Gender diversity in European firms and the R&D-innovation-productivity nexus

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Abstract

In this paper, we empirically explore whether gender diversity in European firms, measured at different organisational levels, contributes to enhancing their performance in terms of innovation and productivity. Particularly we propose a structural econometric framework that allows us to simultaneously account for gender diversity at the workforce and ownership level throughout different phases of the innovation process, from the decision to engage in R&D to productivity. Our results reveal that gender diversity is strongly related to firms' performance, besides the traditional factors envisaged by the literature. However, some differences emerge according to the firms' organisational levels. Indeed, workforce gender diversity seems to be relevant to all phases of the innovation process. By contrast, the positive influence of ownership gender diversity seems more narrowed as limited to the innovation development/implementation phase; moreover, increasing women's participation beyond a certain threshold is negatively associated with firms' productivity.

Keywords Workforce and ownership gender diversity · R&D · Innovation · Productivity · European firms

JEL Classification J16 · L25 · O31 · O33

1 Introduction

Innovation and productivity are key to firms' competitive advantage and countries' economic growth and have, thus, received widespread attention from economic literature. Among the sources of firms' innovation and productivity, a growing strand of research is focusing on the role of diversity in the composition of the firms' human resources. Implicit to this is the idea that human capital diversity, analysed from different perspectives or

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dimensions—not only in terms of knowledge and skills acquired through education and career paths, but also looking at some demographic characteristics such as nationality, age, and gender—can be linked to firms' innovative behaviour and outcomes (Laursen et al., 2005; Østergaard et al., 2011). To contribute to such a new avenue, in this paper we focus on firms' gender diversity, which remains still unexplored to a large extent (Audretsch et al., 2020a). Indeed, the role of women and, more generally, of minorities within firms' organisation is still marginalised in economics and innovation literature, also due to limited data availability (Link, 2022).

Nowadays, women are largely underrepresented in firms, especially at the top level. Over the last decades, several local, national, and international programs have been directed to promote firms' gender diversity, especially to increase the number of women in leadership positions. Since 2005, legislative initiatives and radical gender quota regulations for the largest companies have been introduced in many European Union (EU) countries, and EU-level binding quotas for company boards have been considered by the European Commission (Smith, 2018). More recently, promoting female entrepreneurship and self-employment has been included among the key actions of the Europe 2020 strategy of the EU Commission. Despite this, the progress towards greater gender diversity in European firms, at all levels, has been slow. Moreover, the recent crisis generated by the Covid-19 pandemic has disproportionally affected women's employment and women-led firms, partly due to their over-representation in the hardest-hit sectors such as food and hospitality industries, retail, and personal services (EU Commission, 2021; Torres et al., 2021).

In theory, diversity in the composition of the firms' human resources, also (though not exclusively) in terms of gender, might entail both positive and negative effects. On the one hand, it could positively contribute to performance, ensuring better support for value creation at all levels of firms' organisation. This is mainly by expanding the firms' knowledge base (Penrose, 1959) and, thus, their ability to absorb external knowledge and interact with different types of knowledge and competencies (Cohen & Levinthal, 1990; Lundvall, 1992). On the other hand, high levels of diversity in firms' personnel could generate conflicts and augment management costs and risks to handle such diversity, therefore resulting in lower benefits and performance of firms (Harrison & Klein, 2007). Hence, too little, and too much diversity could both be harmful to firms' innovation, implying an inverted curvilinear relationship (Østergaard et al., 2011). In this respect, however, different organisational levels within firms must be considered. Furthermore, there is a need to distinguish between diverse performance indicators and national institutional/economic contexts. All these differences are likely to explain the somewhat mixed results provided by extant empirical research (e.g. Link and Strong, 2016; Amoroso and Audretsch, 2022; Xie et al., 2020).

Given this, by taking advantage of firm-level data on EU countries drawn from the most recent *Enterprise Survey* of the *World Bank*, we propose a structural econometric framework to empirically explore *whether gender diversity at different levels of firms' organisation is good for firms' performance*. This is an important and complex issue that deserves research.

Ideally, high levels of inclusion of women in workplaces could positively affect firms' performance through different mechanisms. Nevertheless, in our view, when assessing the role of gender diversity, it is crucial to account for (and distinguish between) different levels of firms' organisation. Indeed, if inclusion and diversity are confined only to certain levels, for instance, if they remain a privilege experienced only by those at senior levels, firms risk missing out on considerable potential benefits. This implies that a positive contribution to the performance of firms cannot be taken for granted. Moreover, the results

provided by previous studies which have tended to focus on just one, specific, organisational level within firms—often emphasising specific departments or occupational groups such as R&D and top management teams or corporate boards—could be misleading. The composition of such specific, smaller, groups or departments does not necessarily reflect the composition of the larger pool of human capital within firms (Laursen et al., 2005; Østergaard et al., 2011). Therefore, in this study we measure gender diversity at two comprehensive and very different levels of firms' organisation, that is, workforce and ownership. Then, we assess the relationship between workforce and ownership gender diversity and firms' performance, considering both innovation (in terms of inputs, i.e. R&D investments, and outputs, i.e. new products and processes) and productivity.

Our contribution to the extant literature is, thus, threefold. First, we extend the line of enquiry on human capital and firms' performance, by contributing to a novel avenue that sheds light on the role of diversity in the composition of the firms' human resources as a further crucial factor that is likely to explain the achievement of different results by firms with otherwise similar characteristics (e.g. in terms of size, sector, investments etc.). Second, we deviate from previous studies, which generally examine gender diversity focusing on a single organisational level or a specific working environment within firms, such as boards, management teams or general employees (e.g. Singh et al., 2008; Díaz-García et al., 2013). Instead, we consider and confront gender diversity both at the bottom (workforce) and top (ownership) levels of firms' organisation. Moreover, under such a framework, we also avoid focusing on just one performance indicator as we account for different indicators throughout the innovation process, examining the association of gender diversity to each phase, from the decision to invest in R&D, to the introduction of new products or processes, until productivity. Finally, compared to previous empirical research which is mostly based on single-country firm-level data, by relying on a large sample of firms in EU countries and, thus, taking advantage of cross-country heterogeneity in terms of women's employment and participation at work, we aim to provide more robust evidence about patterns regarding the role of gender diversity that extends beyond any one country (see also Dohse et al., 2019).

