Determinants of sustainable & responsible innovations: A firm-level analysis for Italy

Determinants of Sustainable & Responsible Innovations: A firm-level analysis for Italy

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Abstract

This paper provides a micro-econometric analysis of the factors facilitating the introduction of Sustainable & Responsible Innovations by firms, with a focus on those aimed at improving occupational health and safety and reducing environmental impacts. Compared to the latter, the former objective of innovation has rarely been investigated with quantitative methods. By means of a bivariate probit model, we assess whether firms pursuing workers' health and safety as innovation objective are also ascribing high importance to environment preservation. The evidence provided by using data for Italian firms highlights the key role of external knowledge and innovation sources and internal human resource practices for the achievement of Sustainable & Responsible innovative outcomes. Many similarities but also some differences between innovative firms emerge, according to whether they are committed to health and safety or environment protection.

Keywords: sustainable innovation; responsible innovation; occupational health and safety; environment protection.

JEL codes: O31, O35, Q55.

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1. Introduction

The issue of Sustainable Development (SD) is at centre of the economic and policy debate especially after the launch of the 2030 Agenda for SD by the United Nations (2015). To achieve the 17 SD Goals of the UN (along with those established by the 2015 Paris Agreement on climate change) Sachs at al. (2019) have identified six “big” socio-economic transformations in different fields (such as education, health, energy and transport, natural resources). Most of these socio-economic changes involve the introduction and adoption of new technologies, including those for reducing carbon emissions and recycling materials and for improving the health and well-being of people. Indeed, on the one hand, “enhanced sustainable performance cannot be achieved without innovations” while, on the other, the concept of SD should entail “the inter-dependence between social, economic and environmental dimensions of sustainability” (Silvestre and Tirca, 2019; p. 326).

In this vein, over the last decades, business companies have accounted for social and environmental concerns in their innovation activities, as witnessed by their increasing attention to the issue of Corporate Social Responsibility (CRS) with a special emphasis on Sustainable Innovations (Scott, 2005; Boons et al., 2013; Adams et al., 2016; Varadarajan, 2017). The latter have been mainly viewed as those addressing environmental problems. A parallel concept is that of Responsible Research and Innovation which has been introduced by focussing primarily upon the conduct of ethically acceptable and socially desirable research activities (Stilgoe et al. 2013; Schomberg, 2013). Lubberink et al. (2017) extend this concept to the outcomes of innovative activities and analyse the ways in which Responsible Innovations are implemented in the business context.

In this paper, we employ the term of Sustainable & Responsible Innovations (S&RIs) with a view to focus upon the direction and content of innovations addressing societal challenges, which are not confined to the environment and climate change but encompass a wide range of social problems. Among them, we consider the health and safety of workers. Thus, we contend that firms (and their productive processes) cannot be defined as “sustainable” without taking care of the safety and well-being of their most vital resource. Therefore, compared to previous research, we also focus, along with environmental innovations, on a relatively under-investigated type of SRIs: those aimed at improving occupational health and safety, i.e. new technologies, devices and managerial practices that preserve workers’ health and reduce accidents in workplaces.

Apart from environmental innovations, the literature concerning other types of S&RIs at the level of business companies includes conceptual contributions (such as Stilgoe et al. 2013) and a range of works mainly based on cases studies and qualitative approaches while quantitative methods have been rarely used. We attempt to fill this gap by providing a micro-econometric analysis aimed at identifying the factors behind firms' engagement in both health & safety and eco-innovations. Hence, the main purpose of this paper is to test whether innovative firms ascribing greater importance to health and safety issues are also those paying more attention to environment protection, and so, if the firms involved in both types of S&RIs have some common traits or, rather, are driven by different factors. Along with other features described below, this represents the main original contribution of the paper.

For the above purpose, we employ firm-level data taken from the Community Innovation Survey (CIS) carried out in 2010 for Italian firms. This is the last CIS wave containing a specific question on the importance attached by firms to different objectives in their innovative activities (i.e. aimed at developing new products and/or processes). Together with the typical business goals of innovation (such as the widening of products' range or the reduction of labour costs), in the survey firms were asked to specify the degree of importance (from 0=not relevant to 3=very important) ascribed to two "sustainable & responsible" goals: improving workers' health and safety, on the one hand, and reducing environmental impacts, on the other. These ordinal measures are used as dependent variables of bivariate ordered probit regressions that allow us to assess the influence of various factors on the joint probability of pursuing both types of outcomes. Among the possible determinants of S&RIs, we give special emphasis to the role of firms' interaction with external knowledge and information sources, and the adoption of specific Human Resource Management (HRM) practices.

The interaction with external actors and stakeholders is widely recognised as a key feature of S&RI (Stilgoe et al., 2013; Varadarajan, 2017; Silvestre and Tirca, 2019) and it has been the focus of many studies concerned with eco-innovations (Rennings and Rammer, 2009; De Marchi, 2012; Horbach et al., 2013; Cainelli et al., 2015; Ghisetti et al., 2015; Marzucchi and Montresor, 2017; Gonzalez-Moreno et al., 2019). However, there is still not clear understanding of the impact that different external sources of knowledge, information and even pressure may have on other types of S&RIs, such as those concerned with the improvement of workplace health and safety.

Another relatively under-investigated issue regards the potential role of HRM practices (Wright et al., 2003) in driving the responsible behaviour of firms. In general, the latter have been considered as primary tools for improving the innovation performance of firms through the empowerment of employees (Laursen and Foss, 2003 and 2014; Santangelo and Pini, 2011; Lundvall, 2014; Capozza and Divella, 2018). Although previous research has put "green innovations" in relation to the adoption of specific management procedures and new methods of work organization (Ziegler and Rennings, 2004; Rennings et al., 2006; Rehfeld et al., 2007; Antonioli et al., 2013; Paillé et al. 2014; Guerci et al., 2015), we have no record of studies that explicitly focus on the role of firms' HRM practices in other fields of S&RI. Hence, it will be interesting to see whether they also affect the firms' attitude to safeguard the health and safety of their employees.

The above issue leads us to a further topical consideration, unfortunately of great relevance. Due to the Covid-19 pandemic, the protection of the health of employees has become a mandatory priority in the year 2020: indeed, for firms not affected by stronger restrictions, the protection of workers against the virus has become a binding obligation in order not to interrupt production. Although our findings derive from microdata referring to 2010, we believe that the capability to promptly and effectively implement these legal provisions might have been significantly influenced by some characteristics of the companies highlighted by our empirical analysis.

The paper is organized as follows. In Section 2, by reviewing the literature on the role and determinants of sustainable & responsible innovations, we introduce the research hypotheses to be tested by the subsequent empirical analysis. Section 3 illustrates the dataset and the econometric strategy. In Section 4 we present the results of micro-econometric estimations. Section 4 contains concluding remarks and policy considerations.

2. Backgrounds and hypotheses

2.1 Health and safety and environmental innovations

As mentioned in the introduction, both the debate and empirical research on firms involved in sustainable innovation practices are strongly focused on the so-called "eco-innovations". Indeed, due to increasing concerns about global warming, environmental pollution and growing scarcity of energy and resources, such innovations have become the focus of environmental policies and firms' innovative strategies. Environmental Innovations (or EIs henceforth) mainly represent new or improved products (goods or services) and processes that are beneficial to the environment since they reduce or avoid environmental damages (Rennings, 2000).

Over the last decades, however, firms have been increasingly required to responsibly manage also other societal problems, including the protection of the health and safety of employees in relation to diseases, accidents and hazards (Pouliakas and Theodossiou, 2013; ILO, 2014). This specific issue, for instance, has been included - among other aspects of environmental and social sustainability - in a recent survey caried out by the Italian Statistical Office (Istat, 2020) involving a large sample of Italian firms representative of the whole population.

To address the above issue, firms may introduce or adopt Health and Safety Innovations (or HSIs henceforth). The latter refer to new technologies aimed at providing employees with the best safety and field-specific equipment as well as the application of new techniques, procedures and tools that make the work tasks less cumbersome and easier to accomplish[1]. There are many examples of technologies that can be used to minimize work-related health problems, and especially injuries and fatalities[2]. By resorting to innovation, high-risk sectors such as mining, oil and gas, and aviation industries have made several improvements in safety systems, devices, and procedures (Hudson, 2003). Nevertheless, a lower rate of introduction and adoption of innovations for employees' health and safety still characterises other industries (such as the construction sector) and, especially, SMEs, where occupational health and safety conditions are generally poorer than in large firms (Arocena and Nunez, 2010; Wong et al., 2015; Bianchini et al., 2017). Even for this reason, although not comparable to those associated with environmental damages, work-related health problems and accidents at work still represent a heavy burden in social and economic terms[3].

