percent to a high of 22.80 percent of the registered working positions. On average, the index assumes a value of 10.93 percent and a median value of 9.50 percent. Since the median value is lower than the mean value, it is not surprising that the degree of skewness of the distribution is slightly positive. Finally, the kurtosis coefficient indicates a slightly platykurtic distribution, and the coefficient of variation is 0.4256.

Moving on to the second group of independent variables, the unemployment rate ranges from a low of 2.70 percent to a high of 23.40 percent. On average, the index has a value of 10.85 percent and a median value of 9.50 percent. Since the median value is lower than the mean value, it is not surprising that the degree of skewness of the distribution is slightly positive. Finally, the kurtosis coefficient indicates a slightly platykurtic distribution, and the coefficient of variation is 0.4774.

The share of large firms per thousand firms varies from a low of 0.09 percent to a high of 0.64 percent. On average, the index assumes a value of 0.32 percent and a median value of 0.28 percent. Since the median value is lower than the mean value, it is not surprising that the degree of skewness of the distribution is slightly positive. Finally, the kurtosis coefficient indicates a slightly platykurtic distribution, and the coefficient of variation is 0.4039.

The number of individuals with a high school diploma varies from a minimum of 28.8 thousand to a maximum of 2.48 million. On average, each region has 733 thousand individuals with a diploma, while the median region has 427.8 thousand. The distribution of the number of graduates is slightly skewed and leptokurtic, and the coefficient of variation is 0.8526.

The crime index ranges from a minimum of zero to a maximum of 1.65 voluntary homicides per 10,000 inhabitants. On average, the index assumes a value of 0.67 percent and a median value of 0.60 percent. As the median value is lower than the mean value, it is not surprising that the degree of skewness of the distribution is slightly positive. Finally, the kurtosis coefficient indicates a slightly leptokurtic distribution, and the coefficient of variation is 0.5964.

The GDP per capita varies from a low of 16.04 to a high of 45.91. On average, the index has a value of 27.76 and a median value of EUR 28.95 thousand per inhabitant. The distribution has a slight degree of positive skewness, and the kurtosis coefficient indicates a platykurtic distribution. Finally, the coefficient of variation is 0.2810.

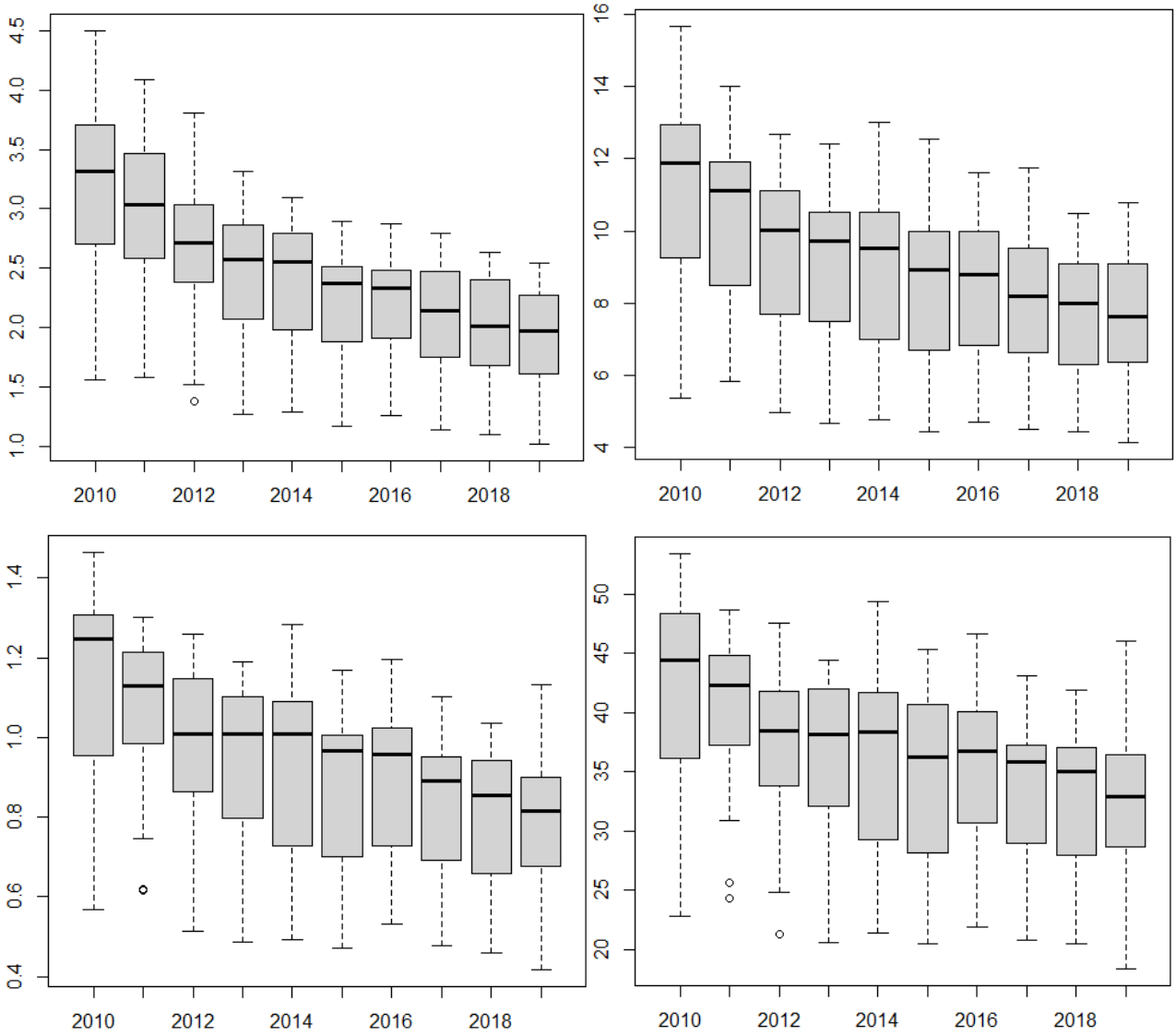
Table 4. A brief description of the independent variables.