The rest of the paper is organised as follows. In Sect. 2, after discussing the theoretical background of the study, we survey the related literature and develop specific research hypotheses. In Sect. 3 we explain the econometric model, while in Sect. 4 we describe the data and variables employed. In Sect. 5 we present the results and, in the last section, we discuss the main evidence and conclude the work.

2 Theoretical background, literature review and hypotheses

In the knowledge-based economy, firms rely more on their intangible resources than on their tangible ones to gain a competitive advantage (Teece et al., 1997). According to the resource-based view, the role played by the knowledge base, mainly residing in firms' human capital resources, is prominent to explain their performance (Penrose, 1959; Barney, 1991). Regarding this, however, scholars argue that not only the quantity but also the quality of the firms' human capital matters, which leads to looking at the specific composition of the pool of individuals within firms from different perspectives (Laursen et al., 2005). Indeed, this latter can be examined not only in its cognitive dimension—i.e. by considering the "achieved" characteristics such as the knowledge and skills acquired through education and career paths - but also in its demographic

dimension—i.e. by looking at some "ascribed" demographic characteristics such as nationality, age, and gender. From all these perspectives, including that of gender, diversity in the composition of the firms' human resources is likely to expand the knowledge base at all levels of firms' organisation (Østergaard et al., 2011) and, by this, to increase firms' performance *via* different channels or mechanisms.

As highlighted by the evolutionary literature, firms that encompass a more extensive and diverse knowledge base are those with better problem-solving routines, broader search activities (Nelson & Winter, 1982; Dosi, 1988) and increased ability to absorb/exploit external knowledge sources (Cohen & Levinthal, 1990). Such firms should thus be characterised by higher opportunities for learning through interaction and exchange of different types of knowledge and competencies (Lundvall, 1992). Especially at the workforce level, considering both general employees and R&D or management teams, this is likely to positively affect firms' performance by sparking creativity and ensuring increased abilities to tackle complex problems through the generation of new ideas and the production of better solutions (Quintana-García and Benavides-Velasco, 2008). At the ownership level, scholars also posit that gender diversity on the board can be associated with an improved decision-making process, particularly by adding new perspectives to board discussions and improving board deliberations on complex issues (Huse & Solberg, 2006).

Further arguments are also advanced by studies in the management literature. For instance, firms that effectively manage diversity can reduce costs by lowering the rate of turnover of women (and other minorities) who leave work due to dissatisfaction with their careers and advancement opportunities; moreover, such firms can attract the most productive workforce through reputational effects (Cox and Blake, 1991; Azmat and Boring, 2020). Indeed, higher gender diversity inside the workplace is likely to increase individuals' perception of acceptance and inclusion and, through this, their engagement and participation at work, which are key determinants of human capital development and firms' performance in terms of innovation and productivity (Capozza & Divella, 2019).

On the other hand, however, it is also acknowledged that high levels of diversity in the firms' human resources may imply the need of strengthening interaction and communication, at all levels, to avoid conflicts and distrust (Østergaard et al., 2011). Therefore, if it is too high, diversity could lead to increased conflictuality and management costs for the firms, mainly because of rising difficulties in the interaction between different groups and knowledge bases that result in less communication and interaction, or due to longer times needed to make decisions and reach an agreement (Laursen et al., 2005; Harrison & Klein, 2007). Additionally, diversity in ascribed characteristics, such as gender, could produce negative consequences for firms if the members of the minority group experience less job satisfaction, lack of commitment, and perceived discrimination (Milliken & Martins, 1996).

Given all this, a positive association between gender diversity, at different organisational levels within firms, and their performance in terms of innovation and productivity cannot be taken for granted and need to be empirically explored: indeed, only firms able to effectively manage human capital diversity, at all levels, are likely to reap the potential benefits.

In the following subsections, we, therefore, review the relevant empirical literature on the role of gender diversity in firms' innovation and productivity, both at the workforce and ownership levels of firms' organisation. Then, building on the discussed theoretical background and the surveyed empirical evidence, we derive our research hypotheses to be tested.

2.1 Gender diversity in firms' workforce and ownership

A growing literature is analysing the relationship between gender diversity in the workforce and the performance of firms. The results provided, although mostly validate a positive relation, appear rather fragmented and scarcely comparable because of differences in defining performance indicators (e.g. innovation measured in different ways), in working environments (e.g. R&D or management teams, corporate boards, general employees, etc.) and national economic contexts that may affect the role of gender diversity.

By using a representative sample of German enterprises in manufacturing industries, a study by Pfeifer and Wagner (2014a) shows that firms with a higher share of female employees are more active in R&D. Using data from an innovation survey in Spain, Díaz- García et al., (2013) find that gender diversity in R&D teams generate certain dynamics that foster novel solutions leading to radical innovations. Looking at Danish manufacturing and service firms, a study by Østergaard et al. (2011) provides evidence of a positive relationship between employee gender diversity and the likelihood of introducing an innovation. For Colombian firms, especially the involvement of female employees in science, technology, and innovation (STI) activities is found to exert a positive influence on the likelihood of introducing technological innovations (Gallego & Gutierrez, 2018; Xie et al., 2020) also find that, for firms in China, gender diversity within R&D teams positively affects the generation of new product sales per unit of R&D investments. Horbach and Jacob (2018) shed light on how having a large share of highly qualified women in the workforce and, particularly, a female presence in management teams, is positively correlated with firms' eco-innovation activities in German firms. As for Italian manufacturing firms, Castiglione et al. (2022) find a positive relationship between the presence of women in management teams and firms' productivity. Garnero et al. (2014) show that workforce gender diversity is beneficial for firm productivity only in high-tech/knowledge-intensive sectors. Fewer works, instead, report a negative relation between employee gender diversity and productivity, even though firms with higher shares of females among their employees exhibit a higher level of profitability (Pfeifer & Wagner, 2014b).

