Analysis of the relationship between the adoption of the OHSAS 18001 and business performance in different organizational contexts

Esteban Lafuente[1]
Department of Management, Universitat Politècnica de Catalunya (Barcelona Tech)
EPSEB, Av. Gregorio Marañón, 44-50, 3era planta. 08028. Barcelona. Spain
Email: esteban.lafuente@upc.edu

Jesús Abad
Department of Management, Universitat Politècnica de Catalunya (Barcelona Tech)
EPSEB, Av. Gregorio Marañón, 44-50, 3era planta. 08028. Barcelona. Spain
Email: jesus.abad@upc.edu

Abstract
This paper investigates how the characteristics of operational processes—systematic and project-based—affect the impact of adopting the safety management systems on different performance metrics. The proposed approach allows the development of a framework which matches safety problems and risks encompassed by organizational tasks with solutions generated by new safety knowledge linked to the adoption of the OHSAS 18001 standard. Our analysis of the effect over work accidents, as well as operational and economic performance of implementing the OHSAS 18001 in Spanish manufacturing, construction and professional services organizations during 2006–2009 shows that organizations modify existing safety practices to mitigate work accidents, and that safety learning effects widely vary across industry sectors. Organizations whose current knowledge is mostly codified and processes are highly systematic benefit more from safety knowledge and experience, whereas the effects of the OHSAS 18001 dilute in organizations whose knowledge is high in tacitness, and whose processes difficult the visibility of the consequences of work accidents. This study has important implications for managing knowledge acquisition processes. The findings offer valuable insights on how managers can develop communication and coordination actions to cope with the potential incompatibilities between safety management systems, the properties of knowledge and work environmental conditions.

Keywords: Work safety; OHSAS 18001; accumulated safety experience, accident reduction; operational performance, economic performance.

Paper published in Safety Science, please cite as:

Lafuente, E., Abad, J. (2018). Analysis of the relationship between the adoption of the OHSAS 18001 and business performance in different organizational contexts. *Safety Science*, 103, 12-22.

[1] Corresponding author.

Analysis of the relationship between the adoption of the OHSAS 18001 and organizational performance in different organizational contexts

"*Questions will be asked about whether more safety measures could have been applied to a route that only opened up, in its current high-speed form, 18 months ago. The answer to such questions is, inevitably, always yes. Accidents are usually the result of several failures. The more safety systems there are in place, the less likely it is that all can fail.*"
—The Economist: Train tragedy (July 27 2013).[2]

1. Introduction

Managing risks at work is a key concern in today's working environment. Scholars and practitioners have witnessed a striking change in the role of safety management, which has evolved from a narrow view linked to a costly administrative burden to an operating priority with significant economic and social impact (Abad et al., 2013; Das et al., 2008). According to the European Agency for Safety and Health at Work (EU-OSHA, 2013), the economic costs and operational losses of work accidents to workers, businesses, and public administrations represent 3% of the EU's gross domestic product. The growing awareness of the importance of safety management has led European governing bodies to adopt specific policies within the EU 2020 strategic plan aimed at stimulating safe work conditions (European Commission, 2007).

Existing research on safety management supports the notion that businesses adopting safety systems experience performance improvements (Abad et al., 2013; de Koster et al., 2011; Lo et al., 2014). The analysis of how enhanced safety management systems improve various dimensions of performance is the focus of this study.

In this context, the OHSAS 18001 certification is becoming the dominant international safety system adopted by organizations to engage in processes to promote continuous improvements of work safety conditions (Fernández-Muñiz et al., 2012; Lo et al., 2014). Moreover, the OHSAS 18001 is the basis for the new ISO 45001 standard on work safety that will likely be available in 2017, which makes the strategic importance of the OHSAS 18001 more evident. The increased relevance of safety

[2] http://www.economist.com/blogs/charlemagne/2013/07/spains-rail-crash

management for managers and policy makers had led to a growing body of work on the role of safety systems on performance; however, literature is relatively silent on how the OHSAS 18001 impacts performance metrics unrelated to work safety (Abad et al., 2013; Lo et al., 2014). The OHSAS 18001 is a source of knowledge but the characteristics of the safety system themselves, of the environment in which the system is used, and of the operational tasks which condition both the visibility of the consequences of accidents can each affect its influence.

In consonance with these arguments, this paper examines the conditions under which the acquisition of safety knowledge and accumulated safety experience impact various performance dimensions. Specifically, we evaluate the effect of adopting the OHSAS 18001 and cumulative safety experience on safety, operational and economic performance; while accounting for differences in the organizational context that can affect the effects of safety systems.

The empirical application considers a unique dataset of 149 Spanish manufacturing, construction and professional services firms during 2006-2009. The sample includes businesses that adopted the OHSAS 18001 in different years and a group of noncertified firms. This setting provides an opportunity to assess how safety knowledge and safety experience enhance different performance metrics in contexts where work environmental conditions and the causes and consequences of work accidents are complex and heterogeneous.

This study contributes to the literature on safety at work in two main ways. First, the proposed analysis of the effect of the operational context in moderating the relationship between the OHSAS 18001 and various performance metrics extends the literature on work safety. Second, by examining the effects of safety systems and accumulated OHSAS experience in different organizational contexts managers will be better equipped to identify those actions that can contribute to exploit the knowledge and experience that result from the adoption of safety systems.

The remainder of the paper is organized as follows. Section 2 presents the theory that underpins this study and the proposed hypotheses. In section 3 the sample, variables and methods are presented. Empirical results are found in section 4, while the final section provides the discussion and concluding remarks.

2. Background literature and hypotheses development

The OHSAS 18001 standard is available in the marketplace since 1999. This framework was developed by several standardization and certification bodies in 'response to urgent customer demand for a recognizable occupational health and safety management system standard against which their management systems can be assessed and verified' (BSI, 2007). The fundamental objective of the OHSAS 18001 standard is to support and promote good practices in the area of occupational health and safety via systematic and structured management systems (Chang and Liang, 2009). Also, prior studies suggest that safety practices linked to the OHSAS 18001 improve both competences at existing operational procedures and the functioning of the business (Abad et al., 2013; Lo et al., 2014). As a result, adopting organizations could be in a solid position to minimize risks to its employees, and subsequently to reduce work accidents (Fernández-Muñiz et al., 2012). From a safety management perspective, the OHSAS 18001 entails the introduction of value-adding codified knowledge. This new knowledge is a source of continuous improvement that helps to mitigate work accidents by applying systematic safety controls and improving the previous safety practices (Robson et al., 2007).

We therefore propose a learning cycle (Figure 1) which first focuses on the factors that encourage the implementation of the OHSAS 18001 (Stage 1). Next, we turn our attention to the short-term effects on organizational performance resulting from the adoption of the new safety-specific knowledge (OHSAS 18001), as well as the long-term effects derived from the accumulated OHSAS experience over time (Stage 2).

----- Insert Figure 1 about here -----

Concerning the first stage of the proposed framework, previous studies widely support that internal motivations related to improving safety practices are the most influential variables explaining the adoption of the OHSAS 18001 (Robson et al., 2007). Thus, the adoption of the OHSAS 18001 can be understood as a reaction to poor safety performance (Abad et al., 2013; Bevilacqua et al., 2016; Lo et al., 2014).

Organizations with weaker safety practices will show poor safety outcomes—in our case observable through the work accidents rate and the proportion of injuries and fatal accidents—and this is detrimental to business routines and operations. In this scenario, evidence of ineffective safety practices gives managers incentives to adopt safety tools such as the OHSAS 18001 standard. Therefore, the enhancement of safety practices through organizational change represents the baseline of the process presented in Figure 1. This logic and evidence suggest the following relationship between safety outcomes and the adoption of OHS management systems (Stage 1):

H1: *A negative relationship exists between work safety outcomes and the adoption of the OHSAS 18001 standard.*

With this hypothesis as the starting point of the proposed model, we now focus on the effects of new safety-specific knowledge and OHSAS experience on performance (Stage 2 in Figure 1).