	Min.	Median	Mean	Max	skew	kurtosis	CV
ONR	7.40	11.55	13.07	23.20	0.81	-0.36	0.3129
DBP	4.700	9.500	10.927	22.800	0.81	-0.54	0.4256
DIS	2.70	9.50	10.85	23.40	0.80	-0.32	0.4774
Az	0.08696	0.28077	0.32184	0.64383	0.33	-1.05	0.4039
DIP	28.76	427.78	733.00	2487.63	0.96	0.25	0.8526
CR	0.0000	0.6000	0.6707	1.6500	0.64	0.12	0.5964
PIL	16.04	28.95	27.76	45.91	0.20	-1.00	0.2810

Figure 1 illustrates the time trend of the dependent variables. In particular, the decreasing trend of the median values, the frequent closeness of the median values to the values of the third quartile, the relatively greater stability of the minimum values compared to the decreasing trend of the maximum values, and the scarce presence of outliers can be observed.

Figure 1. A temporal representation of dependent variables.

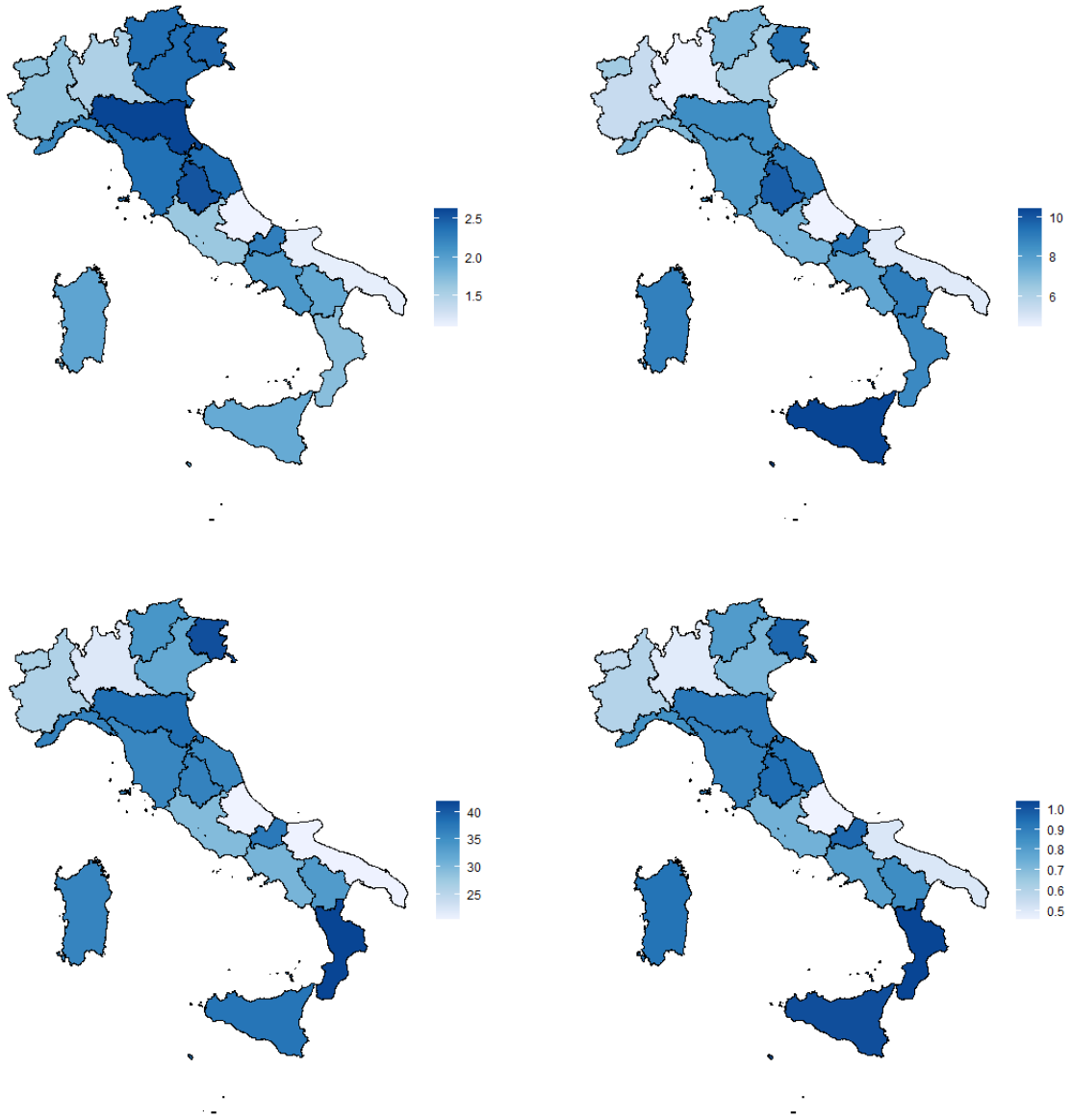
a) Accidents per 100 employee; b) serious accidents per 1000 employee; c) days of absence from work per employee d) compensation for per employee



Finally, Figure 2 shows the spatial distribution of the four dependent variables included in the analysis for 2018. Higher values of the employee injury rate are observed in some central (Umbria, Tuscany and Marche) and northeastern regions (Emilia-Romagna, Veneto, Trentino-Alto Adige and Friuli-Venezia Giulia), while the serious injury rate seems to take on higher values in the Islands (Sicily and Sardinia), in some southern regions (Calabria, Basilicata and Molise) in the Umbria-Marches area, in the Tuscan-Romagna area and in Friuli-Venezia Giulia. On the other hand, the highest incidence of private costs (days of absence) and social costs (compensation paid) of accidents is observed in Calabria and Sicily, in Molise, in the Tuscany-Emilia Romagna and Umbria-Marche areas and in Friuli-Venezia Giulia.