Regarding the role of women in firms' ownership—either self-employed women who run their own business or those on corporate boards of the largest companies—who can primarily influence innovation through their strategic decisions (Talke et al., 2010), the evidence provided, up until now, is more mixed. Specifically, extant research on innovation in women-owned firms, particularly entrepreneurial firms, has become more prominent in recent years, providing systematic evidence and various theoretical explanations of gender differences in firms' performance. Although this research often points in the direction that women-owned firms are less innovative and performing than male-owned ones (Link & Strong, 2016), the results greatly vary with countries and economic contexts examined (Amoroso & Link, 2018; Audretsch et al., 2020a, b; Link and Hasselt, 2020), which overall supports that more research is needed in this regard.

According to the extant literature, the finding that women-owned firms might be less innovative than their male counterparts could be explained by the fact that women-led firms are more concentrated in less innovative sectors (Fontana et al., 2016). Indeed, by comparing patent rates of female and male firms in the same high-tech sectors, the study by Demiralp et al. (2018) shows that men-owned firms significantly lag behind. In another work, Amoroso and Link (2018) support this view by providing evidence of

a mixed relationship between the gender of founders and firms' performance, at least in terms of employment growth and innovative sales: in fact, such relationship turns out to be positive in high-tech manufacturing sectors, but negative in low-techs and in Southern European countries. The authors hence posit that the gender gap in performance is rather a sectorial issue, namely related to the tendency of women-founded firms to cluster in low-profitability sectors. Similarly, Amoroso and Link (2021) find that the probability of patenting and choosing any form of intellectual property (IP) protection, is negatively related to the number of women in the founding team, claiming that this is probably due to women's underrepresentation in more patent–intensive STEM fields, particularly to a higher presence of women–owned firms in the service sectors, where other forms of innovations, such as new business or marketing practices, not detectable with patents or other forms of IP, are more frequent.

Other arguments are based on differences in other dimensions of human capital (e.g. education or experience). Coleman (2005), for instance, using data on US firms from the Survey of Small Business Finance, finds that controlling for differences in education and past experience, female–owned firms, despite their smaller size, are more profitable and have higher sales growth than male-owned ones. Findings from a study on UK corporate boards (Singh et al., 2008), which explores gender differences in education, profile, and career experiences, also contradict the general perspective that women are unprepared for boardroom positions.

Further studies shed light on how women owners could be more risk-averse than men (Charness & Gneezy, 2012; Palvia et al., 2015) and, thus, are less likely to undertake innovation activities if the economic environment is perceived as too risky and uncertain (Estrin & Mickiewicz, 2011; Belitski et al., 2016; Hsieh et al. 2018). Regarding this, however, another strand of research has highlighted that the key factor affecting the innovation behaviour of women–led firms is access to finance and availability of resources (Gicheva & Link, 2013, 2015; Sauer & Wilson, 2016). Therefore, the circumstance that in many institutional contexts (especially developing countries) women might be more restricted in access to economic resources needed for innovation (World Bank, 2019) and, thus, more likely to experience gender–based discrimination in this respect—including limited venture and equity investments in women-led firms (Balachandra et al., 2019; Kleinert and Mochkabadi, 2021)—could be the real reason why women behave differently with respect to investment risks. In line with this, Audretsch et al. (2020a) demonstrate that a crucial element in making women-owned firms innovate is increased access to resources, including firms' internal resources and income after tax. Therefore, institutional contexts characterised by high gender inequality in access to capital and weak fiscal freedom might severely hamper innovation in womenled firms. For instance, in a recent study, Belitski and Desai (2021) show a negative effect of women ownership on productivity in Pakistani and Indian firms.

By using a sample of Spanish women entrepreneurs, Fuentes et al. (2015) also show that knowledge acquisition positively influences the entrepreneurial process and that both knowledge acquisition and entrepreneurial orientation improve the operational and financial performance of women-owned firms. Another study by Amoroso and Audretsch (2022), based on a sample of firms located in different European countries, confirms that female–led firms have an advantage compared to male–led ones in reaping the benefits of the knowledge acquired from research institutes and value-chain partners, which is perhaps due to a natural preference or tendency of women to organise activities into collaborative networks. Such a feminine approach is thus associated with increased R&D efforts.

2.2 Hypotheses development

Hence, considering the theories discussed above, we contend that gender diversity, mainly by expanding the knowledge base at different levels of firms' organisation, can give rise to and favour those virtuous dynamics of new knowledge generation and accumulation that then lead to increased innovation and productivity performance.

At the workforce level, this is likely to happen because a more extensive and diverse knowledge base entails higher abilities to absorb, integrate, and combine different types of knowledge and competencies within the firms. This, in turn, should boost creativity and problem-solving capacities, which are both crucial for innovation and innovation-driven productivity. The existing empirical literature seems to support this view, despite all the stressed limitations (see Sect. 2.1) and some studies providing opposite evidence.

At the ownership level, an extended and diverse knowledge base entailed by women's inclusion is also likely to add new perspectives to board discussions and, therefore, enhance board deliberations on complex issues. In this case, extant empirical research does not provide clear-cut results, which further supports the need to investigate the role of gender diversity at this level with respect to the innovation-productivity nexus of the firms.

In light of all the above, we introduce the following three research hypotheses to be tested in our empirical analysis. Compared to previous studies, mostly based on single-country firm-level data, we rely on a sample of firms in different EU countries. We, thus, take advantage of cross-country heterogeneity in terms of women's employment and participation at work to provide more robust evidence:

Hypothesis 1 Gender diversity, both at the workforce and ownership level, is positively related to firms' R&D efforts.

Hypothesis 2 There is a positive association between gender diversity, in the workforce and ownership, with the technological innovation outcomes of the firms.

Hypothesis 3 Gender diversity, both at the workforce and ownership level, is positively related to firms' productivity.