The full implementation of the OHSAS 18001 entails the development of new tasks which are performed by members of all organizational levels. These encoded tasks serve as knowledge repositories, and the short-term impact of the OHSAS 18001 relies on the managers' capacity to transmit the value of the safety tool to organizational members. Nevertheless, organizations do not realize the positive effects of the OHSAS 18001 at the same intensity, and we argue that the characteristics of the business' operational process play a role.

Existing studies on the relationship between safety systems and safety performance mostly focus on perceptual outcomes linked to safety climate and behavior (Fernández-Muñiz et al., 2012; Robson et al., 2007), while few studies address this issue using objective safety measures, such as work accidents rates (Abad et al., 2013) and safety violations (Lo et al., 2014). But, does the knowledge acquired through the OHSAS 18001 impact other performance dimensions? Moreover, does the OHSAS 18001 have a homogenous impact on performance across organizations?

From an organizational point of view, we expect that the OHSAS 18001 impacts various performance dimensions. First, the prioritization of safety practices creates a safer working environment, which fulfils the workers' safety needs and allows them to pursue operational goals (Das et al., 2008; Ghahramani, 2016). Second, the OHSAS 18001 can contribute to decrease operational costs through the timely documentation of safety risks and the implementation of corrective actions whenever a safety incident occurs. Thus, increased safety controls might reduce operational losses linked to poor safety conditions, such as unpredicted production breaks, absenteeism and labor turnover, and this will likely impact economic performance (de Koster et al., 2011; Lo et al., 2014).

Concerning the characteristics of business operations, manufacturing organizations seem more compatible with the systematic and codified nature of the OHSAS 18001 than organizations in other industries. Manufacturing businesses enjoy a deeper systematization of operational tasks, well defined communication channels, and greater coordination and control mechanisms at all operational levels.

On contrary, the benefits of safety systems will likely be weaker in organizations with less systematic operational conditions. For instance, construction businesses are characterized by an organizational structure where multiple subcontractors with competing goals interact, and by changing work environments due to variations in project designs (Choudhry, 2014). This implies the development of project-specific safety plans, which limits the intensive use of safety knowledge (Caponecchia and Sheils, 2011; Kines et al., 2010). In the case of professional services organizations, knowledge is a critical input and the strong interaction with customers often guides the production process (Garicano and Wu, 2012). In this case, a mismatch might exist between the properties of the safety knowledge and internal operations, and organizations face communication challenges that, if not taken care of, might mitigate the potentially positive effects of the safety tool.

Taken together, these arguments and evidence suggest that the OHSAS 18001 creates reliable knowledge and thrives on operational refinement and performance by enhancing the execution of existing routines. Therefore, we hypothesize:

H2a: *A positive relationship exists between the implementation of the OHSAS 18001 standard and safety, operational, and economic performance.*

H2b: *The positive relationship between the implementation of the OHSAS 18001 standard and safety, operational, and economic performance is stronger in organizations whose operational tasks are highly systematic.*

We now turn our attention to the relationship between accumulated OHSAS experience and performance. Organizations adopt or develop managerial practices—including safety management systems—seeking to reduce inefficiencies through continuous enhancement of internal practices (Abad et al., 2013; Ghahramani, 2016). The effective implementation of the OHSAS 18001 does not result solely from managerial decision-making processes. The performance effects of safety systems may well be visible over time and employees' involvement is critical to effectively disseminate the new safety knowledge (Podgórski, 2005). The OHSAS 18001 creates codified knowledge in the form of written procedures, and the systematic repetition of safety tasks creates valuable experience. For example, prior studies on work safety show that specific training coupled with information contribute to increase the employees' alertness on the negative effects of occupational risks, thus increasing the effectiveness in the implementation of safety systems (Arezes and Miguel, 2008; Burke et al., 2011). This way, experience generated through task repetition improves safety knowledge among workers.

From an organizational perspective, the depth of new knowledge is heterogeneous across organizations, and the characteristics of the environment in which safety knowledge is used influence the effects of this knowledge on performance (Abad et al., 2013). In the context of this study, workers of manufacturing businesses develop their tasks in a work environment dominated by methodical processes and accurate information systems. Therefore, the knowledge embedded in the OHSAS 18001 standard can be used many times and by different workers, which contributes to exploit safety knowledge in the long-run via the systematic repetition of safety tasks by employees.

On contrary, project-based organizations—e.g., in construction and professional service sectors—make an intensive use of tacit knowledge that requires experience to exploit, and have specific work patterns that might create an incompatibility between safety systems and internal practices. As we mentioned above, the work environment of construction sites is dominated by an informal culture in which knowledge is mostly tacit. Also, subcontractors in this sector tend to prioritize operational goals over safety goals (Caponecchia and Sheils, 2011), and construction workers mostly acquire knowledge from on-site training programs, and from practical experience guided by experienced co-workers (Kines et al., 2010). Although the high visibility of the consequences of work accidents in this sector, high knowledge tacitness jointly with the difficulties of modifying workers' behavior might mitigate the effects of safety learning in the long-run (Zohar and Luria, 2003).

In the case of professional services businesses, knowledge-based tasks heavily rely on the allocation of talent, which likely causes low rates of both work accidents and severe injuries in these organizations. Also, the limited visibility of the consequences of work accidents in this type of business reduces the valuation of the merits of safety knowledge and practices. The difficulties in recognizing the value of safety knowledge might discourage employees to fully incorporate safety tasks in their day-to-day operations. In this case, the characteristics of the operational processes might restrain the long-term effects of the OHSAS 18001 on performance.

Following these arguments, accumulated OHSAS experience linked to task performance repetition will translate into superior subsequent performance if the future behavior of employees is modified as a result of the changes associated to the adoption of the OHSAS 18001. Performance improvements follow task performance experience and this is evidence of a successful safety process (Stage 2 in Figure 1). We thus hypothesize:

H3a: *A positive relationship exists between accumulated OHSAS experience and safety, operational, and economic performance.*

H3b: *The positive relationship between accumulated OHSAS experience and safety, operational, and economic performance is stronger in organizations whose knowledge and processes are highly codified and increase the demonstrability of the merits of safety knowledge.*

The theoretical deductions coming from the literature leads us to conclude that the OHSAS 18001 is a valid managerial tool for improving safety conditions at the workplace and performance. Additionally, operational differences potentially create variations in the full implementation of the OHSAS 18001 across organizations and industries, and this might condition the proposed positive relationship between the OHSAS 18001 and performance.

In sum, the adoption of the OHSAS 18001 in heterogeneous organizations has important implications, and this research seeks to contribute a deeper understanding of the conditions under which the effects of adopting safety systems occur in organizations operating in manufacturing, construction and professional services industry sectors.

3. Sample, variables and methods

3.1 Sample

The data used in this research was collected specifically for the purpose of this study and come from three sources. First, information on the adoption of the OHSAS 18001—identification of adopting firms and the exact certification date—for the sample businesses was obtained by creating a collaboration project with the Spanish Association for Standardization and Certification (AENOR). AENOR is the leader agency in the certification of management systems on safety at work based on OHSAS 18001 in Spain. Second, in coordination with one of the largest Spanish occupational injuries insurance companies—FREMAP—we accessed information about relevant variables related to occupational health and safety (number of work accidents, work accident rates, and severity of work accidents). Following the Spain's Occupational Risks Prevention Act of 1995, FREMAP is one of the many occupational injuries insurance companies accredited by the Spanish government.

