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Labor flexibility and innovation: the importance of firms' heterogeneity

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Labor flexibility and innovation: the importance of firms' heterogeneity

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Abstract

This work investigates the relationship between the numerical flexibility of a firm's workforce and its innovative performance, taking into account the heterogeneity of firms and labor contracts. Using longitudinal data on Italian firms, we find that the share of temporary employees has a positive and significant effect on innovation for small and micro firms in low-tech and less knowledge-intensive sectors and a negative effect for medium and large firms in high-tech and knowledge-intensive sectors. These results suggest that managers and entrepreneurs may use temporary employment as an effective human resource practice to foster innovation in those firms whose technology or knowledge do not require vast and firm-specific investments. They also highlight possible unintended consequences of changes in the employment protection legislation for firms' innovative performance. Functional flexibility (training policies) and wage flexibility (second-level wage bargaining scheme) are neither substitutes nor complements to numerical flexibility, suggesting that firms use numerical, functional, and wage flexibility in different combinations.

JEL classification: D22; L23; M54; M55; J41

Keywords: Numerical flexibility; labor contracts; firm innovation; industrial relations

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1. Introduction

This paper focuses on the relationship between labor flexibility and firms' innovative performance. Firms' ability to innovate is fundamental to boosting their success (Geroski, 1999; Delgado-Gomez and Ramirez-Aleson, 2004; Coad and Rao, 2008), and policymakers are interested in targeting and strengthening innovative firms to maintain the capacity of a country's economy to grow in the long-run (Dosi et al., 1990; Aghion and Howitt, 1992; Corrado et al., 2013). Moreover, in decades of repeated technological and demand shocks (such as the Great Recession and the recent COVID-19 pandemic), innovation capabilities are fundamental to enhancing firms' chances of survival and growth (Salgado et al., 2019; Hassan et al., 2020).

In the last decades, increasing attention has been paid to the intangible factors that enhance firms' innovation, such as the quality of human capital and how firms organize their workforce. The positive effect of the workforce quality on firms' innovation is well-documented (Leiponen, 2005; OECD, 2011; Messinis and Ahmedb, 2013). Various authors suggest that also labor flexibility,[1] which favors an efficient reallocation of employees within and between firms, may enhance firms' innovative ability (Atkinson, 1984; Hunter et al., 1993; Kalleberg, 2001; Cappelli and Neumark, 2001, European Commission, 2005). Labor flexibility includes numerical flexibility (the possibility of adjusting the level of employment), functional flexibility (the possibility of reallocating employees across tasks), and wage flexibility (the possibility of adjusting wages).

Previous studies provided robust evidence of the positive role of functional and wage flexibility for innovation (Grout, 1984; Michie and Sheehan, 2003; Haucap and Wey, 2004; Arvanitis, 2005; Zhou et al., 2011; Martínez-Sánchez et al. 2011; Wachsen and Blind, 2016). In contrast, the empirical evidence on the role of numerical flexibility is more mixed, documenting either positive or negative effects depending on the type of labor contracts, the kind of innovation, the industry, and the type of data considered (Michie and Sheehan, 2003; Arvanitis, 2005; Altuzarra and Serrano, 2010; Martínez-Sánchez et al. 2011; Zhou et al. 2011; Wachsen and Blind, 2016; Kato and Zhou, 2018).

In this paper, we systematically investigate how different forms of numerical flexibility affect various types of innovation in various types of firms. This is a crucial question from a policy perspective because, on the one hand, it highlights whether different measures can be used to foster innovation in different types of firms, and, on the other hand, it calls attention to possible unintended consequences of labor market reforms for firms' innovative performance. To this end,

[1] In the management literature, labor flexibility is also referred to as human resource flexibility. See Milliman et al. (1991), Upton (1995), Martínez- Sanchez et al. (2011), among others.

we consider three tools through which numerical flexibility may be implemented: (i) the use of temporary employees, (ii) a reorganization of full-time and part-time positions, and (iii) the use of external workers, such as project-, freelance-, and agency workers. We investigate how each of these tools contributes to three different types of innovation: (i) new products, (ii) new processes, and (iii) the acquisition or filing of patents. We explore how these effects vary according to firms' size, the technological intensity of the industry where firms operate, and firms' adoption of other types of flexibility, particularly functional flexibility and wage flexibility.