3 The model

The CDM model (Crepon et al., 1998) is a structural econometric model often used by researchers to explore the relationship between firms' R&D efforts, innovation, and productivity by breaking it down into three recursive stages: (i) the firm's decision to invest in R&D and, conditionally on that, the amount of R&D investments; (ii) the transformation of innovation inputs and other internal or external resources into innovation outputs; (iii) the effect of innovation outputs on firm's productivity. In this work, we extend the CDM model by introducing two measures of gender diversity -at the workforce and ownership level- at each stage, to comprehensively examine their association with the different phases of the innovation process (Fig. 1).

The first stage analyses the innovative efforts. Since R&D expenditure can be measured only if firms report it, we account for the possible selection into R&D using the Heckman's selection-model (Heckman, 1979). Formally:
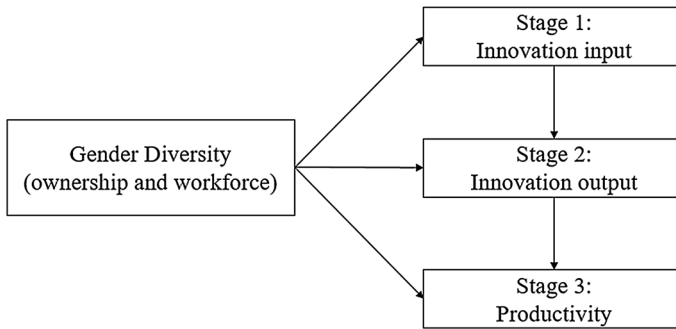
Fig. 1 Workforce and ownership gender diversity and the R&D-innovation-productivity nexus

$$R\&D\,decision_i = \begin{cases} 1, if\,R\&D_i^* = G_i'\alpha_1 + X_i'\alpha_2 + e_i > c \\ 0, if\,R\&D_i^* = G_i'\alpha_1 + X_i'\alpha_2 + e_i \leq c \end{cases} \tag{1}$$

where i indexes the firm, $R\&D\,decision_i$ is the observed binary variable for R&D engagement, $R\&D_i^*$ is an unobserved latent variable that defines the probability of undertaking R&D. The observed $R\&D\,decision_i$ takes value 1 if the unobserved $R\&D_i^*$ is larger than a certain threshold level c, 0 otherwise. Moreover, G_i is the vector of our core variables measuring gender diversity at two different firm's organisational levels, workforce and ownership; and X_i is the vector of controls expected to affect the dependent variable. Finally, e_i is the error term.

Conditional on the firm's decision to invest in R&D, we specify the equation for R&D intensity as follows:

$$R\&D\,intensity_i = \begin{cases} R\&D\,intensity_i^* = G_i'\beta_1 + X_i'\beta_2 + \epsilon_i \,if\,R\&D\,decision_i = 1 \\ 0 \quad if\,R\&D\,decision_i = 0 \end{cases} \tag{2}$$

where $R\&D\,intensity_i^*$ is the unobserved latent variable reflecting the firm's R&D investments, and ϵ_i is the error term. We measure $R\&D\,intensity_i$ as the logarithm of R&D expenditure. Under the assumption that the error terms e_i and ϵ_i are univariate normal with zero mean and independent of the explanatory variables, we can estimate the system of Eqs. (1) and (2) as a Heckman selection model in a two-step estimation.

The second stage analyses the knowledge production function (Pakes & Griliches, 1984)—i.e. the transformation of innovation inputs into innovation outputs, namely the innovation development/implementation phase—by the following equation:

$$Innovation_i = \begin{cases} 1, if\,Innovation_i^* = R\&D\,intensity_i^*\gamma + G_i'\delta_1 + Z_i'\delta_2 + u_i > c \\ 0, if\,Innovation_i^* = R\&D\,intensity_i^*\gamma + G_i'\delta_1 + Z_i'\delta_2 + u_i \leq c \end{cases} \tag{3}$$

where $Innovation_i$ is a binary variable taking value 1 if firm i has introduced a technological innovation (i.e. a product and/or a process innovation), 0 otherwise. Among the innovation inputs, on the right-hand side of the equation, we consider the variable $R\&D\,intensity_i^*$, which is the predicted value from the first stage. By using the predicted instead of the observed R&D intensity, we account for the possibility that firms (especially those of smaller size) might be involved in some R&D activities without reporting them. Moreover, we consider that firms' innovative efforts, i.e. in terms of R&D, are potentially endogenous

to the knowledge production function. Indeed, there could be an endogeneity problem in case of unobservable characteristics correlated with both R&D intensity and the knowledge production function (see Griffith et al., 2006; Hall et al., 2009; Baumann and Kritikos, 2016 and, more recently, Medda, 2020; Audretsch and Belitski, 2020 and Audretsch et al. 2020b which adopt the same approach in various versions of the CMD model).

As in the previous stage, G_i indicates the vector of core variables accounting for workforce and ownership gender diversity, and Z_i refers to the vector of other explanatory variables inserted as controls, while u_i is the error term.

To estimate Eq. (3), we use a probit model. Considering that the model is estimated in sequential stages, conventional standard error estimates would be biased, therefore we compute bootstrap standard errors with 1000 repetitions.

The third stage analyses productivity. We estimate a log-transformed Cobb-Douglas production function augmented by the knowledge stock (Griliches, 1979), and by our two—workforce and ownership—gender diversity measures, plus various controls:

$$y_i = \pi_i \, Innovation_i^* + G_i' \psi_1 + V_i' \psi_2 + v_i \tag{4}$$

where y_i represents the labour productivity of firm i. To account for the knowledge input, we include the variable $Innovation_i^*$ considering the predicted probability that firm i introduces a technological innovation computed from the second stage. Again, we use the predicted probability of innovating to account for the potential endogeneity issue concerning innovation. Next, G_i refers to the vector of core variables measuring workforce and ownership gender diversity. Moreover, V_i is the vector of explanatory variables, among which the labour input, measured by the number of employees, and the capital input, proxied by the expenditure in fixed assets per employee. Since the labour input is included in the right-hand side of the equation, the production function does not impose constant returns to scale. Finally, v_i indicates the error term.