Figure 2. A geographical representation of dependent variables.

a) Accidents per 100 employee; b) serious accidents per 1000 employee; c) compensation for per employee d) days off work per employee



Source: based on INAIL data

4. Methodology and Results

As already pointed out by Castaldo et al. (2022), over the last thirty years, the literature has deepened the relationship between work accidents (or workers' compensation) and the economic cycle, focusing on the significance of the correlation between work accident rates and the main macroeconomic indicators (GDP, fixed investments, unemployment rate). Starting from these premises, to analyse the regional heterogeneity of the occupational injury phenomenon in Italy, the present work adopts the broad perspective of Castaldo et al. (2022) by including in addition to the main indicators of the economic cycle, some indicators referable to the dynamics of the labour market and the institutional characteristics of the socioeconomic contexts characterising the Italian regions. Given the different context (the Italian economy) and the different scale of reference (the observation units are the regions), the indicators taken into account in the empirical analysis are slightly different from those considered in the cited article, but the same perspective of analysis is adopted: to verify the presence of a link between the workplace accidents occurring annually and the productive and social characteristics of the regional systems, controlling for the business cycle indicators and for a series of institutional factors. The present work sets itself the objective, which seems not yet achieved, of producing empirical evidence concerning a series of statistical relationships of interest concerning, in any case, the incidence of accidents at work and their private (company) and social (public) cost.

The OLS regression model with longitudinal data assumes the following specification:

$$Y_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 Z_{it} + \beta_2 U_{it} + T_t + FE_i + \varepsilon_{it}$$

where subscripts *i* and *t* represent the regional scale of the Italian context and the temporal dimension, respectively, with annual observation frequency. As dependent variable *Y*, we initially use the incidence of accidents in the total number of employees (Inf_Dip); then, at a later stage, we extend the analysis to the incidence of serious accidents in the total number of employees (Gra_Dip), to the average number of days of absence from work (Gg_Dip) and to the average amount of compensation per employee (Ind_Dip). *X* is a vector of characteristics of the labour markets of the regions considered (nonregular employment, low paid employees), *Z* is a vector of business cycle controls (unemployment rate, GDP per capita, complexity of business organisation) and *U* is a vector of other territorial variables (human capital stock, presence of crime, economic welfare). Finally, *T* and *FE* are the temporal (annual) and spatial (regional) fixed effects, respectively, ε is the error term that tends to be i.i.d. $(0, \sigma^2)$. To choose between fixed and random effects estimation, the Lagrange multiplier test of Breusch–Pagan (1980) and the Hausman test (1978) are used.

As explained in more detail below, adopting a stepwise estimation strategy that also considers fixed and random effects leads to different estimates of the parameter set associated with the independent variables. This makes it possible to gain a deeper understanding of the factors most correlated with accident incidence. At a later stage, based on the same covariates, the study of the phenomenon is deepened by using the other dependent variables shown in Table 1 to address the

accident phenomenon from other points of view, which in our opinion have not thus far been considered in the literature.

4.1. Results

Moving on to inferential analysis, Table 5 shows the results obtained with the OLS pooling model, which ignores the presence of regional effects and treats all variables as exogenous, and with the fixed-effects (FE) and random-effects (RE) estimators, which control for the presence of unobserved heterogeneity at the regional scale. Initially, the work injury rate is regressed only against the vector of covariates chosen to describe intra-labour market trends (non-regularly employed, low paid employees). Proceeding by subsequent stages, the explanatory variables linked to the business cycle (unemployment rate, firm size) and finally some indicators useful to delineate the regional socioeconomic context (pervasiveness of secondary education, presence of crime, economic well-being) are added.

Table 5. OLS pooling, fixed effects (FE) and random effects (RE) estimates

(Dependent variable: Inf_Dip)

	Pooling1	Pooling2	Pooling3	FE	RE
ONR	-0.166***	-0.096**	-0.110***	-0.145***	-0.138***
	(0.042)	(0.045)	(0.041)	(0.041)	(0.033)
DBP	0.111***	0.110***	0.076***	0.060***	0.075***
	(0.032)	(0.029)	(0.025)	(0.022)	(0.017)
DIS		-0.121***	-0.109***	-0.105***	-0.109***
		(0.030)	(0.029)	(0.017)	(0.013)
Az		-3.037**	-2.374***	-4.779***	-5.528***
		(1.245)	(0.885)	(1.114)	(1.022)
DIP			-0.160	-2.774***	-0.131
			(0.103)	(0.976)	(0.161)
CR			0.065***	0.026***	0.032***
			(0.016)	(0.009)	(0.011)
PIL			-0.009	-0.071**	0.000
			(0.022)	(0.031)	(0.023)