The parallel between the protection of the environment and that of the workers' health and safety is particularly meaningful when dealing with the issue of innovation. Indeed, innovations in both fields are negatively affected by the so-called "dual externality problem" (Jaffe et al., 2005): a positive externality (due to the incomplete appropriability of the benefits arising from innovative activities) that reduces the private incentives to innovate, and a negative one, which stimulates harmful behaviours for the environment and the health and safety of workplaces. To avoid the consequent underinvestment in technologies that reduce environmental and health and safety damages, a set of complementary "stick and carrot" policies is necessary. Stringent laws and regulations imposing substantial costs to non-compliant firms coupled with innovation policies providing public support to innovative firms.

Although regulation has been ascertained to be one the main drivers of EIs (Horbach et al. 2021), a firm' compliance with laws could be achieved even with the minimal level of effort and investment enforced by the same laws (Guerci et al., 2015). In other words, because regulations do not compel a company to innovate, the investment in innovative activities for protecting the environment and/or

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[1] Safety, protecting and life-saving devices are included in many sub-categories of the International Patent Classification. For instance, among the IPC class of Human Necessity (A) the sub-class A62 comprises several life-saving and fire-fighting devices, while in Mechanical Engineering (F) the sub-class F16P (termed "safety devices in general") includes specific devices preventing injuries to people operating with machines. The next footnote provides some examples of recent HSI innovations.

[2] For instance: digital "smart" signage and high-speed communication systems that allow employees to become more aware of the dangers they can encounter; smart watches and other wearable technologies (e.g. bracelets, hats, gloves, jackets and clothing), which allow employees to monitor their condition in real time and give immediate feedbacks about changing environmental conditions (i.e. increasing temperature or exposure to harmful substances); personal protective equipment improved through technology (e.g. safety glasses with anti-fog and anti-scratch coatings on lenses that serve to reduce glare and improve clarity); new materials used to make uniforms, hats or boots more comfortable and, at the same time, more protective.

[3] According to recent estimates of the European Agency for Safety and Health at Work (EU-OSHA), the costs for work-related ill-health and injuries account for about 3.3% of the EU GDP, corresponding to 476 € billion (see: https://osha.europa.eu). This figure is composed of various direct and indirect costs (e.g. damages' compensations, medical expenses, foregone revenues, and replacement costs), but also to a reduced employees' productivity and work capacity (ILO, 2014).

the health and safety of employees implies additional voluntary efforts. The latter signal that the company ascribes importance also to the extra-technological content of innovations and, then, is particularly concerned with societal challenges (Scott, 2005).

Having said that, it is clear that also for HSIs the regulatory framework may stimulate firms to invest in or to acquire new devices that are more effective in protecting workers and reducing injures in workplaces (see the examples in footnote 2); these new devices can be patented (see footnote 1) and, being industry-specific, are mainly introduced by specialised suppliers (often by interacting with the user companies and sometime jointly with them[4]); then, the different markets for safety and protecting devices can renew and grow, providing further impulses for HSIs.

With respect to the determinants of EIs and HSIs, it should be stressed that the types of the innovative activities, the nature of the knowledge sources and learning processes and the technological opportunities or obstacles that firms face in relation to workplace health and safety issues could be remarkably different from those entailed by environmental protection. Accordingly, the key research question addressed in this paper is whether (and to what extent) the key drivers of HSI are the same as those behind firms' engagement in EI.

2.2 External knowledge and innovation sources and S&RIs

Despite the enforcement of governmental regulations[5], occupational health and safety as well as environmental protection are often insufficiently tackled by firms.

Compared to other innovations, EIs are likely to be more complex, being characterised by higher levels of novelty and, then, variety and risk (De Marchi, 2012; Ghisetti et al., 2015). Indeed, in this field, inexperienced firms face several sources of uncertainty, as there are no widely accepted

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[4] Cases of safety devices patented by the user companies themselves are rarer and limited to large companies. Just for an example, Samsung Heavy Industries, operating in shipbuilding, has applied for 70 patents in the IPC classes A62 and F16P (see footnote 1) over the years 2015-2020. In the same period, the company has applied for about 5350 patents worldwide. Thus, those concerned with safety devices account for only 1.3% of the total patent applications filed by the company.

[5] In Italy, the Legislative Decree 81/2008 on "Occupational Health and Safety" has applied the European Directive 89/391 by introducing a new model of protection based on a culture of prevention and workplace risk assessment. Along with the risks related to the physical health of workers, this regulatory framework also highlights the employers' obligation to assess the work-related stress risk. In addition, remarkable efforts have been made to boost occupational health and safety performance of SMEs, particularly by providing financial support for the implementation of interventions, with a view to encouraging smaller businesses to go beyond the notion of mere compliance with legislation in favour of continuous improvement (EU-OSHA, 2010). With respect to the environmental regulation, with the aim of implementing the EU directives, the Law 308/2004 and the Legislative Decree 152/2006 – aka the "Environment Code" – have conferred on the Italian Government the reorganization, coordination and integration of environmental legislations. The Environment Code encompasses different sectors such as, soil and water protection, waste management and polluted sites, air protection and emissions reduction. The Code left out other specific areas (e.g. accidents related to dangerous substances; waste from electrical and electronic equipment; noise and electromagnetic pollution) that have been regulated by subsequent legislative measures.

standards, either in terms of technologies and production processes or of measures for evaluating their environmental performance.

As stressed by Horbach et al. (2012), environmental innovations rely on a wide knowledge base. Consequently, not only the presence of internal R&D activities (especially if specifically focused on environmental issues) but also, and most importantly, the interaction with several sources of external knowledge should be more important for EIs than for other innovations. This can be explained by the fact that, with the exception of eco-industries whose core business is to develop green technologies, for most firms eco-innovations require knowledge and capabilities that do not belong to their core competences (see among others Rammer and Rennings, 2009; Horbach et al., 2013; Ghisetti et al., 2015; Gonzalez-Moreno et al., 2019). For instance, Rammer and Rennings (2009), by employing the German variant of the CIS in 2005, show that firms innovating in energy and resource efficiency, besides relying more strongly on their internal R&D activities, are also more likely to use different external sources of knowledge and information, particularly suppliers, competitors, universities and public research institutes. Horbach et al. (2013), by using CIS data for French and German firms in 2004, find that in both countries, compared to other innovations, eco-innovation activities tend to require more external knowledge from different sources, and especially from universities, consultants and conferences[6]. Ghisetti et al. (2015), by using the CIS 2008 for eleven European countries, estimate the impact of the "breadth" and "depth" of external knowledge sourcing on the probability that firms introduce EIs as well as on the number of different types of EIs introduced. More in detail, the variable "knowledge breadth" accounts for the overall number of different external sources upon which firms rely for innovation (regardless of whether these sources are little or very important for the innovative activities of a firm). Instead, the "knowledge depth" stands for the number of different external sources to which a firm also attributes a high degree of importance. The authors argue that, compared to other innovations, eco-innovations are more likely to give rise to broader knowledge requirements, that is, hard to find in just one or few external providers. Moreover, previous evidence that firms perceive the lack of suitable cooperation partners as an important barrier for innovation in this field (e.g. Rennings and Rammer, 2009) leads them to consider also deep knowledge sourcing as an essential input for EIs. Gonzalez-Moreno et al. (2019), employing data drawn from an ad hoc survey on Spanish firms, provide more accurate measures of the breadth and depth of firms' cooperative relationships in the food sector, studying their influence on the development of eco-innovations.

[6] To distinguish eco-innovations from general innovations, the authors refer to a specific question of the fourth CIS wave on the environmental impact of innovation. Since in the France survey this question included also the impact upon employees' health and safety, the dependent variable used in their study detects whether the innovative activities carried out by firms lead to high or medium reduction of environmental pollution and/or health and safety effects. In our case, instead, CIS 2010 data allow us to consider HSI and EI separately and, thus, estimate their specific determinants.

With respect to HSIs, although in absence of the same robust evidence available for EIs, the interactions with external actors are likely to be equally important. In this case, however, the object of the transfer is often an innovation package that can be adopted rather than a piece of knowledge that can be used for the internal generation of innovations. Indeed, only for firms specialised in the provision of safety devices the exchange of knowledge with clients, universities and so on could be important. Instead, most of the firms involved in HSIs do not generate them internally but adopt the new solutions offered by external providers. In this case, the information coming not only from specialised suppliers of HSIs but also from other companies, consultants, and industry associations can play an important role.

Regarding this specific type of responsible innovation, two widely recognised barriers for firms are the scarce availability of financial resources and the lack of knowledge and concern on safety issues (Wong et al., 2015). Indeed, the benefits of a health and safety outlay materialise only in the long term and this makes such investment less attractive, especially for smaller businesses. These latter are also less able than larger companies to screen the regulatory framework and deal with the relevant norms. These inherent characteristics of SMEs, besides contributing to their resistance to regulation, may also obstruct their potential to innovate in a responsible way. Accordingly, we contend that frequent interactions with several external actors may help to overcome the described shortcomings. In addition, the breadth and depth of external linkages may also act as important "push" factors that that enhance the firms' orientation to sustainability. Among them, Varadarajian (2017) stresses the role of institutional pressures (coercive, mimetic, and normative) which are exerted not only by regulators and policy makers, but also by stakeholders (investors, customers, suppliers, employees, etc.) and competitors[7]. By committing to S&RIs (i.e. both EIs and HSIs), firms may enhance their capacity to attract and retain qualified and motivated employees. Moreover, even for small businesses, the improved reputation gained through S&RI may imply fairer treatment by suppliers and better access to credit from investors and banks that value socially responsible activities (Russo and Perrini, 2010).