The two databases obtained from AENOR and FREMAP were merged on the basis of the business' unique identification code. This process led us to access detailed information about the OHSAS 18001 certification date and data about key measures related to work safety for 152 businesses during 2006-2009. Note that reliable and complete data about work accidents is not available for three businesses, thus they were dropped from the final sample. Therefore, data availability limits the final sample to 149 businesses.

Third, and based on the unique identification code, accounting and organizational data were obtained for the period 2005-2009 from the Spanish database SABI (Sistema de Análisis de Balances Ibéricos). This database, provided by the Bureau Van Dijk©, contains detailed balance and income statement information, as well as qualitative data for Spanish businesses. By looking at the size distribution of the sample, we observe that 31.54% of businesses are small (less than 50 employees), 41.11% of businesses fall into the medium-sized category (between 51 and 250 employees), and large firms represent 27.35% of the sample. Also, 43% of the sampled businesses operate in manufacturing sectors, while 31.54% and 25.50% of businesses operate in construction and professional service sectors, respectively.

3.2 Variable definition

Dependent variables. We examine three dimensions of organizational performance. First, safety performance is measured through the rate of work accidents which is calculated, for each firm (*i*), as the number of accidents at work divided by the number of employees. Work safety conditions are what the OHSAS 18001 seeks to enhance, and this variable directly captures safety outcomes by accurately measuring safety at work (Abad et al., 2013). Second, operational performance is measured via two variables: labor productivity, measured by the ratio of sales relative to the number of employees; and the operating productivity ratio calculated as the cost of goods sold divided by sales. The cost of goods sold include production costs exclusively associated with the organization’s core activity, and do not include general and administrative expenses. We do not employ a broader cost measure including the two accounting terms (cost of goods sold and administrative expenses) because they are linked to economic performance through the operating profit. Third, economic performance is defined through return on assets (ROA), measured as the ratio of operating profit (before depreciation) divided by total assets. In all regression models, the four performance variables are expressed as their annual variation between period *t*-1 and *t*. Table 1 presents the descriptive statistics for the variables used in this study.

----- Insert Table 1 about here -----

Safety knowledge and experience. Organizations adopting the OHSAS 18001 should establish a variety of safety controls to minimize risks to its employees (Bevilacqua et al., 2016; Lo et al., 2014). The implementation of the safety system entails the development of different tasks which are performed by members of all organizational levels. Thus, to identify the adoption of the OHSAS 18001 (revision 2007) we use a dummy variable that takes the value of one for adopting organizations, and zero otherwise. Additionally, our detailed data include the exact OHSAS 18001 adoption date, which allows at distinguishing adopting businesses where the safety system might impact future performance from those where its effects on performance are potentially spurious due to time considerations. To enhance estimation accuracy, we consider that the adoption of the OHSAS 18001 corresponds to a specific period (*t*) if certification took place between the second half of year *t-1* (from July to December) and the first semester of period *t* (from January to June). This way, we can clearly examine the extent to which the OHSAS 18001 impacts subsequent performance changes.

Concerning OHSAS experience, we argue that safety tasks are systematically executed by employees according to the system's specifications, and this temporal experience will likely translate into a more efficient execution of operational tasks. Thus, we measure OHSAS experience as the cumulative number of full years since the adoption of the OHSAS standard. Among adopting organizations (117 businesses) average OHSAS experience is 2.13 years. However, businesses adopted the OHSAS 18001 at a different pace: four businesses adopted the OHSAS 18001 in 2004, five in 2005, 19 in 2006, 30 to 2007, and 59 in 2008. Also, seven businesses adopted the safety system in 2009, which implies that these (adopting) organizations do not have OHSAS experience according to the approach adopted in this study.[3] Therefore, the final sample includes a control group of 32 non-certified organizations. To further validity of our analysis, we verified the industry configuration of the group of control group (non-OHSAS businesses). Note that, though business in professional service sectors report a lower OHSAS adoption rate (68.42%) than firms operating in manufacturing (82.22%) and construction sectors (81.25%), the industry configuration of the group of non-certified businesses (construction sector: 37.50%, professional service sectors: 34.37%, and manufacturing sectors: 28.13%) reinforces the validity of the proposed analysis.

Rate of injuries and fatal accidents. Organizations adopting the OHSAS 18001 mostly seek to improve safety outcomes since a weaker safety system may negatively affect future performance (Lo et al., 2014; Robson et al., 2007). Thus, in addition to the rate of work accidents the model explaining

[3] We also estimated an alternative safety experience measure based on quarterly periods. Here, an organisation is said to have adopted the OHSAS 18001 in a given year (*t*) if certification took place between the last quarter of year *t-1* (from October to December) and the first three quarters of period *t* (from January to September). Under this criterion two businesses switched to the safety experience category (1 year of experience), and empirical results (available on request) remain unchanged.

the adoption of the OHSAS 18001 includes the rate of injuries and fatal accidents measured as the ratio of injuries and fatal accidents divided by the number of work accidents.

Type of production process. The effective implementation of knowledge is associated with its perceived benefits, which are reliant on the characteristics of operational tasks. Prior studies on work safety have mostly documented the impact of the OHSAS 18001 in manufacturing sectors with highly systematic operations (Fernández-Muñiz et al., 2012; Lo et al., 2014). Nevertheless, we argue that the distinctive characteristics of project-based organizations—high human capital intensity and high product variability with frequent customer interaction—might condition the impact of the OHSAS 18001 on performance. To distinguish the potential effect of the OHSAS 18001 in different operational contexts, we introduced a dummy variable taking the value of one for organizations with systematic operational tasks (manufacturing), and zero for businesses with project-based operations.

Control variables. We control for size, age, and time in the different model specifications. Business size is measured by the number of employees, while business age is expressed in years. Note that in the regression models both business size and age were logged to reduce skewness. Finally, we included a set of time dummy variables to rule out the potential effect of time trends.

3.3 Methods

Following our theoretical arguments (section 2) managers adopt the OHSAS 18001 on the basis of expected performance improvements. Therefore, without modeling the OHSAS 18001 adoption first, any model explaining the effect of this safety system on performance would yield biased results, regardless of whether the model controls for covariates linked to safety outcomes (Wooldridge, 2002). At this point, note that the characteristics of the OHSAS variables (adoption and cumulative experience) entail important considerations that condition our modeling strategy.

First, we examine the effects of the OHSAS 18001 on future performance changes. The adoption of the OHSAS 18001 is mostly driven by factors related to work safety conditions (see section 2). This problem is one of self-selection (Angrist, 1998; Heckman and Robb, 1985). Therefore, the first stage employs treatment effect models to analyze the effect of the OHSAS 18001 on subsequent performance. This method—proposed by Rubin (1974) and further developed by Imbens and Angrist (1994) and Angrist et al. (1996)—controls for self-selection problems by modeling performance changes as a function of an endogenous dummy variable linked to the adoption of the OHSAS 18001. In treatment effect models, the outcome variable is observed for all organizations and the endogenous dummy variable indicating the treatment condition enters into the outcome equation (Wooldridge, 2002). In this study, the treatment effect model has the following form:

$$\begin{aligned}\text{Adoption of}\\ \text{OHSAS 18001}_{it} &= \alpha_0 + \beta_1 \text{Work accidents ratio } (t-1)_{it} + \beta_2 \text{Rate of fatal accidents } (t-1)_{it} \\ &\quad + \beta_3 \text{Control variables}_{it} + \varepsilon_{it} \end{aligned} \tag{1}$$

$$\Delta \text{ Performance}_{it} = \alpha_0 + \delta_1 \text{Adoption of OHSAS 18001}_{it} + \delta_2 \text{Control variables}_{it} + u_{it} \tag{2}$$

Equation (1) is the treatment probit model where *i* indexes organizations, and β_j is the vector of parameters. In the outcome equation (equation 2) performance refers to changes in the work accidents rate, labor productivity, cost of goods sold divided by sales, and return on assets. Coefficients (δ_j) are estimated via OLS. The terms ε_i and u_i are the normally distributed errors for the probit and OLS regressions, respectively.