We carry out this analysis on Italian firm-level longitudinal data (*Rilevazione Longitudinale Imprese e Lavoro*, RIL, 2005-2018), representative of partnerships and limited liability companies of all size classes in the non-agricultural private sectors. The Italian context is particularly interesting for a systematic analysis of the relationship between numerical flexibility and innovation because of (i) the high proportion of micro and small firms, which received little attention in previous studies; (ii) the numerous reforms of the Italian labor law over the last two decades, which increased significantly the possibility of using numerical flexibility (see Section A.1, Online Appendix, for more details); iii) the poor innovative performance of Italian firms (Bugamelli et al. 2012), which makes it crucial to identify how innovation determinants vary across firms.

Our work contributes to the literature on human resource practices as intangible drivers of firms' innovation in various ways. First, by considering various types of numerical flexibility, innovation, and firms, this paper provides systematic evidence on the heterogeneous effects of numerical flexibility. Second, by adopting a more robust econometric methodology than previous studies, we separately identify *between-firm* and *within-firm* effects and provide estimates that can be interpreted in causal terms. In particular, we find that *ceteris paribus*, the share of temporary employees has a positive and significant within-firm effect on product and process innovation in micro and small firms active in medium-low-tech manufacturing and less knowledge-intensive services, and a negative effect in medium and large firms operating in industries and services with high technological and knowledge intensity. No within-firm effects emerge for the proportion of project-, freelance- and agency workers and tenured part-time employment. Third, by examining the interaction between numerical, functional, and wage flexibility, we show that they are neither substitutes nor complements.

The rest of this paper is organized as follows. Section 2 reviews the theoretical and empirical literature on numerical flexibility and innovation. Section 3 describes the data and the variables used for this work. Section 4 presents the econometric analysis, and Section 5 provides some concluding remarks and implications for policy and management.

2. Related literature

2.1 Theoretical background

Numerical flexibility refers to firms' possibility to rapidly adjust their level of employment in response to technological or demand shocks (Wright and Snell, 1998). It may be pursued through various tools, such as (i) the use of temporary contracts (which are associated with short durations and moderate dismissal protection), (ii) a re-organization of the existing workforce (e.g., by taking advantage of part-time positions, overtime, or flexible monthly hours), and (iii) external workers, such as project-, freelance- and agency workers (whose labor relationships are generally faster to be opened or closed compared to tenured employees' positions).[2]

At the firm level, the tools through which numerical flexibility is implemented may affect firms' innovative performance through three main channels: adjustment costs, changes in the firm's knowledge, and other factors that affect firms' productivity.

First, the use of temporary or external workers reduces firms' adjustment costs[3] in case of technology or demand shocks, allowing them to save more resources for investments and innovations (Martínez-Sánchez et al., 2011; Pierre and Scarpetta, 2013). Moreover, since innovation is risky, the use of these types of labor contracts allows firms to adapt their workforce quickly and cheaply to the possible different returns to innovation, making the decision to invest in it more attractive (Saint-Paul, 2002; Bartelsman et al. 2008; Acharya et al., 2013; Adessi et al. 2014). However, using these types of contracts may even raise firms' costs when it leads to hiring more supervisors to monitor opportunistic behavior (Storm and Naastepad, 2007). This cost increase is likely to occur mainly in medium and large firms, with consequences discussed below.

Second, in line with the resource-based view of the firm (Penrose, 1959; Peteraf, 1993), numerical flexibility may constitute easier access to knowledge not already available within the firm (Matusik and Hill, 1998; Nesheim, 2003; Martínez-Sánchez et al., 2020). Fixed-term and external workers may bring new knowledge and new practices (Kochan et al., 1994), allowing firms to overcome the conservative behavior of long-tenured employees (Ichniowski and Shaw, 1995). This inflow of ideas may be particularly important for small firms, which rely on the knowledge of a limited number of workers. In some cases, firms may intentionally hire temporary employees or external workers to produce or implement innovation (Bierly et al., 2009). However, the use of fixed-term contracts and external workers may reduce incentives (or signal unwillingness) to invest

[2] Borrowing from Blundell et al. (2013), we can interpret (ii) as the "intensive margin", and (i) and (iii) as the "extensive margin" of firms' labor demand.