Cons	3.400*** (0316)	4.779*** (0.712)	4.920*** (0.893)	0.102*** (0.012)	6.250*** (0.867)
F-stat	7.565 ***	15.103***	30.117***	60.919***	
Wald *Chi*^{2}					420.85***
Adj.R^2	0.216	0.427	0.510	0.669	0.632
BP1 (Chi^2)			323.4***		
BP2 (Chi^2)			20.06***		
HA (Chi^2)					42.251***
N	21	Obs.	210		

Robust standard error in parentheses: *** p<0.01, ** p<0.05, * p<0.1

In Pooling Models 1, 2 and 3, the coefficients associated with the variables representing labour market conditions are always statistically significant, which leads one to reflect on the weight that power relations between employers and employees have in influencing the dynamics of work accidents. It is, however, a relationship that apparently operates with different signs along the two channels considered, in that it appears that as the number of nonregular employees increases, work accidents decrease, while as the number of low-paid employees increases, consistent with the results highlighted by Lenaerts et al. (2020), work accidents increase. In fact, the negative sign of the coefficient associated with the level of nonregular employees could be due to forms of underreporting, as Boone and Ours (2006) have well pointed out. For the business cycle variables, in Pooling 2 and 3 models, the coefficients associated with firm size and unemployment rate are both negative and statistically significant, with results that are in line with the literature on the topic of the relationship of accident frequency and characteristics of the production system (Frick and Walters, 1998; Dorman 2000; Antonsson, 2002; Champoux and Brun, 2003; Hasle and Limborg, 2006; Nordlöf et al., 2017; Micheli et al., 2018) and the business cycle (Robinson, 1988; Lilley et al., 2002; Dembe et al., 2005; Folkard & Lombardi, 2006; Lindroos et al., 2008). The inverse relationship with the unemployment rate and firm size can be interpreted in terms of a greater effectiveness of company workplace safety policies in contexts where the workforce is more selected and firms are more organised. In any case, the empirical evidence produced suggests that occupational accidents are influenced by the business cycle, particularly by factors related to company organisation (Castaldo et al., 2022).

However, part of the literature (e.g., Ferguson et al., 1985; Rasmussen, 1987; Vredenburgh, 2002; Boone and van Ours, 2006; de la Fuente et al., 2014) observes that the inverse relationship between occupational injuries and unemployment rates may depend on workers' reluctance to report injuries where their bargaining power versus employers is reduced. From a policy perspective, this result may suggest the need for greater worker protection by safety monitors in times of high unemployment to foster behavioural improvement in terms of accident reporting.

Finally, in the Pooling3 specification, the coefficients – associated with both the prevalence of secondary education and the number of voluntary homicides – are statistically significant and have the expected sign (negative in the former, positive in the latter); the coefficient associated with the economic well-being of individuals is not statistically significant. Thus, the initial hypothesis of the influence of institutional factors on the incidence of work-related injuries would seem to be supported, at least in part, by the empirical evidence.

In the fixed effects (FE) and random effects (RE) models, the quality of the estimates seems to improve significantly, both with reference to the significance of the coefficients and with reference to the goodness of fit to the model data. Specifically, in the fixed-effects model, all coefficients are significant and with an expected sign, while in the random-effects model, although the estimates generally confirm the results of the fixed-effects model, two coefficients are not significantly different from zero (diffusion of secondary education and level of wealth per capita).

Overall, the coefficients associated with all the explanatory variables considered are significant in all three estimated models, except for the diffusion of secondary education and the level of wealth per capita (which are not significant in both the pooling3 and RE models).

Table 5 also shows the values of the F and Chi2 statistics and the Breusch–Pagan and Hausman tests to which the pooling and fixed effects models and the random effects models are subjected, respectively. What emerges is that both Breusch–Pagan tests exhibit high significance in favour of the presence of individual effects, and the Hausman test indicates the fixed-effects model as the preferred one.

Table 6 shows the estimated coefficients of the Pooling OLS regression model ('Pooling3') for the dependent variables Gra_Dip, Gg_Dip and Ind_Dip. The fit of the model to the data is comparable with that of the Pooling3 model for Inf_Dip. In particular, a number of empirical findings emerge.