In the subsequent empirical analysis, it will be also tested whether the interactions with specific external actors exert different impacts on the likelihood that firms engage in HSI and EI. As already stressed, studies on environmental innovations at firm level have found that several external sources of knowledge play an important role, including research organizations. In fact, most of the firms introduce EIs by performing internal innovative activities along with exploiting external knowledge sources. In the case of HSI, instead, most of the firms acquire technological innovations developed

[7] For a sample of Italian firms, Guerci et al. (2015) find that, to enhance firms' environmental performance, customer pressure is even more effective than that exerted by regulatory stakeholders.

elsewhere. Thus, it is likely that firms adopting health and safety innovations take particular advantages from the interaction with "close" institutional partners operating in the business realm (such as suppliers, customers and consultants) rather than with "distant" ones active in the domain of basic and applied research (such as university and public research centres)[8].

In the light of the above arguments, to assess the role of external interactions in the introduction of health and safety and environmental innovations, we introduce the following hypotheses:

- Hypothesis 1: firms with *broader* interactions with external actors are more likely to attach greater importance to occupational health and safety and environmental protection in their innovation activities.

- Hypothesis 2: firms undertaking *more intense* interactions with external actors are more likely to consider occupational health and safety and environmental protection as highly important in innovation.

- Hypothesis 3: the interactions with specific external actors have a different impact on the firms' propensity to consider occupational health and safety and environmental protection as highly important in innovation.

2.3 HRM practices and other determinants of S&RIs

The participatory behaviour of employees, stimulated by tailored Human Resource Management (HRM) practices[9], plays a crucial role in facilitating firms' adoption of Sustainable & Responsible innovations.

Previous research has related eco-innovations to specific management procedures such as "Environmental Management Schemes" (e.g. Rehfeld et al., 2007; Rennings et al., 2006; Ziegler and Rennings, 2004). More recently, Antonioli et al. (2013) have considered, along with HRM practices, the role of workplace organizational changes as determinants of environmental innovations. With a field study on 555 Italian firms, they show that the joint presence of high shares of employees involved in training programmes and relevant changes in production organization is, in general, not associated with a greater adoption of EIs. However, a positive relationship emerges for firms belonging to more polluting and, then, more regulated sectors. Although for a smaller sample of Italian firms, Guerci et al. (2015) find a more positive impact of HRM practices in that both the training and involvement of employees to environmental concerns as well as the presence of performance management and compensation increase the "green" performance of companies. By

[8] By using CIS data for manufacturing firms located in Germany, Italy and France, Franco et al. (2014) show that the cooperation with research organizations (distant partners) increase the firms' capability to absorb external knowledge more than the cooperation with other business firms (close partners).

[9] Wright et al. (2003) grouped several HRM practices into four main groups: selection (recruitment of employees), training, pay per performance and participation (involvement in the decision process).

considering Chinese companies, with data coming from 151 matched questionnaires from top managers, chief executive officers, and frontline workers, Paillé et al. (2014) show that the involvement of employees on environmental protection (by means of discretionary acts which are not required or rewarded) mediates the relationship between the presence of strategic HRM and the firms' environmental performance.

With respect to innovations concerned with the health and safety of workplaces, Harrison and Legendre (2003) and Arocena and Núñez (2010), show that the empowerment of employees through initiatives that give them some freedom and discretion over the work pace and tasks facilitates the achievement of HSIs and the reduction of health and safety damages. The employees who are more committed to an organization will not adopt counter-productive behaviours and, thus, will be more likely not only to follow safety rules (cf. Wright et al., 2003), but also to demand and welcome the introduction of new tools and practices aimed at increasing workplace safety.

In line with most of the above-mentioned studies, we contend that the HRM practices more helpful for firms to achieve S&RI are the training on the job and the adoption of participatory methods of work organisation. Accordingly, we formulate a fourth hypothesis:

- Hypothesis 4: firms adopting HRM practices, both in the form of training and new methods of work organisation, are more likely to ascribe greater importance to the goals of occupational health and safety and environmental protection when dealing with innovation.

It should be stressed that in testing the hypotheses introduced in this section and the previous one, we also control for the role played by other factors such as the presence of public support for innovation and that of R&D activities and investment in advanced capital goods. The inclusion of the latter control variables is important since we are not able to distinguish between firms that are involved in the provision (supply) or adoption (demand) of both types of SRIs. Previous studies on the determinants of eco-innovations have stressed the crucial role of R&D as an indicator of the firms' absorptive capacity, i.e. the capability of assimilating and using external knowledge (Ghisetti et al., 2015; Gonzalez-Moreno et al., 2019). In principle, compared to general innovations and environmental ones, those aimed at protecting employees' health and safety should be more related with firms' production processes and, thus, with the acquisition of new machinery, equipment and devices developed elsewhere (see the end of the previous section). This hypothesis is supported by the findings of the recent survey conducted by the Italian Statistical Office (Istat, 2020) on firms' involvement in sustainable activities. Italian companies were asked to report the type of actions for the safety of workplaces that were undertaken in 2018 in addition to those required by the law. Among the firms that have carried out these additional voluntary actions, about 50% of them have invested in new machinery and equipment. The firms that have adopted advanced safety procedures, based on specific and detailed protocols, account for 31% of the total, while only 19% have appointed a manager, with a dedicated budget, for safety issues.

3. Sustainable & Responsible innovations in Italian firms

3.1 Data and variables

To test the hypotheses introduced in the previous section, we use firm-level data taken from the Italian Community innovation Survey (CIS) 2010 that refers to the three-year period 2008-2010 and has involved both manufacturing and service firms with at least 10 employees. The micro-data have been provided by the Italian National Institute of Statistics (ISTAT). It should be stressed that the CIS 2010 is the last survey containing a specific question on the degree of importance attached by firms to the two kinds of S&RI examined in this paper: the improvement of employees' health and safety and the reduction of environmental impacts.

The final representative sample of the Italian CIS 2010 is made of 18,328 firms. However, since our aim is to detect the main factors associated with the importance attached by firms to sustainable and responsible innovations, we have restricted the analysis to firms having introduced at least one product or process innovation during the reference period: the firms considered as "innovative" for the purpose of this study are 6,000. This restriction entails a risk of sample selection bias which will be stressed in discussing the econometric methodology (see Section 3.2) and, then, addressed in the Appendix as robustness check.

As for the impact of innovation upon employees' health and safety and environment protection, in order to identify and keep separated these goals from other (more usual) business objectives of innovation[10], we have referred to the CIS questions asking firms to rate the importance of "improving health and safety" and "reducing environmental impacts". Since the respondent firms are asked to choose among four possibilities, namely between "not relevant", "low", "medium" or "high" importance, we have defined the main dependent variables of this study, HSI (Health and Safety Innovation) and EI (Environmental Innovation), as ordinal indicators taking values from 0 to 3 according to the degree of importance attached by firms to these objectives.[11]

[10] Other innovation objectives included in the CIS questionnaire are: increase range of goods and services; replace outdated products and processes; enter new markets; improve quality of goods and services; improve flexibility and/or capacity for producing goods and services; reduce labour costs per unit output. In the Appendix, some of the above objectives of innovation will be examined in conjunction with those concerned with the environment and the health and safety of workplaces.

[11] It needs to be stressed that we have referred to such a narrow definition of "innovation" due to the particular structure of the 2010 CIS questionnaire, where only the firms that have introduced new products or processes are asked to indicate the importance of some particular objectives among which those identified as relevant for this study. We acknowledge that most extensive and update conceptualizations have highlighted that SRIs can also involve new organizational and

Table 1.a shows that the percentages of innovative firms attaching "high" and "medium" importance to the goal of health and safety (28 and 33%, respectively) are greater than those arising for environmental protection (20 and 29%). However, as expected, these shares are lower than those related to other typical business goals of innovation[12]. It should be recognised that by simply signalling the pursuing of a relevant sustainable and responsible objective by firms in their activities related to product and process innovation, such indicators could only indirectly and partially capture the creation of actual workers' or environmental benefits. The choice of such indicators has been somewhat dictated by the limited set of variables on firms' S&RIs collected by the 2010 CIS. This clearly represent a limit, especially for further analyses on this important issue, given that subsequent waves of the CIS do not even report the same two questions exploited in this study nor allow to detect more accurate information.