[3] These costs are linked to the change in the level and/or the composition of labor due to shocks. Adjustment costs may well translate into output losses (Hamermesh and Pfann, 1996; Pieri, 2018) and, thus, into productivity/profitability losses.

in creating and acquiring firm-specific knowledge by both employers and employees (Becker, 1964; Thelen, 2004; Berton et al., 2016). It may also imply a higher rate of workers' replacement, leading to a loss of firms' knowledge stock and a weakening of the learning process of the firm (Shaw et al. 2013).[4] Whether using temporary and external workers leads to a gain or a loss of a firm's knowledge depends on the incentives these workers have for contributing to the creation and acquisition of firm-specific knowledge. In small firms, temporary workers who contribute to improving the firm's knowledge are more likely to increase their chances of obtaining a tenured position, given the strict personal relationships that characterize these firms. Hence, knowledge gains are more likely to overcome knowledge losses in small firms than in large firms.

Finally, numerical flexibility may also foster innovation by increasing firms' productivity in other ways. The use of both temporary contracts and part-time positions allows for a more effective reallocation of the firm's workforce, which increases firms' productivity (Hopenhayn and Rogerson, 1993; Gerali et al., 2021). Moreover, temporary workers may have an incentive to work harder to obtain tenured positions, especially in small firms where monitoring is easier. Along these lines, Ichino and Riphahn (2005) and Jacob (2010) show that lower employment protection, by reducing absenteeism, can increase productivity. However, if temporary and part-time employees perceive that the chances of obtaining tenured or full-time positions are meager, they may be less motivated, committed, and loyal to organizations (Michie and Sheehan, 2003; Posthuma et al., 2005). This would lead to more opportunistic behavior, such as lower effort, hiding information about how to carry out their task more efficiently, and leakage of knowledge to competitors (Shapiro and Stiglitz, 1984; Akerlof and Yellen, 1990; Belot et al., 2007). Again, the strict personal relationships between employers and employees in small firms make these negative effects less likely to occur in these firms than in their medium-large counterparts.

Overall, numerical flexibility may have both positive and negative effects on innovation, and establishing the *net* effect is ultimately an empirical question. However, we expect a positive net effect in micro and small firms and a negative net effect in medium and large firms for three main reasons. First, lower adjustment costs associated with temporary and external workers are less likely to be offset by higher monitoring costs in micro and small firms than in their larger counterparts. Second, 'new' knowledge from temporary or external workers is more relevant for micro and small firms, given the limited workforce on which their knowledge is based. Third, these workers have more incentives to share their knowledge and be committed and loyal to the firm in micro and small

[4] This may be particularly severe if knowledge is embodied in the tacit skills of firms' employees (Dosi and Grazzi, 2006).

enterprises. Indeed, employers have better information on their workers' effort in these firms, and workers have more chances to obtain a tenured position by increasing their effort.

2.2 Empirical evidence

The empirical evidence on the relationship between numerical flexibility and innovation is mixed. At the industry level, some studies found that stricter employment protection legislation (EPL) leads to significantly lower innovation intensity (Barbosa and Faria, 2011; Murphy et al., 2017). However, the most recent evidence on the role of numerical flexibility in prompting innovation is generally negative, especially in knowledge-intensive and high-tech sectors. Cetrulo et al. (2019) find a negative relationship between the share of temporary employment and innovation in five European countries (France, Germany, Italy, Spain, and the Netherlands) for knowledge-intensive industries where tacit and firm-specific knowledge are a fundamental source of innovation (Breschi et al. 2000). The relationship is either not significant or even positive for less knowledge-intensive industries. Reljic et al. (2021) essentially confirm the negative relationship between non-standard employment (temporary and part-time employees) and innovation, especially for high-tech sectors, in a similar group of industries and countries (France, Germany, Italy, the UK, and the Netherlands).

The evidence at the firm level is even more mixed. The relationship between the share of temporary workers and product innovation has been estimated as positive (Arvanitis, 2005), negative (Martínez-Sanchez et al., 2019), and non-significant (Michie and Sheehan, 2003). Similarly, the relationship between this share of workers and process innovation has been found to be either negative (Michie and Sheehan, 2003) or non-significant (Arvanitis, 2005; Martínez-Sanchez et al., 2019). These studies differ in terms of the country and type of firms considered. Arvanitis (2005) uses a cross-section of Swiss firms with at least 20 employees. Martínez-Sanchez et al. (2019) consider a cross-section of Spanish industrial firms with at least ten employees. Michie and Sheehan (2003) work with a cross-section of UK manufacturing and services firms with more than 50 employees. They also differ in other proxies for numerical flexibility included in the estimation. Both Arvanitis (2005) and Michie and Sheehan (2003) include the share of part-time workers, also with contrasting effects: non-significant in the first study and negative in the second one. Michie and Sheehan (2003) control for the share of casual/seasonal contracts, whose effect on process innovation is found to be negative. Finally, Martínez-Sanchez et al. (2019) consider the use of R&D external workers, which is positively associated with innovation.