First, the labour market variables, i.e., those defining the presence of nonregular employment positions and low-pay employees, confirm a negative and positive correlation, respectively, with the employee variable in each of its different definitions, excluding that for compensation. This, to some extent, confirms what emerges from the regressions on Inf_Dip, namely, that since low-pay employees in the Italian regional context can be identified with low-skill workers and/or workers with a low degree of unionisation, the variable is positively associated with the accident phenomenon. However, the statistical insignificance of the parameters estimated for these specifications must be stressed.

In this context, it is also observed how the higher presence of unemployment shows a negative correlation with occupational accidents, which is in line with the underreporting hypotheses also highlighted in the literature (Boone and Van Ours, 2006). It is then observed that company size, GDP per capita and education level show an inverse correlation with the accident phenomenon, presumably reflecting a greater propensity to invest in safety as economic resources increase and a better physical working environment when there is an environment characterised by higher levels of education. In this framework, nonsignificant relationships are reported when the dependent variable is defined in terms of compensation, a sign that the dynamics between this variable and those defining the accident phenomenonare not perfectly coincident.

Finally, it is observed that the presence of crime is correlated with lower compliance with workplace

safety regulations and therefore positively and significantly correlated with the dependent variables.

Therefore, while the regularity of work positions generally seems to have a role in providing information on the private and social costs of the accident phenomenon, the business cycle conditions seem to provide information on the size of the accident phenomenon (in this case, days would be a proxy for the intensity of the accident phenomenon, rather than a measure of its private cost), while the context variables are those most correlated with both the size of the accident phenomenon and its private and social costs.

Table 6 also shows the values of the Chi^2 statistics of the Breusch–Pagan tests. What emerges is that both tests exhibit high significance in favour of the presence of individual and, in two out of three cases, temporal effects.

Table 6. OLS pooling estimates

(Dependent variables: Gra_Dip, Gg_Dip, Ind_Dip)

	Gra_Dip	Gg_Dip	Ind_Dip
ONR	-0.163	-0.028**	-1.066**
	(0.150)	(0.014)	(0.463)
DBP	0.027	0.007	-0.052
	(0.074)	(0.007)	(0.237)
DIS	-0.230***	-0.022***	-0.407
	(0.083)	(0.008)	(0.255)
Az	-8.151**	-0.703**	-19.716
	(3.637)	(0.348)	(14.622)
DIP	-1.104***	-0.010***	-3.924***
	(0.357)	(0.032)	(1.168)
CR	0.234***	0.024***	0.870***
	(0.074)	(0.007)	(0.237)
PIL	-0.136**	-0.014***	-0.332*
	(0.055)	(0.004)	(0.191)
Cons	18.761***	1.964***	67.351***
	(2.814)	(0.241)	(8.650)

F-stat	21.955***	34.110***	19.345***
Adj.R^2	0.551	0.53	0.462
BP1(Chi^2)	409.45***	373.14***	407.79***
BP2(Chi^2)	3.970**	5.473**	0.309
N	21	Obs.	210

Robust standard error in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Given a certain heterogeneity of the accident phenomenon[4], consistent with what was done in the previous estimates, the fixed-effects and random-effects models were also estimated in this case. In the first case, the fit of the model to the data is good but lower than that of the FE model for Inf_Dip. The results of the estimates, shown in Table 7, net of any nonsignificance, confirm the relationships between the covariates and the different dependent variables considered already observed in the pooling regressions. Again, the most notable exceptions concern the regression on Ind_Dip, which reports nonsignificant estimates for nonregular employment, low-pay employees, and GDP per capita.

Therefore, it emerges that by introducing fixed effects, the intra-labour market dynamics seem to generally have a role in providing information on the private costs and size of the accident phenomenon, and the business cycle conditions (unemployment and production structure in terms of firm size) seem to provide information on both the size and costs of the accident phenomenon. Among the other economic and contextual variables, while the level of GDP per capita loses its significance in explaining the private and social costs of the accident phenomenon, crime has a significant effect on the phenomenon and, therefore, seems to confirm the inverse relationship between compliance with occupational safety regulations and illegality.