The table also reports descriptive statistics for the explanatory variables that will be used in the subsequent econometric analysis. A first set accounts for the importance of nine sources of external knowledge and innovation: suppliers; clients or customers; competitors; consultants; universities; government and public research labs; conferences; scientific journals; professional and industry associations. The table reports separate percentages for each type of interaction according to the degree of importance ascribed by innovative firms: from 0 ("null") to 3 ("high"). However, in line with previous studies (cf. Ghisetti et al., 2015; Gonzalez-Moreno et al., 2019), in a first regression analysis external interactions are included by means of synthetic indicators of "breadth" and "depth".

marketing methods. To some extent, this is also supported by the CIS dataset employed, since most firms that have indicated employees' health and safety and /or environmental protection as important objectives for their new products and processes have also been involved in organizational and marketing innovation.

[12] The "high" and "medium" percentages concerned with other business objectives are the following: 53 and 37% for improving the quality of goods and services; 46% and 35% for increasing the range of goods and services; 36 and 33% for entering new markets. For the remaining goals (see previous footnote), the shares are in line with those ascribed to health and safety.

Table 1.a – Descriptive statistics (percentages) of dependent and independent variables; Italian firms with product and/or process innovations included in CIS 2010 (observations=6,000)

	0	1	2	3
Responsible innovations (ordinal)				
Health and safety	0.230	0.155	0.334	0.281
Environment protection	0.310	0.199	0.288	0.203
External interactions (ordinal)				
Suppliers	0.149	0.158	0.465	0.228
Customers	0.304	0.215	0.306	0.175
Competitors	0.421	0.274	0.238	0.067
Consultants	0.363	0.219	0.296	0.122
Universities	0.712	0.146	0.096	0.046
Government or public research labs	0.793	0.128	0.061	0.019
Conferences	0.354	0.248	0.307	0.092
Scientific journals	0.439	0.263	0.245	0.054
Professional and industry associations	0.485	0.243	0.205	0.068
HRM practices (dummy)				
On-the-job training	0.582	0.419		
New work organisation	0.473	0.527		
Public support (dummy)				
National or EU public support	0.863	0.137		
Regional public support	0.806	0.194		
Innovative activities (dummy)				
R&D engagement	0.505	0.495		
Advanced machinery, equipment or software	0.152	0.849		
Firm size (dummy)				
Small (10-49 employees)	0.444	0.556		
Medium (50-249)	0.743	0.258		
Large (250 and more)	0.814	0.187		
Firm industry (dummy)				
High-tech manufacturing industries	0.875	0.125		
Low-tech manufacturing industries	0.703	0.297		
Knowledge-intensive business services	0.800	0.200		
Public utilities	0.961	0.039		
Transport	0.956	0.044		
Construction	0.898	0.103		
Trade and other services	0.807	0.193		

"Breadth" stands for the number of sources to which firms have attached "some" importance (i.e. excluding only those with "null" importance), while "depth" accounts for the number of sources evaluated as "highly" important by firms. Both indicators range from 0 to 9 and are included in the regression analysis also with squared terms with a view to check for the presence of a non-linear effect on responsible innovations. Table 1.b reports descriptive statistics for the above variables.

Table 1.b – Descriptive statistics of breadth and depth of external interactions

	Mean	Standard deviation	Minimum	Maximum
Breadth of external interactions	4.98	2.53	0	9
Depth of external interactions	0.87	1.16	0	9

A second group of explanatory variables, illustrated in Table 1.a, detects the influence of other potential determinants, namely the use of HRM practices, the engagement in innovative activities and the exploitation of public support for innovation. More in detail, "On-the-job training" is a dummy variable equal to 1 if a firm has invested in personnel training specific for its innovation activities and 0 otherwise, whilst "New work organisation" is another dummy variable for firms that have adopted new methods of organising work responsibilities and decision-making (i.e. first use of new systems of employees responsibilities, team work, decentralisation etc.). For innovative activities, "R&D engagement" is a binary indicator of whether firms have undertaken research and development activities (either internally or acquired externally[13]); then, a second dummy variable refers to firms that have acquired "Advanced machinery, equipment or software" to achieve product or process innovations. As Table 1.a shows, 85% of firms have been involved in the latter type of innovative activity, while only 50% of them have been engaged in R&D. "Public support" is composed of two binary variables used to check whether the firms' engagement in S&RIs has been incentivised by public measures introduced by different levels of government: national and European, on the one hand, or regional, on the other.

To account for firm specific characteristics, we have inserted a set of firm size and industry dummies as standard controls. Firm size dummies are defined according to the number of employees. As shown in Table 1.a, 81% of the 6,000 firms with product and/or process innovations are classified as SMEs, i.e. having between 10 and 249 employees. Sectorial aggregations are based on the two-digit NACE (Statistical Classification of Economic Activities). With respect to high- and low-tech industries, we have followed the OECD ISIC Rev. 3 technology intensity definition of manufacturing industries (OECD 2011). More specifically, we have grouped together manufacturing firms in high- and medium-high technology industries into the unique category of "High-tech"; likewise, manufacturing firms in low- and medium-low technology industries have been grouped together in "Low-tech". Then, to identify firms in Knowledge Intensive Business Services (KIBS) and keep them separated from less "advanced" services, we have referred to Eurostat classification[14]. The other sectors are

[13] In the CIS questionnaire, external R&D activities are defined as those purchased by the responding firms but performed by other enterprises (including other firms and subsidiaries in the firms' group) or by public or private research organisations.

[14] See http://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an3.pdf.

Public utilities, Construction, Transports, Trade, and other services. The share of high- and low-tech manufacturing firms account for about 42% of the total; the share of firms belonging to KIBS is 20%, followed by that concerned with Trade and other services (19%) and Construction (10%).
As a final consideration, it should be stressed that, due to the unavailability of firm-level data, no regulatory variables were included among the determinants of both EI and HSI. The impact of regulation, as a stimulus for innovating in these fields, could be partially captured by other explanatory variables, such as the industry dummies (being some industries more regulated than others) and the exploitation of public support for innovation. Indeed, as stressed in Section 2.1, a mix of stringent regulations and public incentives is the most effective way to foster innovations for protecting either the environment and the health and safety of workplaces.

3.2 Econometric specification

We estimate a bivariate ordered probit model with a view to testing whether firms' engagement in HSI and EI is correlated and if firms attaching more importance to the goal of environment protection have similar or different characteristics with respect to those more involved in improving the health and safety of workers. The bivariate ordered probit model allows us to consider that firms might simultaneously pursue different types of responsible innovation by incorporating a correlation structure for the unobservable factors related to the two outcomes. Among the unobservable firms' characteristics that are likely to influence the orientation towards both SRIs, an important role is played by the culture and values of managers and entrepreneurs which, in turn, is affected by the culture and values of the environment in which their companies operate (Lubberink et al., 2017). Bischoff (2021) shows that, along with specific support programs of local governments and business associations, the firms' adoption of sustainable and socially responsible values and norms is strongly influenced by the sustainability culture of the local context.
The bivariate ordered probability model can be obtained from the following latent variable model

$$y_{ih}^{*} = x_{ih}' \beta_h + \varepsilon_{ih} \; with \; h = HSI, EI \qquad (1)$$

where the subscript *i* indicates firms while *h* refers, alternatively, to HSI or EI. The explanatory variables included in vector *x* have been illustrated in previous section (see Tables 1a and 1b).
The observed ordinal variables denoting the importance attached by a firm *i* to HSI and EI are:

$$y_{ih} = \begin{cases} 0 - \text{not relevant} \quad \text{if} & y_{ih}^* \le \mu_{1h} \\ 1 - \text{low} \quad \text{if} & \mu_{1h} < y_{ih}^* \le \mu_{2h} \\ 2 - \text{medium} \quad \text{if} & \mu_{2h} < y_{ih}^* \le \mu_{3h} \\ 3 - \text{high} \quad \text{if} & y_{ih}^* > \mu_{3h} \end{cases}$$

The error terms of equation (1) assume a bivariate standard normal distribution with a correlation coefficient rho: $\varepsilon_{ih} = \begin{bmatrix} \varepsilon_{iHSI} \\ \varepsilon_{iEI} \end{bmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}; \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix}\right)$

The rejection of the null hypothesis rho=0 indicates that, due to unobservable firms' characteristics, the extents of HSI and EI are correlated and, thus, their respective equations should be estimated simultaneously by means of maximum likelihood.

Due to the structure of the CIS questionnaire, whether a firm has been somehow involved in HSI or EI is only observed for "innovative" firms that have managed to introduce at least one new product or process. This potentially creates a selection bias which can arise if the analysis is restricted to a sub-sample of firms not-randomly drawn from the larger population and, thus, produce distorting coefficients (Heckman, 1979). Given this, as robustness check, we also estimate a bivariate ordered probit model for HSI and EI with sample selection, i.e. including a third (selection) equation in which the dependent variable accounts for the firms' probability of being innovative. The results of these estimates exclude the presence of selectivity biases (see the Appendix for details).