The second stage evaluates the effects of cumulative OHSAS experience on performance. Note that the safety-specific knowledge resulting from the implementation of the OHSAS 18001 is accumulated and used exclusively by adopting organizations. In this case, the sample is censored and this gives rise to a sample selection bias (Heckman, 1990). Thus, standard regression models are not a viable approach to assess the effects of OHSAS experience, and an analysis that addresses potential sample selection offers a more comprehensive modeling approach.

Heckman (1979) characterizes the sample selection problem as a special case of the omitted variable problem in which the inverse Mills ratio (λ) is the omitted variable in the outcome equation. Thus, we use the two-step Heckman method (Heckman, 1979) to estimate consistent coefficients for the effects of cumulative OHSAS experience on subsequent performance changes. The probit model in equation (1), in which the dependent variable equals to one if the organization adopted the OHSAS

18001 standard, is used to estimate the inverse Mills ratio. The second step estimates the outcome equation with the inverse Mills ratio as an explanatory variable as follows:

$$\Delta \text{ Performance}_{it} = \alpha_0 + \delta_1 \text{OHSAS experience}_{it} + \delta_2 \text{Control variables}_{it} + \delta_3 \lambda_{it} + \nu_{it} \qquad (3)$$

In equation (3) performance refers to changes in the analyzed performance variables, namely work accidents rate, labor productivity, cost of goods sold divided by sales, and return on assets. OHSAS experience is an ordinal variable capturing the number of full years since certification. Coefficients (δ_j) are estimated by OLS and the model is performed solely on the sample of adopting organizations. Finally, the term ν_i is the normally distributed disturbance term.

4. Empirical findings

The findings for both the driving factors and the short-term impact of the OHSAS 18001 on performance changes are presented in section 4.1 (Tables 2 and 3), while section 4.2 shows the results when analyzing the effects of cumulative OHSAS experience on performance changes (Tables 4 and 5). In all tables model 1 shows the results when predicting safety performance (work accidents rate). Models 2 and 3 report the results for operational performance (labor productivity and the cost of goods sold divided by sales), and the findings when the dependent variable is economic performance (return on assets) are presented in model 4.

To address the threat of collinearity, we computed the average variance inflation factor (VIF) for all variables. The average VIF value for the probit model is 1.44. In the treatment models the average VIFs range between 6.66 when estimating the cost of goods sold divided by sales, and 7.51 in the return on assets model (Tables 3 and 4). The average VIFs for the Heckman models (Tables 5 and 6) range between 5.20 (return on assets model) and 8.02 (safety performance). In all outcome equations the highest VIF values that exceed 10—a generally accepted rule of thumb for assessing collinearity—were observed for the treatment effect and the omitted variable correcting for sample selection. These terms are estimated from equation (1), which explains their correlation with the exogenous covariates (Greene, 2003; Heckman, 1990). We computed VIFs including only the strictly exogenous variables used in the outcome models, and the resulting average VIF is 1.37 and ranges between 1.04 and 1.93. The results for this diagnostic test do not raise collinearity concerns.

4.1 Adoption and short-term impact of the OHSAS 18001 on performance

The treatment regression models relating the adoption of the OHSAS 18001 and performance changes are depicted in Tables 2 and 3 for the full sample and for each industry, respectively. Concerning the probit model estimating the adoption of the OHSAS 18001, results show that the coefficients for the work safety variables are positive and statistically significant. That is, organizations with higher work accidents rates and a greater proportion of injuries and fatal accidents are more likely to adopt the OHSAS 18001. These results support the first hypothesis stating that organizations with poor safety performance are more likely to adopt the OHSAS 18001.

----- Insert Tables 2 and 3 about here -----

Hypothesis 2a proposes a positive relationship between the adoption of the OHSAS 18001 and safety, operational and economic performance. This hypothesis is partially supported. The results in Table 2 show that the coefficient for the OHSAS 18001 is negative and statistically significant only when the dependent variable is the change in the rate of work accidents (Model 1: $p < 0.05$). The OHSAS 18001 was designed to improve safety performance, and this result confirms that enhanced safety controls resulting from the adoption of the OHSAS 18001 contribute to reduce work accidents.

To help interpret the results, we computed the average treatment effect on the treated (ATET) following the matching method by Rosenbaum and Rubin (1983). The ATET is computed for each adopting organization as $ATET(\mathbf{x}_i) = \frac{1}{N}\sum_{i=1}^{N}[D_i - \hat{p}_i(\mathbf{x}_i)]y_i \big/ [\hat{p}_i(D_i = 1) \times (1 - \hat{p}_i(\mathbf{x}_i)]$ (Angrist, 1998). The Rosenbaum-Rubin method also allows at computing the effect of non-adopting the OHSAS 18001 on performance, that is, the non-treatment effect on non-adopting organizations (ATENT) conditional on the analyzed variables (**x**) as $ATENT(\mathbf{x}_i) = \frac{1}{N}\sum_{i=1}^{N}[D_i - \hat{p}_i(\mathbf{x}_i)]y_i \big/ [\hat{p}_i(D_i = 0) \times (1 - \hat{p}_i(\mathbf{x}_i)]$.

Note that the adoption of the OHSAS 18001 is a binary event with dissimilar rates of implementation across the analyzed periods. In this context, the matching method by Rosenbaum and Rubin (1983) constitutes a valid tool to balance binary coded events for which it is not possible to match treated and control units adequately on an individual basis (Rosenbaum and Rubin, 1983, p. 51). Therefore, the ATET and ATENT effects are computed for each period by pairing each adopting business with one or more non-adopting businesses, and the resulting effects are obtained as the average of contrasts between OHSAS and non-OHSAS businesses at each value of the independent variables included in the model (Angrist, 1998, p. 254).

For safety performance the estimated ATET is –0.1375, which implies that the average effect of introducing the OHSAS 18001 is a reduction in the work accidents rate of 13.75 percentage points. The treatment effect on safety performance is significantly greater (t-test: –29.96 and $p < 0.001$) than the estimated reduction in the work accidents rate for non-adopting organizations (ATENT: –0.1097).

Hypothesis 2b states that the positive impact of adopting the OHSAS 18001 standard over performance is stronger in organizations whose operational tasks both match the systematic nature of the OHSAS 18001. Results in Table 3 indicate that the positive effect of safety knowledge is significant in manufacturing ($p < 0.10$) and professional service organizations ($p < 0.01$), and that the work accidents rate is the only performance dimension that improves as a result of enhanced safety practices. As predicted, significant performance improvements follow the adoption of the OHSAS 18001 in manufacturing organizations, which are characterized by highly methodical processes. On contrary, the adoption of the OHSAS 18001 does not impact any performance variable in the group of construction organizations.

It is also noteworthy that the greatest reduction in the rate of work accidents resulting from the adoption of the OHSAS 18001 is reported for businesses in professional service sectors. The distinctive characteristics of knowledge-based tasks translate in lower work accidents rates which are mostly low in severity. Also, lower organizational efforts are required to reduce risk factors linked to non-severe work accidents compared to those necessary to minimize work risks associated with severe injuries (Lo et al., 2014). Although the value of safety knowledge is difficult to measure in professional services organizations, this finding suggests that exposure to low-severity accidents facilitate communication tasks and coordination efforts among employees to reduce accidents (Garicano and Wu, 2012).

4.2 The relationship between cumulative OHSAS experience and performance changes

This section examines the effect of cumulative OHSAS experience on the analyzed performance variables. Results for the full sample are presented in Table 4, while Table 5 shows the findings for each of the analyzed industry sectors. It should be kept in mind that the variable linked to business age controls for the time since an organization was created, while the effects of time trends are also factored into the models through time dummy variables. Therefore, the OHSAS experience variable captures experience itself and is not a proxy for the organization's market experience.