Table 7. Fixed effects estimates

(Dependent variables: Gra_Dip, Gg_Dip, Ind_Dip)

	Gra_Dip	Gg_Dip	Ind_Dip
ONR	-0.403***	-0.030*	-0.596
	(0.142)	(0.016)	(0.559)
DBP	0.122*	0.013*	0.258
	(0.065)	(0.007)	(0.221)

[4] This observation suggests the presence of individual effects, a hypothesis also confirmed by the results of the Hausman test - which suggests the adoption of a fixed effects approach.

DIS	-0.251***	-0.021***	-0.465**
	(0.053)	(0.006)	(0.195)
Az	-10.355***	-1.558***	-56.674***
	(3.863)	(0.411)	(13.617)
DIP	-8.401***	-0.814**	-21.906**
	(2.994)	(0.341)	(11.070)
CR	0.068**	0.009***	0.322***
	(0.031)	(0.003)	(0.109)
PIL	-0.233**	0.000	0.676
	(0.098)	(0.012)	(0.498)
Cons	0.031***	2.434***	59.211***
	(0.04)	(0.472)	(19.981)
F-stat	38.868***	31.391***	34.273***
Adj.R^2	0.556	0.573	0.502
n	21	Obs.	210

Robust standard error in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Table 8 shows the estimated coefficients of the random-effects (RE) model for the dependent variables Gra_Dip, Gg_Dip and Ind_Dip. The fit of the model to the data is good but still inferior to that of the pooling regression model with RE for Inf_Dip. In particular, various empirical findings emerge.

Considering the level of serious accidents on employees, as in the fixed-effects model, all the estimated coefficients are significant and with an expected sign (respectively: negative and positive for nonregular employment and low-pay employees; negative for business cycle variables; negative for the level of diffusion of secondary education and for the level of GDP per capita; positive for nonvoluntary homicides).

A different result occurs with reference to the number of days of absence from work. The coefficient associated with the level of employees with low pay is not statistically significant, while the coefficient associated with the level of wealth per capita is significant and with an expected sign (respectively: negative for nonregular employees; negative for business cycle variables; negative for

the level of diffusion of secondary education and positive for nonvoluntary homicides).

Finally, in the model that considers the average level of compensation as the dependent variable, the coefficient on the variables illustrating labour market dynamics and the coefficient on the level of wealth per capita are not significant. The other estimated coefficients are significant and have an expected sign (negative for the business cycle variables, negative for the level of diffusion of secondary education and positive for the variable representing the presence of crime).

Ultimately, the results obtained with this approach also seem, at least for the most part, to be in line with the general considerations made thus far. Finally, Table 8 shows the values of the *Chi²* statistics for the Hausman test, which indicates the fixed-effects model as the preferred one.

Table 8. RE estimates

(Dependent variables: Gra_Dip, Gg_Dip, Ind_Dip)

	Gra_Dip	Gg_Dip	Ind_Dip
ONR	-0.319***	-0.028**	-0.028**
	(0.118)	(0.014)	(0.012)
DBP	0.167***	0.007	0.016***
	(0.053)	(0.007)	(0.005)
DIS	-0.284***	-0.022***	-0.026***
	(0.043)	(0.008)	(0.005)
Az	-13.612***	-0.703**	-1.744***
	(3.263)	(0.348)	(0.315)
DIP	-1.170**	-0.010***	-0.099*
	(0.589)	(0.032)	(0.052)
CR	0.087**	0.024***	0.011**
	(0.039)	(0.007)	(0.004)
PIL	-0.137*	-0.014***	0.001
	(0.081)	(0.004)	(0.008)
Cons	22.662***	1.964***	1.918***
	(3.131)	(0.241)	(0.321)
Wald *Chi²*	257.674***	34.110***	222.32***