Another potential issue is that related to the cross-sectional nature of the data, which do not allow us to estimate dynamic relations and clear up the actual direction of causality between the dependent and independent variables. This constitutes a typical, well acknowledged, limitation of empirical studies based on CIS data drawn from one single wave, implying that the results should be interpreted in terms of structural associations between the variables employed, recognizing that these might derive from the presence of cumulative two-way linkages.

4. Regression results

Table 2 reports a first set of findings arising from the bivariate ordered probit model estimating the probability of being engaged in one or both types of Sustainable & Responsible innovation.

A first important result can be found at the bottom of the table, where the null hypothesis that the correlation between the error terms of the two equations is equal to zero is strongly rejected. Moreover, as indicated by the athrho parameter, a significant and positive correlation is found between the error terms, confirming the interdependence of firms' decisions to undertake different S&RI strategies. This overall supports the choice of the bivariate probit model.

Table 2 – Bivariate ordered probit estimates. Dependent variables: importance of workers' health and safety (HSI) and environment protection (EI) as objectives of innovation (CIS 2010)

	HSI	EI
Depth of external interactions	0.0569** (0.0261)	0.0512* (0.0265)
Depth of external interactions^2	0.0066 (0.0057)	0.0094 (0.0060)
Breadth of external interactions	0.1419*** (0.0246)	0.1563*** (0.0254)
Breadth of external interactions^2	-0.0046** (0.0024)	-0.0039* (0.0024)
On-the-job training	0.0779*** (0.0302)	0.0332 (0.0301)
New work organisation	0.3140*** (0.0298)	0.1958*** (0.0299)
National or EU public support	-0.0481 (0.0438)	0.0481 (0.0432)
Regional public support	0.1010*** (0.0371)	0.1353*** (0.0365)
R&D engagement	-0.0583* (0.0321)	0.0633* (0.0324)
Advanced machinery, equipment or software	0.1254*** (0.0419)	0.0525 (0.0421)
Medium size	-0.0666* (0.0352)	0.0448 (0.0357)
Large size	0.0686* (0.0417)	0.2067*** (0.0409)
High-tech manufacturing	0.2261*** (0.0549)	0.2585*** (0.0547)
Low-tech manufacturing	0.3253*** (0.0431)	0.3408*** (0.0437)
Knowledge intensive business services	-0.4660*** (0.0482)	-0.3823*** (0.0480)
Public utilities	0.3907*** (0.0830)	0.7204*** (0.0850)
Transport	0.2207*** (0.0784)	0.1313* (0.0797)
Construction	0.4501*** (0.0561)	0.4962*** (0.0576)
Log pseudolikelihood	-13.779.493	
athrho	0.9212***	
Wald test of independent (H0: rho=0)	926.77***	
Number of observations	6000	

"Small size" and "Trade and other services" used as reference categories. ***p<0.01, **p<0.005, *p<0.10

In particular, the results point to the complementarity between HSI and EI, suggesting that there are some unobservable characteristics causing firms to report high commitment to both health and safety and environment protection. Along with the fact that some eco-innovations could also improve workplace health and safety, some crucial features that cannot be observed are the sensitivity of owners or managers to socially sustainable and responsible innovations as well as their attitude to comply with the relevant norms and regulations.

With respect to the impact of external knowledge and innovation sources we find that, in line with Hypotheses 1 and 2, both measures of "breadth" and "depth" positively affect the probability of introducing both HSI and EI. Given the higher significance and greater magnitude of the coefficients, the positive role of knowledge breadth seems to be much stronger for both types of S&RIs. Moreover, the estimated parameters of the squared terms of the "breadth" variable indicate the presence of an inverted U relation that, in turn, suggests that the number of external sources exerts a positive influence only up to a point, especially in the case of HSIs. Instead, the positive effect of the "depth" variable is not bounded. These findings are fully consistent with those achieved by Ghisetti et al. (2015) and Gonzalez-Moreno et al. (2019): they suggest that increasing the intensity of the interactions with external actors is always beneficial to S&RIs, while enlarging the number of interactions "above a certain level may expose firms to redundant and/or inconsistent information signals" (Ghisetti et al., 2015, p 1087).

As for the impact of internal HRM practices, the provision of on-the job-training increases the likelihood of achieving innovations aimed at improving workers' health and safety, while it does not exert a significant impact on environmental innovations. In this respect, Hypothesis 4 is thus not confirmed. Instead, the adoption of new methods of work organization turns out to play a more pervasive role, being positive and highly significant with respect to both types of SRI. Hence, as far as work organisation is concerned, Hypothesis 4 is fully supported.

Other remarkable differences regard the impact of the firms' innovative activities. As can be seen, we find evidence that being engaged in R&D positively affects firms' involvement in EIs (though with low level of significance), while the relation with HSIs is negative (and again slightly significant). Conversely, the acquisition of advanced machinery, equipment and software does not exert a significant impact on EIs while it highly enhances the propensity to introduce innovations for the sake of workers' health and safety. These results suggest that improvements of occupational health and safety are mainly achieved through adoption of new production processes and technologies rather than by means of R&D activities aimed at innovation generation. On the contrary, innovations with environmental benefits, at least to some extent, are probably more complex and, then, require the presence of R&D activities that allow an effective exploration and absorption of new and unfamiliar pieces of knowledge which must be integrated with the internal knowledge base of the firms (cf. Ghisetti et al., 2015; Gonzalez-Moreno et al., 2019).

Another interesting result is that public support for innovation positively affects the adoption of both HSIs and EIs, though only when the supporting measures are introduced at regional level. Thus, local governments appear to be particularly active in providing private firms (most probably SMEs) with public incentives to innovate for protecting both workplaces' health and safety and the environment. To some extent, this finding might also be interpreted as indirectly confirming the widely acknowledged role of public regulation in the same fields.

With respect to firm size, it emerges that large companies are more likely to attach higher importance to environmental innovations while the role of firm size in fostering HSI is less statistically significant: indeed, the negative effect for medium-sized firms as well as the positive one for large companies are significant only at a 10% level of confidence. Finally, the estimated parameters for sectorial dummies appear to be in line with expectations. Indeed, as opposed to the reference category ("Trade and other services"), KIBS is the only sector showing a significantly lower propensity to both SRIs. Public utilities assign a particularly high priority to environmental innovations, while the highest importance to health and safety innovations is also attached by the firms belonging to Construction. It should be noticed that both sectors are subject to more stringent and specific regulations: the former since it includes energy providers and the latter being particularly prone to accidents at work.

Table 3 reports the results of a further regression analysis in which the "depth" of each type of interaction with external actors – i.e. the degree of importance measured on a 0-3 scale - is estimated separately. The aim of this additional analysis is that of testing Hypothesis 3, by checking whether the propensity to HSIs and EIs relies on different external sources of knowledge and innovation. In this case, the "breadth" variable is not included due to its strong correlation with the separate sources (when included, also with the squared term, it does not have a significant impact on both types of S&RIs).

Starting from similarities, the external sources of knowledge and innovation that positively affect both types of S&RIs are those coming from suppliers, clients, consultants, scientific journals and professional and industry associations, whilst competitors do not exert a significant impact on both HSIs and EIs. Instead, universities, government/public research labs and conferences are found to be more significantly associated with environmental innovations only, suggesting that, in this respect, a very important role is played by scientific knowledge and research organisations. Together with that concerning the involvement in R&D activities, this finding confirms that innovations with environmental benefits are relatively more complex and, then, more knowledge-demanding than those affecting occupational health and safety.

Table 3 – Bivariate ordered probit estimates. Dependent variables: importance of workers' health and safety (HSI) and environment protection (EI) as objectives of innovation (CIS 2010)

	HSI	EI
Depth of external interactions (from 0 to 3):		
Suppliers	0.1164*** [0.0160]	0.1100*** [0.0163]
Customers	0.0852*** [0.0154]	0.0861*** [0.0152]
Competitors	-0.0064 [0.0173]	0.0239 [0.0172]
Consultants	0.0859*** [0.0156]	0.0611*** [0.0155]
Universities	0.0173 [0.0233]	0.0791*** [0.0227]
Government and public research labs	0.0532* [0.0287]	0.0938*** [0.0281]
Conferences	0.0312* [0.0182]	0.0804*** [0.0184]
Scientific journals	0.0783*** [0.0202]	0.0488** [0.0204]
Professional and industry associations	0.1056*** [0.0170]	0.0871*** [0.0172]
On-the-job training	0.0696** [0.0303]	0.0302 [0.0302]
New work organisation	0.3049*** [0.0299]	0.1903*** [0.0299]
National o EU public support	-0.0478 [0.0444]	0.0344 [0.0437]
Regional public support	0.1008*** [0.0372]	0.1277*** [0.0366]
R&D engagement (in-house and external)	-0,0457 [0.0326]	0.0718** [0.0327]
Advanced machinery, equipment or software	0.1058** [0.0424]	0.0411 [0.0424]
Medium size	-0,0556 [0.0355]	0.0625* [0.0359]
Large size	0.0944** [0.0421]	0.2241*** [0.0413]

Table 3 (continued)

High-tech manufacturing	0.2538*** [0.0556]	0.2695*** [0.0552]
Low-tech manufacturing	0.3360*** [0.0434]	0.3475*** [0.0439]
Knowledge intensive business services	-0.4491*** [0.0487]	-0.3717*** [0.0486]
Public utilities	0.4172*** [0.0838]	0.7329*** [0.0845]
Transport	0.2142*** [0.0783]	0.1401* [0.0798]
Construction	0.4401*** [0.0564]	0.4992*** [0.0577]
Log pseudolikelihood	-13.740.291	
athrho	0.9197***	
Wald test of independent equations (H0: rho=0)	993.26***	
Number of observations	6.000	

"Small size" and "Trade and other services" used as reference categories. ***p<0.01, **p<0.005, *p<0.10

For the remaining explanatory variables, the results are fully consistent with those of the previous regression. The only, albeit marginal, difference refers to the effect of the firm size variable, as in this case large companies turn out to be more likely to perform both types of S&RIs.