Hypothesis 3a proposes that the safety experience linked to the implementation of the OHSAS 18001 enhances safety, operational and economic performance. Results in Table 4 support this hypothesis when performance is measured through safety and operational variables, while we find no support for this hypothesis when the dependent variable is economic performance. We find that, among adopting organizations, the work accidents rate decreases as a result of the accumulated OHSAS experience ($p < 0.05$). The estimated annual average reduction in the work accidents rate resulting from each extra year of OHSAS experience is 0.75 percentage points (Model 1 in Table 4).

----- Insert Tables 4 and 5 about here -----

For labor productivity, results in Model 2 of Table 4 show that the coefficient for accumulated OHSAS experience is positive and statistically significant ($p < 0.05$). Similarly, the result in Model 3 indicates that OHSAS experience significantly reduces the ratio of cost of goods sold divided by sales ($p < 0.10$). These findings are consistent with the argument that the safety experience resulting from the implementation of the OHSAS 18001 enhances operational performance (Lo et al., 2014).

Hypothesis 3b proposes that the positive impact over performance of accumulated OHSAS experience is stronger in businesses with highly systematic processes. Results support this hypothesis. As predicted, the effect of OHSAS experience is conditioned by the matching between the codified nature of the OHSAS 18001 and the work environment in which knowledge is used. From Table 5 we note that, among adopting firms, the positive effect of the accumulated OHSAS experience is prevalent in manufacturing firms, which are characterized by highly methodical processes and well developed information systems (Lo et al. 2014). Model 1 in Table 5 shows that the impact of OHSAS experience on changes in safety performance is significant ($p < 0.05$). This result suggests that these features make the experience resulting from the repetition of safety tasks more beneficial in that safety knowledge enhances the detection of both risk factors and the origin of accidents in the long-run.

Additionally, we note that the operational benefits derived from the adoption of the OHSAS 18001 are not immediate in manufacturing organizations. Models 2 and 3 in Table 5 evaluate the effects of accumulated OHSAS experience, and in both models the coefficient for this variable is significant ($p < 0.05$). By comparing the results in Table 3 with those depicted in Table 5 we observe that the operational shift linked to the introduction of the safety system is significantly visible in the years following the implementation of new safety practices.

On contrary, the coefficient for the variable linked to OHSAS experience is not significant in the models analyzing construction and professional services organizations. In construction organizations work risks are mostly visible; however, work environments are volatile due to both variations in project designs and the interplay between different subcontractors with competing objectives (Caponecchia and Sheils, 2011). Construction sites are hierarchically organized with managers, foremen and construction workers (Kines et al., 2010), but the temporary nature and the strong informal culture in construction sites limit the effects derived from the adoption of the OHSAS 18001. These findings might also suggest that the presence of multiple subcontractors with competing objectives may hamper the channeling of safety knowledge within these organizations.

Results indicate that accumulated OHSAS experience does not significantly impact performance in professional services organizations. It should be noted that professional services organizations report the lowest rate of work accidents (5.69%), and this result is significantly different to that found for manufacturing (6.94% and *t*-test: 1.73, $p < 0.10$) and construction businesses (10.69% and *t*-test: 6.07, $p < 0.01$). Similarly, the proportion of injuries and fatal accidents in professional services organizations (11.45%) is significantly lower than values found for manufacturing (23.31%

and *t*-test: 2.95, $p < 0.01$) and construction businesses (13.58% and *t*-test: 1.87, $p < 0.10$). Thus, the low rates of both work accidents and injuries and fatal accidents might count against OHSAS experience in these firms. The operational characteristics of these businesses might discourage employees to incorporate safety tasks in their day-to-day practices.

5. Discussion, implications and concluding remarks

In this study, we proposed that the adoption of the OHSAS 18001 generates valuable knowledge that impacts various performance dimensions. Furthermore, we argued that cumulative OHSAS experience translates into benefits for the organization. More concretely, we hypothesized that the effects of implementing the OHSAS 18001 amplify in organizations whose operational processes are highly systematic. Our theoretical approach offers a compelling vision of the learning effects derived from the introduction of safety systems.

This study provides further evidence that contributes to understand how organizations capitalize on safety knowledge and experience linked to the implementation of the OHSAS 18001. Overall, the findings are consistent with prior studies that emphasize that poor safety conditions at work—measured by the rate of work accidents and the rate of injuries and fatal accidents—increase the likeliness to modify existing safety practices (Robson et al., 2007) and that, unlike economic performance metrics, significant improvements in the work accidents rate and operational performance follow the adoption of codified safety knowledge. Additionally, results reveal that the effects of new safety knowledge and accumulated OHSAS experience are heterogeneous across industry sectors. Prior work has suggested that organizational complexity (Lo et al., 2014) and enhanced coordination between different management systems (Pagell et al., 2015) contribute to explain the performance of safety practices at the organizational level. In line with these studies, we explored the role of organizational and operational factors on the effectiveness of the OHSAS 18001. More concretely, we argue that inter-industry discrepancies in the effect of the OHSAS 18001 may arise from differences in recognizing the value of safety knowledge as a result of the various types of risk that employees are exposed to, and from operational differences which might condition the coupling of safety knowledge and practices to core organizational activities.

Organizations do not realize the generally positive effects of the OHSAS 18001 at the same intensity. Results suggest that the systematic nature of the OHSAS 18001 is more compatible with organizations in which operational processes are mostly systematic, while the positive effects of the OHSAS 18001 dilute in project-based businesses.

We interpret the results of the study in terms of an organizational change in which the adoption of the OHSAS 18001 becomes more successful in businesses whose processes match the codified nature of the OHSAS 18001. These findings are in line with the arguments that operational characteristics as well as the adaptive capacity of organizations might usefully be made more central to the implementation of managerial control tools, such as the OHSAS 18001.

This paper has relevant implications for scholars and practitioners. From an academic perspective, though prior research shows that safety systems decreases safety metrics related to work accidents and safety violations (Abad et al., 2013; Lo et al., 2014); this study demonstrates that the performance repercussions of the OHSAS 18001 certification are heterogeneous across organizations. Our analysis of the role of the characteristics both of new safety knowledge and of business operations on different performance metrics contributes to a better understanding of the conditions under which the effects of adopting the OHSAS 18001 occur in businesses operating in different industry sectors.

For strategy makers, we first suggest that managers need to turn their attention to the characteristics of both the work environment and operational processes when considering the adoption of safety systems. The prioritization of safety practices creates a safer working environment which fulfils the workers' safety needs and allows them to pursue operational goals (Pagell et al., 2015). In manufacturing businesses—characterized by a greater process automation that makes more evident the negative consequences of work accidents—the adoption of the OHSAS 18001 enhances organizational performance through the timely identification and documentation of risks and the implementation of corrective actions (Lo et al., 2014). Nevertheless, managers tend to pursue short-term goals and this is detrimental to work safety investments (Nahrgang et al., 2011). Also, managers would be well advised to consider the potential benefits of safety systems in the short- and in the long-term. The short-term effects of the OHSAS 18001—more linked to the reduction of work accidents—might not be attractive for managers. Thus, any attempt to promote the adoption of safety systems should be coupled with enhanced information mechanisms that acknowledge the value of safety systems in potentially reducing operational losses linked to poor safety conditions in the long-term.

Second, this research offers insights on the incompatibilities that may emerge between safety management systems and the properties of organizational tasks. Based on results suggesting that, in project-based businesses, factors related to the business operations might neutralize the effects of safety systems, the prescription is to link the adoption of the OHSAS 18001 to enhanced information mechanisms that contribute to overcome potential barriers that existing knowledge and practices create to the adoption of new safety knowledge (Lant et al., 1992).