Equation (4) is estimated via OLS and bootstrapped standard errors are computed with 1000 replications.

4 Data and variables

We use the *Enterprise Survey (ES)*, a firm-level survey based on face-to-face interviews with managers conducted in 2018–2021 by the World Bank. The *ES* provides detailed information on firms' sales, innovative activities, workforce and ownership, besides other general information, and has a wide sectorial coverage of the non-agricultural economy, following the group classification of ISIC Revision 3.1, thus including all manufacturing sectors, construction, services, transport, storage and communications and IT.

At Stage 1, we define the dependent variable *R&D decision* as a binary variable equal to 1 if the firm, during the last three years, has invested in R&D activities, either in-house or outsourced (excluding market research surveys), 0 otherwise. Moreover, for firms with positive R&D investments, we define the variable *R&D intensity*, as the logarithm of expenditure in R&D expressed in Euro.

At Stage 2, we define three binary dependent variables which are alternatively employed in the regressions: *Technological innovation*, equal to 1 if the firm, during the last three years, has introduced any technological innovation (i.e. new or significantly improved products or services, and/or new or significantly improved methods for the production or supply of products or services), and 0 otherwise; *Product innovation* and *Process innovation*,

which respectively account for the introduction of new products and processes separately considered.

At Stage 3, we define the dependent variable *Labour productivity* as the logarithm of sales per employee (in Euro).

Turning to the main explanatory variables, aimed at detecting workforce and ownership gender diversity, we use the Blau index of demographic heterogeneity (Blau, 1977). We define the variable *Ownership diversity*, as equal to $\left(1 - \sum P_k^o\right)$, where P_k^o is the proportion of the owners in each category k, men and women. The variable *Workforce diversity* has the same construction, $\left(1 - \sum P_k^w\right)$, where P_k^w refers to the proportion of workers in each category, men and women. Both variables range from 0 (when a single gender is present) to 0.5 (for firms characterised by a balanced number of men and women).

Additionally, we introduce the binary variable *Female top-manager*, equal to 1 if the top manager in a firm is a woman, and 0 otherwise. Although this variable does not directly measure gender diversity, it further accounts for the presence of a woman in the very leading positions of firms.

Turning to controls, we first consider various measures of firms' endowment of *general* and *specific* human capital, related to the people-embedded knowledge stock acquired through formal (academic) education, or rather referred to the knowledge obtained through prior work experience and on-job training (Capozza & Divella, 2019). Hence, we introduce the variable *Education*, defined as the percentage of the permanent full-time workforce (employees and managers) holding a university degree. Then, we introduce the variable *Top-manager experience*, defined as the logarithm of the number of years of working experience of the top manager in the same firm's industry. Finally, we consider the binary variable *On-job training*, equal to 1 if the firm has formal training programs for its permanent full-time employees, and 0 otherwise.

Moreover, we define the variable *Labour* as the logarithm of the number of permanent full-time employees, which should account for the firm's size, and the variable *Capital* as the logarithm of expenditure in fixed assets (such as machinery, vehicles, equipment, land, or buildings) per employee expressed in Euro, that accounts for firm's fixed capital investments.

Next, we consider the variable *Main market* to measure the size of the market in which a firm operates. Specifically, *Main market (local)* is equal to 1 if the main market in which the firm sells its main product is local, and 0 otherwise; *Main market (national)* is equal to 1 if the main market in which the firm sells its main product is national, and 0 otherwise (omitted category), and *Main market (international)* is equal to 1 if the main market in which the firm sells its main product is international, and 0 otherwise (*local* is treated as the omitted category in estimations). The variable *Age* stands for the firm's age, measured by the logarithm of the number of years since the firm has begun operations.

Finally, potential differences in the technological dynamism of industrial sectors are considered, together with the geographical location of firms. Indeed, various aspects of the national, institutional and economic environment in which firms are embedded may have implications both for the role of gender diversity and for firms' innovation. To control for these factors, we include country and industry dummies in all estimations.[1]

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[1] Based on industry aggregation available in the Enterprise Survey, the grouping criteria of industries is the following: 1 = manufacture of food, beverage and tobacco; 2 = manufacture of textiles and textile products; 3 = manufacture of leather and leather products; 4 = manufacture of wood and wood products; 5 = manufacture of pulp, paper and paper products; publishing and printing; 6 = manufacture of coke and chemicals; 7 = manufacture of rubber and plastic products; 8 = manufacture of other non-metallic mineral products; 9 = manufacture of basic metals and fabricated metal products; 10 = manufacture of machinery and equip-

A specific set of control variables is considered at each stage, in line with most recent works employing the CDM model (Audretsch and Belitski, 2020; Audretsch et al. 2020b). A summary description of the variables introduced in the analysis, along with descriptive statistics, is provided in Table 1.

In Table 2, we show an overall prospect of gender diversity in firms' workforce and ownership across the EU countries.

As can be seen, the mean values of the *Workforce diversity* and *Ownership diversity* indexes are both quite low, which overall suggests a low level of gender diversity in firms across EU countries. Moreover, the average gender diversity in firms' ownership is less than half the average gender diversity in firms' workforce, confirming that the presence of women at firms' top level is particularly disadvantaged. Particularly Austria is the country with the highest value of gender diversity in the workforce, equal to 0.332, while Poland and Portugal exhibit the lowest corresponding value, equal to 0.24. Instead, Ireland reports the highest value of gender diversity in ownership, equal to 0.215, while Italy shows the lowest value, equal to 0.056.

5 Results

In Table 3, we report the results obtained by estimating our proposed CDM model, extended to account for the role of workforce and ownership gender diversity in European firms with respect to different phases of the innovation process, from the decision to engage in R&D to productivity.