Consistent findings emerge from three robustness checks, included in the Appendix controlling for the presence of sample selection bias, the firms' involvement in other innovation objectives, and the marginal effects exerted by the independent variables on HSIs and EIs.

5. Concluding remarks and policy considerations

The empirical analysis carried out in this paper has highlighted the factors facilitating the introduction of Sustainable & Responsible Innovations (S&RIs) by firms: those aimed at improving occupational health and safety (HSI) and reducing environmental impacts (EI). Although limited to the Italian case, to the best of our knowledge, this is the first study that provides a micro-econometric analysis on the sources and determinants of both types of SRIs. In this respect, we found many similarities but also important differences between firms, according to whether they pursue HSIs or EIs.

The achievement of both types of S&RIs is significantly influenced by several external sources of knowledge and innovation. Therefore, to innovate responsibly firms should focus more on developing external networks that allow them to acquire resources that are not available internally. Regarding this, however, we also find evidence that broadly acquired external knowledge, after a certain point, could became difficult to manage and even discourage firms to pursue not only EIs (a result already found in the literature), but also other types of S&RIs such as HSIs. Moreover, the implementation of new work methods aimed at fostering employees' engagement and participation at work is confirmed to be a crucial driver of both HSIs and EIs, which supports the need of encouraging more participatory approaches to foster sustainable and responsible innovations in firms. Not surprisingly, large firms have a higher probability to achieve both innovation outcomes, though especially those concerned with environmental protection.

However, firms ascribing greater importance to HSI invest more in personnel training for innovation, while relying less on R&D activities and more on the acquisition of new machinery and equipment. Accordingly, this type of S&RI might be more linked to the adoption of externally developed technologies rather than internal generation activities. By contrast, firms ascribing greater importance to EIs are more likely to perform R&D and benefit from universities, public research labs and conferences as knowledge sources. Therefore, in accordance with previous research, environmental innovations appear to be relatively more complex and demanding in terms of knowledge and processes of internal generation.

Clearly, these results should be considered in the light of some limitations pertaining the generalizability of the findings, which could be unique to the specific context and time period considered. Also, they are based on a cross-sectional dataset that has not allowed us to investigate dynamic relationships and interpret the results in terms of causality. Therefore, the evidence obtained needs to be validated by more empirical work, for instance comparing the Italian case against those of other countries participating in the Community Innovation Survey. Nevertheless, a limiting factor for further analyses is due to data availability: in fact, the more recent waves of the survey (after that of 2010) do not include specific questions on S&RIs. We therefore hope that in the future CIS this important issue will be taken up again.

Notwithstanding the above limitations, our findings suggest that to boost firms' (and especially SMEs) engagement in Sustainable & Responsible Innovations a mix of policy measures should be implemented. Indeed, the introduction of stringent regulations in the fields of workplaces' health and safety and environment protection is a necessary, though not sufficient condition. To be effective, legal requirements should be coupled with direct economic incentives, especially to support firms' interactions with external actors. In this regard, our findings suggest that public supporting measures should be mainly implemented by regional governments, perhaps because of their better knowledge of the local eco-systems in which SMEs are embedded. Moreover, the recourse to HRM practices should be more encouraged as the active participation of employees plays a key role in allowing a more effective engagement with S&RIs.

Considering the case of HSIs, which have been by far less investigated than EIs, a relevant provision of the Italian legislation is the exemption, in case of unpredictable accidents, of the employers' responsibility if they have adopted effective practices and devices for improving the safety of workplaces. Especially for SMEs, such a measure is certainly helpful to make a health and safety investment as convenient as other kinds of investments. Accordingly, a similar provision should be adopted by all Member States of the EU. On top of this, the evidence provided in this paper indicates that, besides those already mentioned, other factors and institutions facilitate the adoption and diffusion of HSI. Among them, professional and industry associations are important for increasing firms' awareness of health and safety issues and regulations, so that part of their efforts in this field is worth to be publicly supported. External consultants also play an important role in the adoption of HSI and, in this connection, specific public incentives could be provided, especially to small businesses, for acquiring specialised consulting services.

Albeit our findings are drawn from microdata referring to 2010, we believe that most of the above policy considerations retain much of their validity even in the current (tragic) situation in which the protection of workers against Covid-19 has become a mandatory priority.

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Appendix: Robustness checks

A.1 Sample selection bias

Table A.1 reports the results obtained by running a bivariate ordered probit model for HSI and EI with sample selection estimated by using the full sample of firms taking part in the Italian CIS 2010. This approach allows us to estimate the extent of firms' engagement in each type of S&RI conditionally on the probability of being selected and included in the relevant sample, namely of being "innovative". The model is thus characterised of three equations. A first one accounts for whether each case in the sample is observed or not (selection equation), hence, with a dichotomous dependent variable, *Innovation*, equal to 1 if a firm has managed to introduce at least one new product or process, 0 otherwise. The second and third equations account for the ordinal outcomes of interest, HSI and EI, including all the explanatory variables already employed in the bivariate ordered probit estimation (see Table 2 in the main text).

Firms' characteristics (industry and size) that increase the probability of introducing an innovation are used to correct the estimation of the probability of ascribing a high importance to HSI and EI. It is well known that, for identification, sample selection models require at least one regressor in the selection equation to be excluded from the outcome equation. We thus include the binary variable *Firms belonging to a group,* that identify firms which are part of an enterprise group, as a reliable exclusion restriction for the second stage. The selection and the outcome equations are jointly estimated with the Stata cmp routine developed by Roodman (2011).

As it can be seen from the bottom of the table, the correlation coefficient between the error terms of the selection and outcome equations (i.e. atanhrho 1-2 and 1-3) are both non-significant. The results concerned with HSI and EI obtained from this estimation are perfectly consistent with those reported in Table 2. Accordingly, all the above findings lead us to exclude the presence of a selectivity bias.

Table A.1 – Bivariate ordered probit estimates with sample selection

	Selection eq. Innovation	*Outcome eq.* HSI	*Outomce eq.* EI
Depth of external interactions		0.0560** (0.0260)	0.0507* (0.0264)
Depth of external interactions ^2		0.0066 (0.0057)	0.0095 (0.0060)
Breadth of external interactions		0.1402*** (0.0245)	0.1555*** (0.0253)
Breadth of external interactions ^2		-0.0045* (0.0023)	-0.0039 (0.0024)
On-the-job training		0.0775*** (0.0300)	0.0333 (0.0300)
New work organisation		0.3125*** (0.0297)	0.1956*** (0.0298)
National or EU public support		-0.0475 (0.0435)	0.0484 (0.0431)
Regional public support		0.0995*** (0.0369)	0.1345*** (0.0364)
R&D engagement (in-house and/or external)		-0.0577* (0.0320)	0.0632* (0.0324)
Advanced machinery, equipment or software		0.1231*** (0.0416)	0.0515 (0.0421)
Medium size	0.3190*** (0.0263)	-0.0307 (0.0414)	0.0643 (0.0393)
Large size	0.7374*** (0.0388)	0.1404** (0.0596)	0.2462*** (0.0525)
High-tech manufacturing	0.9930*** (0.0475)	0.3111*** (0.0748)	0.3053*** (0.0680)
Low-tech manufacturing	0.5240*** (0.0285)	0.3728*** (0.0513)	0.3673*** (0.0494)
Knowledge intensive business services	0.5171*** (0.0325)	-0.4118*** (0.0593)	-0.3534*** (0.0545)
Public utilities	0.1110** (0.0537)	0.4015*** (0.0827)	0.7262*** (0.0850)
Transport	-0.2036*** (0.0470)	0.1997** (0.0795)	0.1200 (0.0803)
Construction	-0.1930*** (0.0320)	0.4226*** (0.0586)	0.4816*** (0.0588)
Firms belonging to a group	0.2012*** (0.0263)		
Constant	-0.8525*** (0.0211)		

Table A.1 (continued)

Log pseudolikelihood	-23979.902
atanhrho 1-2	0.1389
atanhrho 1-3	0.0764
atanhrho 2-3	0.9232***
Number of observations	18100
Censored observations (firms without innovations)	12100
Uncensored observations (innovative firms)	6000

"Small size" and "Trade and other services" used as reference categories. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

A.2 Relationships with innovation objectives not related to sustainability

A second robustness check has been performed to control for the firms' involvement in other innovation objectives that could be not independent of HSI and EI. For this purpose, we have estimated multivariate ordered probit regressions obtained by adding further equations to our baseline (bivariate ordered probit) models[15].