Results indicate that the effects of the OHSAS 18001 erode in contexts characterized by changing work environments. This result is consistent with Lo et al. (2014) who found that operational complexity influences the relationship between the OHSAS 18001 and performance. Although the adoption of the OHSAS 18001 helps reduce work accidents in the short-term, the low riskiness of knowledge-based tasks creates a disconnection between safety systems and the employees' incentives to incorporate safety tasks in the day-to-day operations, and damages the long-term effect of the OHSAS 18001 on performance changes. Thus, organizations whose processes make less visible the consequences of work accidents might cultivate training programs that function better under these conditions (Burke et al., 2011). Managers should learn that training might function not only by disseminating safety knowledge to employees, but also by imparting on them relevant information and practical experience about work risks which are critical to assimilate, clarify and verify the value of safety knowledge.

It must, however, be mentioned a series of limitations to the present study that, in turn, represent avenues for future research. First, like other studies on the OHSAS 18001 (Abad et al. 2013; Lo et al., 2014), the data do not permit the direct analysis of the process that precedes the adoption of the OHSAS 18001. Further research on this issue would be valuable. For example, future studies should evaluate the managers' response to work accidents, and determine whether organizations with more accurate accidents' documentation processes adopt a greater number of corrective actions, and whether these processes are linked to a greater probability to adopt safety management systems.

Second, businesses are increasingly integrating different management systems to reduce the duplication of managerial tasks and the economic losses that result from operating with multiple management system in parallel (Abad et al., 2014). From a strategic perspective, future research can address this point by evaluating if the effect of safety systems on performance is consistent in businesses that adopted other management systems.

Third, and in connection with our analysis, specifically designed future work can evaluate the robustness of our results by analyzing the role on performance of knowledge properties and operational characteristics in businesses that adopt alternative safety systems. In addition, the results for the OHSAS experience variable may be conditioned by differences in the OHSAS adoption year, creating a potential bias when assessing the performance effects of the OHSAS in early- and late-adopters viz-à-viz. non-adopting businesses. In this sense, future research should evaluate the effects of OHSAS experience on samples with a more extended time period to control for potential biases resulting from time differences in the adoption of safety systems. Fourth, future studies should assess whether relevant operational and organizational factors—e.g., slack resources and market conditions (Wiengarten et al., 2017)—influence the relationship between the adoption of safety systems, certified safety experience and business performance. Finally, the geographic specificity of the study calls for obvious caution when interpreting and generalizing its findings.

Acknowledgements: For their insightful comments that helped us to improve the paper we are grateful to Yancy Vaillant (Toulouse Business School). The authors are thankful to FREMAP and AENOR for their support and valuable collaboration. This work was supported by the Spanish Ministry of Science and Innovation (grant number: ECO2013-48496-C4-4-R).

References

Abad, J., Dalmau, I., & Vilajosana, J. (2014). Taxonomic proposal for integration levels of management systems based on empirical evidence and derived corporate benefits. Journal of Cleaner Production, 78(1), 164-173.

Abad, J., Lafuente, E., & Vilajosana, J. (2013). An assessment of the OHSAS 18001 certification process: Objective drivers and consequences on safety performance and labour productivity. Safety Science, 60, 47-56.

Angrist, J.D. (1998). Estimating the Labor Market Impact of Voluntary Military Service Using Social Security Data on Military Applicants. Econometrica, 66(2), 249-288.

Angrist, J.D., Imbens, G., & Rubin, D. (1996). Identification of causal effects using instrumental variables. Journal of the American Statistical Association, 91, 444-472.

Arezes, P.M., & Miguel, A.S. (2008). Risk perception and safety behaviour: A study in an occupational environment. Safety Science, 46, 900-907.

Bevilacqua, M., Ciarapica, F.E., & De Sanctis, I. (2016). How to successfully implement OHSAS 18001: The Italian case. Journal of Loss Prevention in the Process Industries, 44, 31-43.

British Standards Institution (BSI) (2007). OHSAS 18001: Occupational Health and Safety Management Systems. British Standard Institution, London.

Burke, M., Salvador, R., Smith-Crowe, K., Chan-Serafin, S., Smith, A., & Sonesh, S. (2011). The dread factor: How hazards and safety training influence learning and performance. Journal of Applied Psychology, 96, 46-70.

Caponecchia, C., & Sheils, I. (2011). Perceptions of personal vulnerability to workplace hazards in the Australian construction industry. Journal of Safety Research, 42, 253-258.

Chang, J.I., & Liang, C.-L. (2009). Performance evaluation of process safety management systems of paint manufacturing facilities. Journal of Loss Prevention in the Process Industries, 22(4), 398-402.

Choudhry, R.M. (2014). Behavior-based safety on construction sites: A case study. Accident Analysis & Prevention, 70, 14-23.

Das, A., Pagell, M., Behm, M., & Veltri, A. (2008). Toward a theory of the linkages between safety and quality. Journal of Operations Management, 26, 521-535.

de Koster, R., Stam, D., & Balk, B. (2011). Accidents happen: The influence of safety-specific transformational leadership, safety consciousness, and hazard reducing systems on warehouse accidents. Journal of Operations Management, 29, 753-765.

European Agency for Safety and Health at Work (2013). EU-OSHA Priorities for occupational safety and health research in Europe: 2013-2020. Luxembourg.

European Commission (2007). Improving quality and productivity at work: Community strategy 2007-2012 on health and safety at work. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM (2007) 62.

Fernández-Muñiz, B., Montes-Peón, J.M., & Vázquez-Ordás, C.J. (2012). Safety climate in OHSAS 18001-certified organisations: antecedents and consequences of safety behaviour. Accident Analysis and Prevention, 45, 745-758.

Garicano, L., & Wu, Y. (2012). Knowledge, Communication, and Organizational Capabilities. Organization Science, 23(5), 1382-1397.

Ghahramani, A. (2016). Factors that influence the maintenance and improvement of OHSAS 18001 in adopting companies: A qualitative study. Journal of Cleaner Production, 137, 283-290.

Greene, W. (2003). Econometric Analysis, fifth edition, Prentice Hall, Upper Saddle River, NJ.

Heckman, J.J. (1979). Sample Selection Bias as a Specification Error. Econometrica 47(1), 153-161.

Heckman, J.J. (1990). Varieties of Selection Bias. American Economic Review, 80(2), 313-318.

Heckman, J.J., & Robb, R. (1985). Alternative Methods for Evaluating the Impact of Interventions: An Overview. Journal of Econometrics, 30, 239-267.

Imbens, G., & Angrist, J.D. (1994). Identification and Estimation of Local Average Treatment Effects. Econometrica, 62(2), 467-475.

Kines, P., Andersen, L., Spangenberg, S., Mikkelsen, K., Dyreborg, J., & Zohar, D. (2010). Improving construction site safety through leader-based verbal safety communication. Journal of Safety Research, 41, 399-406.

Lant, T. K., Milliken, F.J., & Batra, B. (1992). The role of managerial learning and interpretation in strategic persistence and reorientation. Strategic Management Journal, 13, 585-608.

Lo, C.K.Y., Pagell, M., Fan, D., Wiengarten, F., & Yeung, A.C.L. (2014). OHSAS 18001 certification and operating performance: The role of complexity and coupling. Journal of Operational Management, 32, 268-280.

Nahrgang, J.D., Morgeson, F.P., & Hofmann, D.A. (2011). Safety at work: A Meta-Analytic investigation of the link between job demands, job resources, burnout, engagement, and safety outcomes. Journal of Applied Psychology, 96(1), 71-94.

Pagell, M., Klassen, R., Johnston, D., Shevchenko, A., & Sharma, S. (2015). Are safety and operational effectiveness contradictory requirements: The roles of routines and relational coordination. Journal of Operations Management, 36, 1-14.