Kleinknecht et al. (2014) highlighted the importance of considering the technological intensity of a firm's industry (as already underlined by industry-level studies). Using a cross-section of Dutch

firms, they find that the share of temporary employees (excluding agency workers) has no impact on innovation in industries characterized by an "entrepreneurial" model of innovation (which relies on generally available knowledge) and a negative effect in sectors characterized by a "routinized" model of innovation (which relies on firm-specific, tacit, accumulated knowledge).

An important limitation of all these studies is that they are based on cross-sectional data, which may capture spurious correlations and produce biased coefficients. Interestingly, using longitudinal data on Japanese startups that operate in the manufacturing and software industries, Kato and Zhou (2018) find an inverted U-shaped relationship between the proportion of non-standard employees (the sum of part-time, temporary employees, and agency workers) and product innovation. An inverted U-shaped relationship between innovation (product or process) and the share of employees with fixed-term contracts is also found by Altuzarra and Serrano (2010) on an unbalanced panel of Spanish manufacturing firms in the period 2000-2002. Zhou et al. (2011), also using longitudinal data on Dutch firms with at least five employees, find that the share of temporary workers positively affects imitative (or 'new to the firm') product innovation. In contrast, the effect is negative for products 'new to the market'. Finally, using Dutch longitudinal data, Wachsen and Blind (2016) show that the share of temporary employees and on-demand workers/contractors is harmful in industries with leading innovators and high entry barriers. In these industries, where innovation depends on accumulated knowledge, firms have incentives to keep loyal and committed workers, offering tenured job positions.

For Italy, the empirical evidence on the relationship between numerical flexibility and innovation at the firm level is relatively scant. Using a cross-section of manufacturing firms (of all sizes), Addessi et al. (2014) show that both R&D and product innovation activities are positively related to the use of temporary employees and agency workers. In contrast, other studies based on longitudinal data document a negative relationship between numerical flexibility and innovation. Franceschi and Mariani (2016) find that the share of temporary employees negatively affects patent applications of manufacturing firms with more than 40 employees. Grinza and Quatraro (2019) find that excess turnover of workers is negatively associated with the number of patents filed by large firms (more than 250 employees). Their analysis is limited to the Veneto (NUTS 2) region and limited liability companies with at least 50 employees operating in four innovative industries (chemicals, metal-mechanics, electronics, and automotive).

Overall, these contrasting findings suggest that the relationship between numerical flexibility and innovation may depend on the type of innovation and labor contracts considered, firm size, and the sector where firms operate. But some important gaps in this literature need to be addressed. First, various studies focus on single proxies of numerical flexibility (either temporary employees, part-

time employees, or external workers) and/or single types of firms (medium-large, operating in specific sectors) or types of innovation (product, process, or patents). However, from a policy perspective, it is fundamental to examine systematically how different forms of numerical flexibility affect various types of innovation in various types of firms. Second, many studies do not separately identify *between-firm* and *within-firm* effects. This distinction is crucial to reconciling cross-sectional and longitudinal studies and accounting for the unobserved heterogeneity of firms and other sources of endogeneity. Third, the evidence on how numerical flexibility interacts with other types of flexibility (functional and wage flexibility) in influencing firms' innovative performance is almost inexistent.[5] Again, this is an important issue because firms may combine numerical, functional, and wage flexibility in different ways to improve their performances (European Commission, 2005). The following analysis aims to address these gaps.

3. Data and descriptive analysis

This work exploits firm-level longitudinal data from the *Rilevazione Longitudinale Imprese e Lavoro* (RIL), a mandatory survey conducted by the *Istituto Nazionale per l'Analisi delle Politiche Pubbliche* (INAPP) on a representative sample of Italian partnerships and limited liability companies of all size classes that operate in the private non-agricultural sectors. Five waves of the survey were conducted in 2005, 2007, 2010, 2015, and 2018.[6] Various features of the RIL survey make it appropriate for this work. First, the very aim of this survey is to collect precise information on the characteristics of the labor demand by Italian firms (number of employees, type of occupation, type of labor contracts, etc.). This allows us to construct fine proxies for three dimensions of numerical flexibility, namely the share of temporary employees, the share of tenured part-time employees, and the proportion of project-, freelance- and agency workers. Second, RIL contains information on the firms' introduction of new products and processes and other innovation metrics, such as patents. Moreover, being RIL a multiscope survey, we can control for a large set of firm characteristics.[7] Information on the industry in which a firm is active (16 sectors of the Italian economy) and the region in which it is located (20 NUTS 2 regions) is also available.[8] Third, by