In Table A.2, we show the results when we consider CAP and FLEX as additional dependent variables, namely besides HSI and EI. These are also categorical indicators taking values from 0 to 3 according to the importance ascribed by firms to "increasing capacity for producing goods and services" (CAP) and "improving flexibility for producing goods and services" (FLEX). Among the regressors, the depth of each type of external interactions has been included to more accurately check whether (and how) their influence varies among different innovation objectives.

[15] Estimations have been carried out using the Stata cmp routine developed by Roodman (2011).

Table A.2 – Multivariate ordered probit estimates. Dependent variables: importance of workers' health and safety (HSI), environmental protection (EI), capacity (CAP) and flexibility (FLEX) for producing goods or services as objectives of innovation (CIS 2010).

	HSI	EI	CAP	FLEX
Depth of external interactions (from 0 to 3)				
Suppliers	0.1153*** (0.0161)	0.1087*** (0.0163)	0.1406*** (0.0161)	0.1397*** (0.0162)
Customers	0.0848*** (0.0154)	0.0857*** (0.0153)	0.0637*** (0.0150)	0.0841*** (0.0150)
Competitors	-0.0057 (0.0173)	0.0253 (0.0171)	0.0246 (0.0169)	0.0334* (0.0172)
Consultants	0.0867*** (0.0156)	0.0612*** (0.0155)	0.0442*** (0.0153)	0.0639*** (0.0154)
Universities	0.0174 (0.0231)	0.0784*** (0.0226)	-0.0438** (0.0218)	-0.0385 (0.0234)
Government and public research labs	0.0537* (0.0284)	0.0945*** (0.0279)	0.0194 (0.0266)	0.0479* (0.0288)
Conferences	0.0321* (0.0182)	0.0807*** (0.0184)	0.0439** (0.0183)	0.0543*** (0.0183)
Scientific journals	0.0782*** (0.0202)	0.0486** (0.0204)	0.0969*** (0.0199)	0.0496** (0.0202)
Professional and industry associations	0.1056*** (0.0169)	0.0873*** (0.0171)	0.0326* (0.0168)	0.0778*** (0.0169)
On-the-job training	0.0689** (0.0302)	0.0305 (0.0301)	0.0735** (0.0299)	0.0477 (0.0300)
New work organisation	0.3067*** (0.0299)	0.1916*** (0.0300)	0.2734*** (0.0294)	0.3202*** (0.0295)
National or EU public support	-0.0454 (0.0443)	0.0347 (0.0437)	0.0427 (0.0430)	-0.0793* (0.0426)
Regional public support	0.0973*** (0.0371)	0.1252*** (0.0366)	0.1466*** (0.0361)	0.0894** (0.0362)
R&D engagement (in-house and/or external)	-0.0464 (0.0324)	0.0717** (0.0326)	0.0062 (0.0325)	0.0527 (0.0321)
Advanced machinery, equipment or software	0.1063** (0.0423)	0.0402 (0.0424)	0.1682*** (0.0412)	0.1637*** (0.0406)
Medium size	-0.0535 (0.0355)	0.0655* (0.0358)	-0.0163 (0.0351)	0.0177 (0.0348)
Large size	0.0874** (0.0419)	0.2211*** (0.0412)	-0.0172 (0.0413)	0.1179*** (0.0412)
High-tech manufacturing	0.2522*** (0.0560)	0.2707*** (0.0555)	0.4252*** (0.0568)	0.4694*** (0.0565)
Low-tech manufacturing	0.3319*** (0.0437)	0.3467*** (0.0441)	0.5709*** (0.0457)	0.5123*** (0.0450)

Table A.2 (continued)

Knowledge intensive business services	-0.4463*** (0.0487)	-0.3653*** (0.0487)	0.3022*** (0.0478)	0.3461*** (0.0485)
Public utilities	0.4183*** (0.0835)	0.7346*** (0.0842)	0.3655*** (0.0772)	0.2142*** (0.0766)
Transport	0.2096*** (0.0771)	0.1472* (0.0789)	0.5354*** (0.0784)	0.4146*** (0.0786)
Construction	0.4369*** (0.0563)	0.4997*** (0.0578)	0.4074*** (0.0559)	0.2486*** (0.0560)
Log pseudolikelihood	-27347.17			
atanhrho 1-2	0.9226***			
atanhrho 1-3	0.4318***			
atanhrho 1-4	0.3796***			
atanhrho 2-3	0.3791***			
atanhrho 2-4	0.3551***			
atanhrho 3-4	0.8014***			
Number of observations	6000			

"Small size" and "Trade and other services" used as reference categories. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

Next, Table A.3 reports the results when MKT and COST are taken into account as additional dependent variables signaling the importance of "entering new markets or increasing market shares" (MKT) and "reducing labour cost per unit output" (COST).

Table A.3 – Multivariate ordered probit estimates. Dependent variables: importance of workers' health and safety (HSI), environmental protection (EI), entering new markets or increasing market shares (MKT) and reducing labour costs per unit output (COST) as objectives of innovation (CIS 2010).

	HSI	EI	MKT	COST
Depth of external interactions (from 0 to 3)				
Suppliers	0.1161*** (0.0160)	0.1083*** (0.0163)	-0.0113 (0.0160)	0.1416*** (0.0161)
Customers	0.0856*** (0.0154)	0.0863*** (0.0152)	0.1502*** (0.0154)	0.0512*** (0.0149)
Competitors	-0.0054 (0.0174)	0.0253 (0.0171)	0.0704*** (0.0176)	0.0955*** (0.0170)
Consultants	0.0862*** (0.0156)	0.0607*** (0.0155)	0.0478*** (0.0155)	0.0358** (0.0155)
Universities	0.0180 (0.0231)	0.0794*** (0.0224)	-0.0135 (0.0229)	-0.0238 (0.0216)
Government and public research labs	0.0539* (0.0284)	0.0934*** (0.0278)	0.0189 (0.0294)	0.0779*** (0.0275)
Conferences	0.0317* (0.0182)	0.0806*** (0.0184)	0.1345*** (0.0184)	0.0428** (0.0182)

Table A.3 (continued)

Scientific journals	0.0769*** (0.0202)	0.0484** (0.0204)	0.0383* (0.0199)	0.0116 (0.0202)
Professional and industry associations	0.1063*** (0.0170)	0.0878*** (0.0171)	0.0220 (0.0170)	0.1326*** (0.0169)
On-the-job training	0.0716** (0.0302)	0.0334 (0.0301)	0.0444 (0.0306)	0.0126 (0.0299)
New work organisation	0.3048*** (0.0299)	0.1928*** (0.0299)	0.1355*** (0.0297)	0.2350*** (0.0296)
National or EU public support	-0.0490 (0.0444)	0.0323 (0.0436)	0.1529*** (0.0438)	-0.0621 (0.0432)
Regional public support	0.0982*** (0.0371)	0.1253*** (0.0365)	-0.0430 (0.0368)	0.0611* (0.0358)
R&D engagement (in-house and/or external)	-0.0448 (0.0324)	0.0737** (0.0325)	0.2221*** (0.0329)	0.0189 (0.0325)
Advanced machinery, equipment or software	0.1077** (0.0422)	0.0409 (0.0422)	-0.0659 (0.0415)	0.0804* (0.0412)
Medium size	-0.0577 (0.0355)	0.0627* (0.0358)	0.0507 (0.0358)	0.1806*** (0.0343)
Large size	0.0876** (0.0420)	0.2170*** (0.0412)	-0.0249 (0.0426)	0.3760*** (0.0421)
High-tech manufacturing	0.2519*** (0.0557)	0.2688*** (0.0553)	0.2950*** (0.0568)	0.4300*** (0.0558)
Low-tech manufacturing	0.3333*** (0.0436)	0.3453*** (0.0441)	0.1075** (0.0433)	0.4035*** (0.0443)
Knowledge intensive business services	-0.4516*** (0.0488)	-0.3687*** (0.0486)	0.0701 (0.0480)	0.1255*** (0.0478)
Public utilities	0.4181*** (0.0832)	0.7308*** (0.0842)	-0.6115*** (0.0904)	0.0632 (0.0782)
Transport	0.2180*** (0.0780)	0.1441* (0.0796)	-0.1894** (0.0787)	0.0695 (0.0779)
Construction	0.4382*** (0.0562)	0.4973*** (0.0576)	-0.1855*** (0.0562)	0.1810*** (0.0554)
Log pseudolikelihood	-28215.58			
atanhrho 1-2	0.9222***			
atanhrho 1-3	0.1365***			
atanhrho 1-4	0.4710***			
atanhrho 2-3	0.2102***			
atanhrho 2-4	0.4571***			
atanhrho 3-4	0.2042***			
Number of observations	6000			

"Small size" and "Trade and other services" used as reference categories. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

Positive and significant correlations emerge between the error terms of all equations (i.e. the atanhrho parameters on the bottom of tables), suggesting complementarity not only between HSI and EI, but also between these latter and other innovation objectives not strictly related to "sustainability". However, it should be noticed the correlation coefficients of the error terms of the HSI and EI equations are much higher than those with respect to the equations concerned with CAP, FLEX, MKT and COST. This suggests that the complementarity between HSI and EI is relatively stronger than that between the same variables and other innovation objectives.