Podgórski, D. (2005). Workers' Involvement—A Missing Component in the Implementation of Occupational Safety and Health Management Systems in Enterprises. International Journal of Occupational Safety and Ergonomics, 11(3), 219-231.

Robson, L.S., Clarke, J.A., Cullen, K., Bielecky, A., Severin, C., Bigelow, P.L., Irvin, E., Culyer, A., & Mahood, Q. (2007). The effectiveness of occupational health and safety management system interventions: A systematic review. Safety Science, 45(3), 329-353.

Rosenbaum, P., & Rubin, D. (1983). The Central Role of the Propensity Score in Observational Studies for Causal Effects. Biometrika, 70, 41-55.

Rubin, D. (1974). Estimating causal effects of treatments in randomized and non-randomized studies. Journal of Educational Psychology, 66, 688-701.

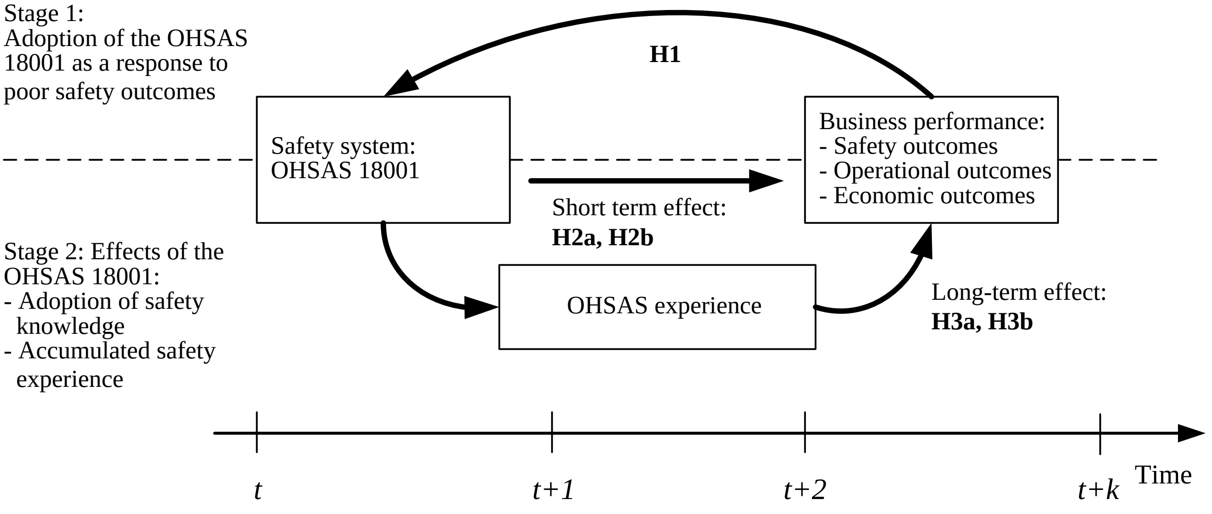
Wiengarten, F., Fan, D., Lo, C. K., & Pagell, M. (2017). The differing impacts of operational and financial slack on occupational safety in varying market conditions. Journal of Operations Management, 52, 30-45.

Wooldridge, J. (2002). Econometric Analysis of Cross Section and Panel Data. The MIT Press, Cambridge, MA.

Zohar, D., & Luria, G. (2003). The use of supervisory practices as leverage to improve safety behavior: a cross level intervention model. Journal of Safety Research, 34, 567-577.

List of Figures

Figure 1. Conceptual model



Source: Authors' elaboration

List of Tables

Table 1. Descriptive statistics for the selected variables (period 2006-2009)

	OHSAS sample		Non-OHSAS sample		Overall	
	Mean	Obs.	Mean	Obs.	Mean	Obs.
Rate of accidents at work	0.0845 (0.0765)	327	0.0796 (0.0833)	269	0.0823 (0.0796)	596
Labor productivity ratio (thousands of euro)	595.75*** (1,529.18)	327	287.14 (410.78)	269	447.98 (1,149.39)	596
Cost of goods sold divided by sales	0.7608*** (0.1935)	327	0.7009 (0.2430)	269	0.7321 (0.2204)	596
Returns on assets (ROA)	0.0454*** (0.0888)	327	0.0788 (0.1879)	269	0.0614 (0.1458)	596
Rate of injuries and fatal accidents	0.1436 (0.3338)	327	0.1568 (0.3539)	269	0.1496 (0.3428)	596
Size (employees)	373.15** (1,062.33)	327	753.18 (2,828.19)	269	544.67 (2,063.23)	596
Firm age (years)	25.2018*** (16.8482)	327	20.1524 (15.2302)	269	22.9228 (16.3196)	596
Manufacturing sectors	0.3761*** (0.4852)	327	0.2416 (0.4289)	269	0.3154 (0.4651)	596
Construction sector	0.4679** (0.4997)	327	0.3829 (0.4870)	269	0.4295 (0.4954)	596
Professional service sectors	0.1560*** (0.3634)	327	0.3755 (0.4851)	269	0.2551 (0.4362)	596

Labor productivity is expressed in thousands of 2010 euro. Standard deviation is presented in brackets. *, **, *** = significant at the 10%, 5%, and 1% level, respectively (two-tailed).

Table 2. Treatment effects model: The effectiveness of the OHSAS 18001 certification

		Safety performance	Operational performance		Economic performance
	Adoption of OHSAS	Δ Work accident rate	Δ Labor productivity	Δ CGS / sales	Δ Returns on assets
		(1)	(2)	(3)	(4)
Adoption of OHSAS		–0.0763** (0.0358)	0.3097 (0.3349)	–0.0583 (0.0507)	–0.1935 (1.3118)
Work accident rate *t-1*	2.4026** (1.0338)				
Rate of injuries and fatal accidents *t-1*	0.6539** (0.2663)				
Size (ln employees)	–0.0450 (0.0507)	–0.0025 (0.0022)	–0.0200 (0.0194)	0.0040 (0.0034)	–0.2689 (0.2523)
Firm age (years)	0.0117** (0.0053)	0.0002 (0.0002)	0.0001 (0.0021)	–0.0004 (0.0004)	–0.0071 (0.0268)
Manufacturing sector	1.0822*** (0.2052)	0.0145 (0.0153)	–0.2338* (0.1414)	–0.0222 (0.0243)	–0.9123 (1.8392)
Construction sector	0.8048*** (0.1775)	0.0137 (0.0129)	–0.2021* (0.1185)	–0.0155 (0.0200)	–0.2805 (1.5416)
Calendar time	0.7660*** (0.0908)	–0.0086 (0.0086)	–0.1509* (0.0804)	–0.0291** (0.0133)	0.2661 (1.0339)
Inverse Mill's ratio (lambda)		0.0459** (0.0212)	–0.1806 (0.1991)	0.0439 (0.0326)	–0.7666 (1.7989)
Intercept	0.0681 (0.3268)	0.0486* (0.0291)	0.8587*** (0.2689)	0.0499 (0.0451)	0.2973 (1.3445)
Wald test (chi2)		120.52***	121.02***	89.82***	86.12***
Pseudo R2	0.2498				
LR chi2	141.83***				
Observations		596	596	596	596

Standard error is presented in brackets. *, **, *** = significant at the 10%, 5%, and 1% level, respectively.