Adj.R^2	0.553	0.530	0.57
HA (Chi^2)	56.467***	35.432***	28.891***
N	21	Obs.	210

Robust standard error in parentheses: *** p<0.01, ** p<0.05, * p<0.1

5. Conclusions

This work proposes an empirical analysis workplace accidents at the Italian regional level using INAIL and ISTAT data for the period 2010-2019. The aim is to elaborate an initial econometric study that could shed light on the main correlations between the socioeconomic variables and the regional context and the accident phenomenon to consider the territorial specificities and thus broaden the information framework needed for policy interventions. From this perspective, different estimation models (OLS pooling model, fixed-effects, and random-effects models) were implemented to better account for the peculiar regional contexts by considering different dimensions of the accident phenomenon as dependent variables. In addition to the accident rate, calculated both as the ratio of total accidents to employees and as the ratio of the subset of serious accidents to employees to consider the degree of severity of the phenomenon, the average number of days of absence per employee and the average amount of compensation paid per employee were also considered. In particular, the latter two variables can better capture the economic dimension of the injury phenomenon at the company level (as a proxy for private cost) and at the social level (as a proxy for social cost in terms of public expenditure).

Following the international literature (Laflamme, 1990; Fabiano et al., 2004; Cornelissen et al., 2017), dependent variables were identified in variables related to the local labour market (in particular, the presence of nonregular employment positions and low-paying employees), the regional production system (specifically, the size aspect of firms) and the socioeconomic context (unemployment, GDP per capita and level of education) and institutional context such as the presence of crime, which, as also highlighted by other works (Castaldo et al., 2022), is associated with a lower compliance with workplace safety regulations.

The results generally confirm some empirical evidence also found in international analyses. Specifically, even at the Italian regional level, firm size, GDP per capita and level of education are inversely correlated with workplace accidents, presumably reflecting a greater propensity to invest in safety as economic resources increase (larger firms and higher GDP per capita) and a better physical working environment with reference to higher levels of education. The opposite emerges for low-pay employees who, in the Italian regional context, can be identified with low-skill workers and/or workers with a low degree of unionisation. On the other hand, unemployment and nonregularity of job positions present a negative correlation with workplace accidents in line with the underreporting hypotheses also highlighted by other works (Boone and Van Ours, 2006).

However, even though the work was conducted following the standard approach suggested by the literature, some changes were necessary to adapt the analysis to the specific Italian regional context.

This has led, on the one hand, to the emergence of future research perspectives for the necessary deepening of certain aspects and, on the other hand, to possible policy recommendations.

In the first case, for example, preliminary descriptive analyses have shown that the 'sectoral riskiness' of the accident phenomenon presents a certain heterogeneity among the Italian regions due to a nonhomogeneous distribution of economic activities across the country. Therefore, even at a national aggregate level, and even in Italy, the highest accident risk can be associated with sectors traditionally defined as 'high risk' in the literature (Lenaerts et al., 2020; Leigh et al., 1989; Maiti and Bhattacherjee, 1999; Maiti et al., 2001, Maiti et al., 2004. Haslam et al., 2005, Khanzode et al., 2011): construction, transport, agriculture, and industry; at the Italian regional level, there is some variability in the identification of sectors with a higher number of accidents.

Even the variable relating to fixed investments, which in many studies (Hartwig et al., 1997; Brooker et al., 1997; Ussif, 2004; Boone and van Ours, 2006; Davies et al., 2009; Asfaw et al., 2011) appears to have a negative correlation with the accident rate, was not included at this stage because preliminary descriptive analyses reveal results that are not unambiguously in line with the literature. This suggested, on the one hand, the need for an in-depth analysis that could constitute an extension of the research and, on the other hand, the need to provide a possible interpretation of this evidence.

In this second perspective, a question was raised on the role of binding budget constraints to which Italian firms are subject (Istat. 2020). In this framework, an entrepreneurial policy of increasing investments could result in a sort of trade-off between alternative uses of resources: investments more oriented towards productivity and/or the modification of the physical working environment vs. investments more oriented towards safety to the detriment of the latter.

Moreover, a sort of complementarity has been highlighted (Pedersen et al., 2012) between investments aimed at modifying the physical environment and corporate policy interventions relating to work organisation, training, and the promotion of a safety culture (Micheli et al., 2018) with a consequent multidimensional nature of OSH policy that would therefore require a broader, more specialised, and economically more robust commitment on the part of firms. In this interpretative perspective, then, a policy to incentivise security investments for Italian firms, which presents characteristics of temporal stability, may be functional to a relaxation of the trade-off between alternative uses of resources and to a perception by Italian firms of less stringent budget constraints.

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