The specific role of the different sources of external knowledge and innovation with respect to HSI and EI do not change, though we find that many of them exert an influence also on CAP and FLEX and then on MKT and COST. Especially the role of customers and consultants turns out to be very pervasive, showing positive and highly significant coefficients in all cases. Other sources appear instead more strictly interrelated to S&RI objectives, particularly universities that turn out highly significant and positively associated only with EIs in both regressions. Some other sources, such as competitors, though confirmed to be not significant for both HSI and EI, have emerged as highly influential for other objectives such as MKT and COST.

With respect to the role of HR practices, the results concerning HSI and EI are also supported. On-the-job training programs turn out to be highly important also for increasing firms' capacity for producing goods and services. The adoption of new work organization methods is confirmed to be always crucial, that is, regardless of the specific objective of innovation pursued by firms.

As for additional controls, it is interesting to note that the coefficient of large size is positive and relatively more significant for S&RIs (especially EIs) and then for FLEX and COST, though it is not significant (and negative in sign) with regard to CAP and MKT: hence, being a firm of large size is also associated with an increased flexibility of production as well as a reduction of labour costs, though it is not related to an increased capacity of production and of entering new markets and increasing market shares.

Likewise, the acquisition of advanced machinery turns out to be positive and significant with respect to all the dependent variables, exception made for EI and MKT which appear, instead, more strictly associated with internal and external R&D investments. The helping role of public support provided at regional level is confirmed for both HSI and EI, emerging as important also for incentivizing firms to pursue other objectives like CAP and FLEX.

A.3 Computation of marginal effects

For a proper assessment of the impacts that our independent variables may exert upon HSIs as opposed to EIs, marginal effects should be computed. The latter are difficult to be identified with the bivariate ordered probit models so far estimated and commented. Thus, to compute conditional marginal effects we transform our dependent variables into binary indicators: accordingly, HSI becomes equal to 1 if innovating firms have ascribed to the goal of improving workers' health and safety a high or medium level of importance (i.e. a score of 3 or 2) and 0 otherwise; similarly EI takes value 1 when firms have attached a high or medium degree of importance to the objective of reducing environmental impacts, 0 otherwise.

Tables A.4 shows the results arising from the bivariate probit model for HSI and EI, by reporting the estimated coefficients and, then, the marginal effects. The latter are computed as the marginal (univariate) probability of outcome 1 Pr(HSI=1) (and then of outcome 2 Pr(EI=1)) holding all other variables at their means; that is, for a binary variable X_k, the marginal effect is: $Pr(Y = 1|X, X_k = 1) – Pr(Y=1|X, X_k = 0)$.

The interaction with almost all the external actors exerts a similar impact upon the probability of attaching importance to both HSI and EI. The only remarkable difference emerges for the interaction with universities which has no significant effect on HSI while a one unit increase of the importance ascribed to this type of interaction increases the probability of EI by 4 percentage points.

With respect to HRM practices, the presence of on-the-job training does not affect EI, while the probability of HSI augments by 3.4 percentage points. Instead, the adoption of new methods of work organization has a quite strong effect on both S&RIs, although the marginal effect on HSI turns out to be significantly higher than that on EI (12 versus 8 percentage points). Similar considerations apply to the role or regional public support for innovation, albeit in this case the marginal effect is higher for EI as opposed to HSI. The same occurs for the effect of firm size, since being a large firm exerts a much higher marginal effect upon EI than HSI (11 versus 6 percentage points).

The engagement on R&D has a positive impact on EI only, while the investment in advanced machinery positively influences only HSI. Finally, the results for sectoral variables indicate higher marginal effects on both dependent variables for firms belonging to Public Utilities followed by those active in Construction.

Table A.4 – Bivariate probit estimates. Dependent variables: high/medium importance of workers' health and safety (HSI) and environmental protection (EI) as objectives of innovation (CIS 2010)

	Coefficients		Marginal effects	
	HSI	EI	HSI	EI
Depth of external interactions (from 0 to 3):				
Suppliers	0.1247*** (0.0181)	0.1050*** (0.0184)	0.0472*** (0.0069)	0.0419*** (0.0073)
Customers	0.0790*** (0.0179)	0.0736*** (0.0174)	0.0299*** (0.0068)	0.0294*** (0.0069)
Competitors	-0.0115 (0.0203)	0.0223 (0.0202)	-0.0044 (0.0077)	0.0089 (0.0081)
Consultants	0.0837*** (0.0179)	0.0513*** (0.0177)	0.0317*** (0.0068)	0.0205*** (0.0070)
Universities	0.0310 (0.0296)	0.1138*** (0.0282)	0.0117 (0.0112)	0.0454*** (0.0112)
Government and public research labs	0.0717* (0.0370)	0.0936*** (0.0359)	0.0271* (0.0140)	0.0373*** (0.0143)
Conferences	0.0420* (0.0216)	0.0911*** (0.0212)	0.0159* (0.0082)	0.0363*** (0.0085)
Scientific journals	0.0637*** (0.0239)	0.0411* (0.0234)	0.0241*** (0.0090)	0.0164* (0.0093)
Professional and industry associations	0.0997*** (0.0202)	0.0874*** (0.0200)	0.0377*** (0.0077)	0.0349*** (0.0080)
On-the-job training	0.0931** (0.0365)	0.0459 (0.0361)	0.0351** (0.0137)	0.0183 (0.0144)
New work organisation	0.3148*** (0.0356)	0.2038*** (0.0354)	0.1190*** (0.0134)	0.0811*** (0.0140)
National or EU public support	-0.0580 (0.0552)	0.0345 (0.0544)	-0.0221 (0.0211)	0.0138 (0.0217)
Regional public support	0.1025** (0.0451)	0.1723*** (0.0440)	0.0383** (0.0167)	0.0686*** (0.0175)
R&D engagement (in-house and/or external)	-0.0792** (0.0394)	0.0808** (0.0389)	-0.0299** (0.0149)	0.0322** (0.0155)
Advanced machinery, equipment or software	0.1469*** (0.0496)	0.0773 (0.0494)	0.0564*** (0.0193)	0.0308 (0.0196)
Medium size	-0.0455 (0.0424)	0.0294 (0.0422)	-0.0173 (0.0161)	0.0117 (0.0169)
Large size	0.1619*** (0.0531)	0.2909*** (0.0519)	0.0601*** (0.0193)	0.1153*** (0.0203)
High-tech manufacturing	0.2747*** (0.0686)	0.2330*** (0.0674)	0.0997*** (0.0237)	0.0925*** (0.0265)
Low-tech manufacturing	0.3580*** (0.0511)	0.3137*** (0.0507)	0.1313*** (0.0180)	0.1245*** (0.0199)

Table A.4 (continued)

Knowledge intensive business services	-0.4780*** (0.0554)	-0.4242*** (0.0568)	-0.1858*** (0.0217)	-0.1662*** (0.0215)
Public utilities	0.4166*** (0.1001)	0.6189*** (0.0935)	0.1446*** (0.0309)	0.2349*** (0.0319)
Transport	0.1712* (0.0882)	0.1085 (0.0892)	0.0629** (0.0313)	0.0432 (0.0355)
Construction	0.4029*** (0.0664)	0.4731*** (0.0644)	0.1421*** (0.0214)	0.1844*** (0.0239)
Constant	-0.7483*** (0.0702)	-1.1331*** (0.0714)		
Log pseudolikelihood	-6470.1945			
athrho	1.0131***			
Wald test of independent (H0: rho=0)	1208.16***			
Number of observations	6000		6000	

"Small size" and "Trade and other services" used as reference categories. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

In conclusion, the overall findings and implications arising from the computation of marginal effects, with a bivariate probit regression, are consistent with those stressed in Section 4 of the main text, based upon a bivariate ordered probit regression.