In columns 1 and 2, we show the results of Stage 1, where we estimate a two-step Heckman selection model composed of a selection equation for R&D decision, and a linear R&D intensity equation. First, it is worth stressing that the estimated coefficient lambda (at the bottom of the table), which accounts for the possible selection bias, turns out positive and highly significant, implying that the hypothesis of uncorrelated error terms is rejected. This confirms the choice of the Heckman procedure that we follow in this study as compared to standard techniques that, applied to the outcome equation (R&D intensity), would yield biased results.

Coming to the relationship between gender diversity and innovation efforts, we find that the estimated coefficient of *Workforce diversity* is positive and highly significant both in the selection and outcome equations, accounting, respectively, for firms' *R&D decision* and *R&D intensity*. The coefficient of *Ownership diversity* is not significant in the selection equation, but positive and slightly significant (at a 10% level of confidence) in the outcome equation. Such evidence on the role of women at the top level of the firms is consistent with the finding that the coefficient of the variable *Female top-manager*, included to simply account for the presence of a woman in the top management position, is negatively and significantly associated with both the dependent variables. Taken together these results only partially confirm Hypothesis 1: indeed, the positive association between gender diversity

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Footnote 1 (continued)

ment (including office machinery); 11 = manufacture of electrical and optical equipment; 12 = manufacture of transport equipment; 13 = manufacturing n.e.c.; 14 = construction; 15 = sale, maintenance and repair of motor vehicles; 16 = wholesale trade; 17 = retail trade; 18 = Hotels and restaurants; 19 = Transport, storage and communication; 20 = Computer and related activities.

Table 1 Description of variables

Variables	Definition	Obs.	Mean	SD
Dependent variables at stage 1				
R&D decision	Binary variable equal to 1 if the firm, during the last three years, has spent on research and development activities, either in-house or outsourced (excluding market research surveys), 0 otherwise.	14,950	0.212	0.409
R&D intensity	Logarithm of expenditure in R&D expressed in Euro.	3,174	11.322	2.161
Dependent variables at stage 2				
Technological innovation	Binary variable equal to 1 if the firm, during the last three years, has introduced technological innovation (new or significantly improved products or services, and/or new or significantly improved methods for the production or supply of products or services), 0 otherwise.	14,950	0.534	0.499
Product innovation	Binary variable equal to 1 if the firm, during the last three years, has introduced new or significantly improved products or services, 0 otherwise.	14,929	0.437	0.496
Process innovation	Binary variable equal to 1 if the firm, during the last three years, has introduced new or significantly improved methods for the production or supply of products or services, 0 otherwise.	14,912	0.282	0.450
Dependent variable at stage 3				
Labour productivity	Logarithm of total sales of firms expressed in Euro per full-time employees.	14,950	11.668	1.387
Gender diversity				
Ownership diversity	Index of demographic heterogeneity of Blau (1977), equal to $\left(1 - \sum P_k^o\right)$, where P_k^o is the proportion of the owners in each category, female and male owners. It ranges from 0 (a single gender exists) to 0.5 (balanced number of men and women).	14,950	0.293	0.164
Workforce diversity	Index of demographic heterogeneity of Blau (1977), equal to $\left(1 - \sum P_k^w\right)$, where P_k^w is the proportion of the all permanent full-time workforce (managers and employees) in each category. It ranges from 0 (a single gender exists) to 0.5 (balanced number of men and women).	14,950	0.117	0.192
Other control variables				
Female top manager	Binary variable equal to 1 if the top manager is female, and 0 otherwise.	14,950	0.158	0.365
Education	Percentage of the permanent full-time workforce (employees and managers) holding a university degree.	14,950	17.240	21.831
Top manager experience	Logarithm the number of years of working experience of the top manager in the same firm's industry	14,950	3.051	0.667
On-job training	Binary variable equal to 1 whether the firm has formal training programs for innovation for its permanent full-time employees, 0 otherwise.	14,950	0.448	0.497
Labour	Logarithm of the number of permanent full-time employees.	14,950	3.094	1.250

Table 1 (continued)

Variables	Definition	Obs.	Mean	SD
Capital	Logarithm of expenditure in fixed assets (such as machinery, vehicles, equipment, land or buildings) per employee expressed in Euro.	14,950	4.540	4.349
Main market	*Local*, equal to 1 if the main market in which the firm sells its main product is local, and 0 otherwise ((omitted category)	14,950	0.339	0.473
	National, equal to 1 if the main market in which the firm sells its main product is national, and 0 otherwise	14,950	0.484	0.500
	International, equal to 1 if the main market in which the firm sells its main product is *international*, and 0 otherwise	14,950	0.177	0.382
Age	Logarithm of the number of years since the firm has begun operations.	14,950	3.073	0.781

	Workforce diversity	Ownership diversity
Table 2 Gender diversity across European countries		
Austria	0.332	0.094
Belgium	0.290	0.121
Bulgaria	0.315	0.102
Croatia	0.320	0.069
Cyprus	0.327	0.142
Czech Republic	0.298	0.085
Denmark	0.283	0.075
Estonia	0.276	0.100
Finland	0.252	0.127
France	0.311	0.131
Germany	0.306	0.081
Greece	0.327	0.145
Hungary	0.292	0.166
Ireland	0.321	0.215
Italy	0.312	0.056
Latvia	0.270	0.107
Lithuania	0.284	0.108
Luxembourg	0.263	0.112
Malta	0.274	0.166
Netherlands	0.278	0.132
Poland	0.246	0.093
Portugal	0.247	0.143
Romania	0.263	0.087
Slovak Republic	0.318	0.102
Slovenia	0.328	0.110
Spain	0.296	0.189
Sweden	0.266	0.093
Mean	0.293	0.117

and R&D engagement is confirmed at the workforce level, though not supported at the ownership level of the firms' organisation.