Table 3. Treatment effects model: The relationship between the OHSAS 18001 and performance changes in the analyzed industry sectors

		Safety performance	Operational performance		Economic performance
	Adoption of OHSAS	Δ Work accident rate	Δ Labor productivity	Δ CGS / sales	Δ Returns on assets
Panel A: Manufacturing		(1)	(2)	(3)	(4)
Adoption of OHSAS		–0.0399* (0.0230)	0.3457 (0.5362)	0.0256 (0.0368)	0.2489 (1.6933)
Work accident rate *t-1*	3.2167** (1.6030)				
Rate of injuries and fatal accidents *t-1*	1.2325** (0.6044)				
Inverse Mills ratio (lambda)		0.0305 (0.0305)	–0.0748 (0.3117)	–0.0073 (0.0216)	–1.6842 (1.4736)
Intercept	0.2758 (0.5830)	0.1077 (0.6873)	–0.0026 (0.4122)	0.0092 (0.0308)	–3.0982 (3.9128)
Wald test (chi2)		37.72***	33.58***	29.57***	26.73***
Pseudo R2	0.2276				
LR chi2	33.23***				
Observations		256	256	256	256
Panel B: Construction					
Adoption of OHSAS		–0.1283 (0.1338)	1.4214 (1.2086)	0.1526 (0.2448)	1.4434 (2.9472)
Work accident rate *t-1*	5.9046*** (2.4561)				
Rate of injuries and fatal accidents *t-1*	0.9831** (0.5082)				
Inverse Mills ratio (lambda)		0.0747 (0.0774)	–0.8369 (0.7034)	–0.0829 (0.1439)	–0.5295 (1.8911)
Intercept	0.2460 (0.6259)	0.0970 (0.1234)	–1.2795 (1.0887)	–0.1475 (0.2551)	1.5956 (2.4232)
Wald test (chi2)		40.32***	35.56***	32.16***	33.79***
Pseudo R2	0.3474				
LR chi2	54.31***				
Observations		188	188	188	188
Panel C: Services					
Adoption of OHSAS		–0.0801*** (0.0299)	0.1751 (0.4841)	0.0376 (0.0498)	–1.5146 (2.2314)
Work accident rate *t-1*	1.9954* (1.1430)				
Rate of injuries and fatal accidents *t-1*	0.3160 (0.4027)				
Inverse Mills ratio (lambda)		0.0523*** (0.0176)	–0.1604 (0.2964)	–0.0370 (0.0303)	1.2847 (1.4336)
Intercept	1.0514** (0.4910)	0.0961*** (0.0284)	0.2450 (0.4482)	–0.0474 (0.0460)	2.8284 (2.6920)
Wald test (chi2)		44.54***	32.44***	30.92***	35.55***
Pseudo R2	0.1683				
LR chi2	38.40***				
Observations		152	152	152	152

All models include as control variables firm size, firm age, and time dummy variables (see equations (1) and (2)). Standard error is presented in brackets. *, **, *** = significant at the 10%, 5%, and 1% level, respectively.

Table 4. Heckman model: The effect of accumulated safety experience on performance

		Safety performance	Operational performance		Economic performance
	Adoption of OHSAS	∆ Work accident rate	∆ Labor productivity	∆ CGS / sales	∆ Returns on assets
		(1)	(2)	(3)	(4)
OHSAS 18001 experience (years)		–0.0075** (0.0038)	0.0375** (0.0183)	–0.0071* (0.0038)	0.3356 (0.4467)
Work accident rate *t-1*	2.4026** (1.0338)				
Rate of injuries and fatal accidents *t-1*	0.6539** (0.2663)				
Size (ln employees)	–0.0450 (0.0507)	0.0017 (0.0037)	–0.0116 (0.0166)	0.0035 (0.0035)	–0.4750 (0.3755)
Firm age (years)	0.0117** (0.0053)	0.0004 (0.0003)	0.0014 (0.0016)	–0.0001 (0.0001)	0.0015 (0.0366)
Construction sector	0.8048*** (0.1775)	0.0179 (0.0159)	–0.1936** (0.0933)	0.0094 (0.0353)	–0.3871 (2.3279)
Manufacturing sector	1.0822*** (0.2052)	0.0210 (0.0155)	–0.2229** (0.1091)	0.0106 (0.0392)	–0.5478 (2.7172)
Calendar time	0.7660*** (0.0908)	–0.0115 (0.0121)	–0.1575** (0.0668)	–0.0101 (0.0128)	0.1435 (1.5440)
Intercept	0.0681 (0.3268)	–0.0468* (0.0244)	0.9871** (0.4706)	0.1556* (0.0909)	0.6108 (1.0875)
Inverse Mill’s ratio (lambda)		0.0680** (0.0330)	–0.0583 (0.1831)	0.0146 (0.0345)	0.4070 (1.2331)
Overall chi2		15.44***	15.03***	11.82**	4.36
Pseudo R2	0.2498				
LR chi2	141.83***				
Observations		596	596	596	596
Certified (OHSAS) observations		327	327	327	327

Standard error is presented in brackets. *, **, *** = significant at the 10%, 5%, and 1% level, respectively.

Table 5. Heckman model: The relationship between accumulated safety experience and performance in the analyzed industry sectors

		Safety performance	Operational performance		Economic performance
	Adoption of OHSAS	Δ Work accident rate	Δ Labor productivity	Δ CGS / sales	Δ Returns on assets
Panel A: Manufacturing		(1)	(2)	(3)	(4)
OHSAS 18001 experience (years)		–0.0049** (0.0024)	0.0843** (0.0394)	–0.0054** (0.0025)	0.0326 (0.4838)
Work accident rate *t-1*	3.2167** (1.6030)				
Rate of injuries and fatal accidents *t-1*	1.2325** (0.6044)				
Inverse Mills ratio (lambda)		0.0605*** (0.0171)	–0.2303* (0.1141)	0.0127 (0.0371)	1.9180 (1.3734)
Intercept	0.1077 (0.6873)	0.1010*** (0.0296)	0.2880 (0.3491)	0.0224 (0.0293)	3.9443* (2.2972)
Wald test (chi2)		11.60**	9.46**	7.88*	5.59
Pseudo R2	0.2276				
LR chi2	33.23***				
Obs. (OHSAS obs.)		256 (143)	256 (143)	256 (143)	256 (143)
Panel B: Construction					
OHSAS 18001 experience (years)		–0.0025* (0.0013)	0.0308 (0.0812)	0.0007 (0.0154)	0.1018 (0.2216)
Work accident rate *t-1*	5.9046*** (2.4561)				
Rate of injuries and fatal accidents *t-1*	0.9831** (0.5082)				
Inverse Mills ratio (lambda)		0.3136 (0.6239)	0.5429 (1.2398)	–0.1973 (0.4909)	–1.7781 (2.7799)
Intercept	0.2460 (0.6259)	–0.0643 (0.1463)	1.7311 (1.1421)	0.0473 (0.1307)	0.7992 (1.6477)
Wald test (chi2)		11.68***	6.37*	3.52	3.78
Pseudo R2	0.3474				
LR chi2	54.31***				
Obs. (OHSAS obs.)		188 (124)	188 (124)	188 (124)	188 (124)
Panel C: Services					
OHSAS 18001 experience (years)		–0.0033 (0.0117)	0.0476 (0.0923)	–0.0036 (0.0165)	–0.5855 (1.2152)
Work accident rate *t-1*	1.9954* (1.1430)				
Rate of injuries and fatal accidents *t-1*	0.3160 (0.4027)				
Inverse Mills ratio (lambda)		0.0643* (0.0352)	–0.1443 (0.2945)	–0.0025 (0.0165)	1.1192 (1.3672)
Intercept	1.0514** (0.4910)	0.0465 (0.0339)	0.0279 (0.2400)	–0.0313 (0.0431)	1.1111 (1.1207)
Wald test (chi2)		12.61**	2.99	2.08	5.07
Pseudo R2	0.1683				
LR chi2	38.40***				
Obs. (OHSAS obs.)		152 (60)	152 (60)	152 (60)	152 (60)

All models include as control variables firm size, firm age, and time dummy variables (see equations (1) and (3)). Standard error is presented in brackets. *, **, *** = significant at the 10%, 5%, and 1% level, respectively.