As for controls, they are generally significant and with the expected sign. In particular, the coefficient of *Education* is positive and highly significant both in the selection and outcome equations, which confirms the expected complementarities between R&D and the general level of human capital. Such complementarities are fundamental not only for the generation of new knowledge but also for increasing firms' absorptive capacity (Cohen & Levinthal, 1990; Griffith et al., 2004). The coefficient of the variable *Age* turns out not statistically significant in both equations, while the coefficient of the variable *Labour*, inserted as a proxy of firm size, is positive and significant both in the selection and outcome equations. These results may suggest that R&D investments are subject to financial constraints that especially apply to smaller firms–e.g. higher cost of capital (Czarnitzki & Hottenrott, 2011; Conte & Vivarelli, 2014)–while young firms do not seem to be disadvantaged in this respect (Pellegrino et al., 2012). The coefficients of the variables *Main market (national)* and *Main market (international)* turn out to be both positive and significant at the 1% level

Table 3 Workforce and ownership gender diversity and the R&D-innovation-productivity nexus

	Innovation effort		Knowledge production function			Production function		
	R&D decision (selection equation)	R&D intensity (outcome equation)	Technological innovation	Product innovation	Process innovation	Labour productivity		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Workforce diversity	0.765***	0.323***	0.240***	0.284***	0.180**	0.202***	0.146***	0.319***
	[0.246]	[0.094]	[0.079]	[0.080]	[0.087]	[0.053]	[0.055]	[0.054]
Ownership diversity	0.085	0.140*	0.139**	0.136**	0.153**	0.256	0.238	0.280
	[0.179]	[0.073]	[0.063]	[0.060]	[0.064]	[0.202]	[0.205]	[0.205]
Ownership diversity squared						− 0.846**	− 0.837*	− 0.824*
						[0.425]	[0.431]	[0.426]
Female top manager	− 0.287**	− 0.149***	− 0.002	0.012	− 0.037	− 0.048**	− 0.051**	− 0.056***
	[0.115]	[0.042]	[0.033]	[0.032]	[0.036]	[0.020]	[0.020]	[0.021]
Education	0.026***	0.009***	− 0.001	− 0.000	− 0.001	0.003***	0.003***	0.005***
	[0.003]	[0.001]	[0.001]	[0.001]	[0.001]	[0.000]	[0.000]	[0.000]
Age	0.028	0.000	− 0.038**	− 0.016	− 0.045***	0.063***	0.051***	0.055***
	[0.042]	[0.018]	[0.017]	[0.016]	[0.016]	[0.011]	[0.011]	[0.010]
Labour	1.035***	0.231***	− 0.086***	− 0.102***	− 0.026	0.025***	0.030***	0.052***
	[0.079]	[0.012]	[0.028]	[0.026]	[0.029]	[0.008]	[0.008]	[0.008]
Main market (national)	0.988***	0.376***						
	[0.172]	[0.037]						
Main market (international)	1.823***	0.718***						
	[0.266]	[0.046]						
Top manager experience			− 0.030	− 0.038**	− 0.017	0.058***	0.070***	0.052***
			[0.019]	[0.018]	[0.018]	[0.011]	[0.011]	[0.012]
On job training			0.371***	0.279***	0.433***			
			[0.025]	[0.024]	[0.026]			

Table 3 (continued)

	Innovation effort		Knowledge production function			Production function		
	R&D decision (selection equation)	R&D intensity (outcome equation)	Technological innovation	Product innovation	Process innovation	Labour productivity		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Capital						0.019*** [0.002]	0.020*** [0.002]	0.021*** [0.002]
Predicted R&D intensity			0.156*** [0.022]	0.154*** [0.021]	0.117*** [0.023]			
Predicted Technological innovation						1.545*** [0.111]		
Predicted Product innovation							1.776*** [0.130]	
Predicted Process innovation								0.856*** [0.099]
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mills(lambda)	2.018***[0.474]							
Observations	14,950		14,950	14,929	14,912	14,950	14,929	14,912
Censored observations	11,776							
Uncensored observations	3,174							
Log pseudolikelihood			− 8,150.61	− 8,458.25	− 7,404.14			
Pseudo R^2			0.2108	0.1733	0.1655			
R^2						0.609	0.608	0.605

Standard errors in brackets. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

with respect either to firms' engagement in R&D and to R&D intensity, therefore confirming the relevance of market demand in spurring innovation, especially by increasing firms' R&D efforts (Griffith et al., 2006).

Next, in columns 3 to 5, we show the results of Stage 2. We consider, as the dependent variable, the introduction of technological innovation, i.e. new products and/or processes (column 3), but also the introduction of product and process innovations separately (columns 4 and 5). In this case, the coefficients are obtained by running probit regressions with maximum likelihood. At this stage, the coefficients of *Workforce diversity* and *Ownership diversity* are both positive and significantly associated (at 1% or 5% level of confidence) with the dependent variables. This evidence fully supports Hypothesis 2, confirming that a higher presence of women both at the bottom and top level of the firms might increase firms' capacity to introduce both product and process innovations.

The coefficient of the variable *Female top manager* turns out not significant. Moreover, we find that the coefficient of the variable *Education* is not significant, while the coefficient of the variable *Top manager experience* is negative and weakly associated with the probability of introducing a product innovation, though not significant in the other regressions. However, a more determinant role in the innovation development/implementation phase seems to be played by *On-job training*, which exhibits positive and highly significant coefficients across all the regressions. Considered together, these results are not surprising as in accordance with the evidence provided by some previous literature that also highlights the crucial role of people-embedded knowledge and competencies acquired through on-job training programs (Laursen & Foss, 2003; Santamaria et al., 2009; Capozza and Divella, 2019).

The coefficient of the variable *Age* is significant and negatively related to *Technological innovation*, particularly to *Process innovation*, suggesting that young firms might be relatively more successful in this respect (Pellegrino et al., 2012; Capozza et al., 2020). The coefficient of the variable *Labour* is also significant and negatively associated with the introduction of technological innovations, particularly with the probability of introducing new products, therefore confirming that, despite the differences concerning R&D efforts, once an output indicator (such as the introduction of new products and processes) is considered, smaller firms are not less innovative than their larger counterparts. This result thus indirectly supports the vital role played even by other innovation inputs, not necessarily rooted in formal R&D departments and systematic R&D activities that, instead, are more likely to take place in larger firms (Santarelli & Sterlacchini, 1990; Santamaria et al., 2009). The coefficient of the *Predicted R&D intensity* is positive and highly significant across regressions, which overall supports that greater R&D efforts increase the likelihood that firms introduce both product and process innovations. These results are in line with Griffith et al. (2006) and Audretsch et al. (2020a) among others, though in contrast with the study by Parisi et al. (2006) that, based on a sample of Italian manufacturing firms, find a positive relationship only with the probability of introducing a new product.

Finally, in columns 6 to 8, we show the results of Stage 3, namely the estimation of the productivity equation. The coefficients reported are obtained through bootstrapped OLS estimations.

In this case, the coefficient of *Workforce diversity* is positive and highly significant (at 1%) in all the regressions, therefore fully supporting a positive association with firms' productivity. As for *Ownership diversity*, a non-linear relationship with productivity emerges. Indeed, the coefficient of the variable *Ownership diversity* is positive but not significant, while the coefficient of *Ownership diversity squared*, included among the regressors to account for non-linear effects, turns out to be negative and significant. These findings

overall indicate that increasing ownership gender diversity, beyond a value of 0.17, is negatively associated with firm productivity. Hence, we can conclude that Hypothesis 3 is not fully supported: indeed, only workforce gender diversity is positively associated with firms' productivity; by contrast, increasing gender diversity in firms' ownership might exert a negative influence.

Consistently with the finding on ownership gender diversity, the coefficient of the variable *Female top manager* is negative and significantly associated with productivity in all estimations. The coefficients of the variables *Education* and *Top manager experience* turn out positive and highly significant in all the regressions (Backman, 2014; Andretta et al., 2021). The coefficient of the variables *Capital* and *Labour* are always positive and significantly associated with productivity as expected. The coefficient of the variable *Age* is also positive and highly significant, pointing to a positive relationship with productivity that, however, could be motivated by selection effects, namely by the fact that only the best firms (with higher productivity) survive so that the average productivity of the cohort of firms increases with age (see Coad et al., 2013). Finally, the estimated coefficients of *Predicted Technological innovation*, *Predicted Product innovation* and *Predicted Process innovation* are positive and highly significant, which fully confirm the expected positive relationship between the introduction of new products and processes and firms' productivity (Parisi et al., 2006; Hall et al., 2009).

6 Discussion and conclusions

In this paper, we address the question of whether gender diversity in the firms' human resources, both at the workforce and ownership level of firms' organisation (Horbach and Jacob, 2018), contributes to enhancing their performance in terms of innovation and productivity. As widely discussed, prior research on this issue is limited, providing rather fragmented and scarcely comparable results, which greatly vary with the specific work environment within the firms, as well as with the performance indicators and the national contexts examined. To the best of our knowledge, there are no studies in which the role of gender diversity at two comprehensive and very different levels of firms' organisation—workforce and ownership—is simultaneously examined in the entire R&D–innovation–productivity process. We contend that, in assessing the role of gender diversity, it is crucial to account for (and distinguish between) different levels of firms' organisation: indeed, the positive contribution of gender diversity to firm performance cannot be taken for granted if inclusion and diversity are confined only to specific departments or smaller occupational groups, as these would not necessarily reflect the composition of the larger pool of human capital within firms.

By employing data on firms in EU countries, the empirical analysis carried out partially supports our conjectures and, particularly, highlights the need to account for different levels of firms' organisation when exploring the role of gender diversity. Indeed, our results reveal that gender diversity is strongly related to firms' performance. Nevertheless, some important differences emerge according to firms' organisational levels. Indeed, workforce gender diversity seems to be relevant to all phases of the innovation process, supporting that firms with a more balanced gender composition among their workforce are more likely to invest in R&D and are also characterised by higher R&D intensity. Moreover, firms with greater workforce gender diversity are more likely to introduce technological innovations (both new products and processes) and exhibit higher productivity. These findings

are overall in accordance with the positive results highlighted by some previous works on the role of gender diversity at the workforce level (e.g. Østergaard et al., 2011; Pfeifer and Wagner, 2014a; Horbach and Jacob, 2018; Gallego and Gutierrez, 2018; Xie et al., 2020).

Differently from workforce gender diversity, the influence of ownership gender diversity seems to be more narrowed as limited to the innovation development/implementation phase. It is not relevant with respect to firms' R&D engagement and intensity. Moreover, a non-linear relation emerges with firms' productivity, which suggests that when it is too low, ownership gender diversity does not contribute to firms' productivity; however, increasing women's participation after a certain threshold might lead to negative results. These findings contrast the positive evidence provided by some recent studies (e.g. Audretsch et al., 2020a; Amoroso and Audretsch, 2022) and, rather, support that, for various reasons—which could be related to a disadvantage of women in accessing the (financial and non-financial) resources needed for innovation due to various types of barriers in the business environment, but also to a general underrepresentation of women in scientific/technical fields (see Sect. 2.2)—women-led firms may underperform as compared to men-led ones (Amoroso & Link, 2018, 2021; Link & Hasselt, 2020; Belitski & Desai, 2021).

The main limitation of our research lies in the cross-sectional nature of the data employed, which implies that the results should be interpreted with caution, that is, in terms of correlations that do not necessarily entail causal relationships between the variables employed. The eventual availability of longitudinal data in the future would thus allow us to further validate the evidence provided.

From a policy perspective, one of the key messages from our study is that simply increasing the presence of women in the workforce, regardless of the degree of education or the specific type of professional occupation, might be highly beneficial for European firms. Therefore, our results emphasise the need for more effective interventions aimed at fostering women's inclusion and participation at work, for instance, by increasing the availability of (and accessibility to) public services that permit a better balance between work and private life/family care. On the other hand, our evidence sheds light on the need for more (and more effective) actions to remove all the barriers in the business environment (e.g. cultural, financial, etc.) that impede or make more difficult innovation, and innovation-driven productivity, by women-led firms.

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