[5] Several works consider multiple types of flexibility in their empirical analyses (Michie and Sheehan, 2003; Martínez-Sanchez et al., 2011; Zhou et al. 2011; Wachsen and Blind, 2016; Voudouris et al. 2016; Ritter-Hayashi et al. 2020; Arrighetti et al., 2021a). However, as far as we know, only Arvanitis (2005) explore the joint (interaction) role of numerical and functional flexibility in firm innovation. Still, the sample of firms included in Arvanitis' work (cross-section of Swiss companies with at least 20 employees) is more limited than the one we exploit, in terms of both firm size scope and numerosity (see Section 3).

[6] See Section A.2.1 in the Online Appendix for additional information on the RIL survey and sample composition. For more details on RIL questionnaire, sample design and methodological issues, see: https://www.inapp.org/it/dati/ril.

[7] See Section A.2.2 in the Online Appendix for a description of the control variables used in the empirical analysis.

[8] See Tables A.1 and A.2 in the Online Appendix for the distribution of firms by industry and regions.

exploiting the panel component of RIL, we can control for potential correlation between firm unobserved heterogeneity and the explanatory variables and, thus, obtain more robust estimates of the relationship between innovation and numerical flexibility.[9]

We selected active[10] firms with at least one employee present in at least two consecutive waves, with non-missing information on all the relevant variables. We excluded firms that changed their NUTS 2 location in the period 2005-2018 and firms with shares of non-standard labor contracts above 95% of their workforce. Our final sample includes 23469 firms. Since questions on the firms' innovative activity refer to the period *t-2* to *t*, we lagged all other variables by one wave to minimize simultaneity issues, both in the descriptive and econometric analysis (Section 4).[11]

Section A.2.2 and Table A.4 (Online Appendix) provide definitions and some descriptive statistics of the variables employed in the empirical analysis. Table 1 describes the main characteristics of firms, including their innovative performance, according to whether they use various types of non-standard employment. The first five rows of Table 1 show that the percentage of innovative firms is systematically (and significantly) higher in the group of firms that use non-standard labor contracts than in the other group. This is true for the use of temporary employees (left block of the table), tenured part-time employees (center block), and project-, freelance- and agency workers (right block).

[Insert Table 1 about here]

Firms that use non-standard labor contracts are different from their counterparts in several other characteristics. In particular, firms using these contracts are larger and are more likely to invest in research and development (R&D), information and communication technologies (ICTs), and plants, machinery, and equipment. Moreover, they have higher shares of employees participating in training activities and of female employees, and are more likely to adopt a second-level wage bargaining scheme and host a union representation. Finally, firms using non-standard employment are more likely to be exporters and belong to a national or a foreign group than their counterparts.

In the next section, we investigate whether the use of non-standard types of employment, measured as continuous variables, affects firms' probability to innovate, *ceteris paribus*.

[9] As underlined in Section 4.1, this is a fundamental difference with respect to previous empirical works on the same topic (Altuzarra and Serrano, 2010; Zhou et al., 2011; Franceschi and Mariani, 2016; Wachsen and Blind, 2016; Kato and Zhou, 2018; Hoxha and Kleinknecht, 2020). Section 4.1 illustrates how we cope with multiple sources of endogeneity.

[10] We excluded yearly observations for firms involved in extraordinary corporate transactions (i.e. liquidations, composition with creditors, extraordinary administration, bankruptcy, cessation of businesses).

[11] This procedure implies that innovation in *t* (t^{th} wave of RIL) is explained by firm characteristics in *t-1* ($t\text{-}1^{th}$ wave of RIL), where $t = \{2005, 2007, 2010, 2015, 2018\}$.

4. Econometric analysis

4.1 Methodology

The econometric analysis is based on the estimation of various types of models.

As commonly done in this field of literature, we start by estimating some random-effects (RE) probit models (see, e.g., Zhou et al., 2011; Wachsen and Blind, 2016; Kato and Zhou, 2018). Although the estimates of the RE probit models cannot be interpreted as causal effects because of the endogeneity problems discussed below, they can be easily compared with those of previous studies. Additionally, RE probit models are not so demanding in terms of within-firm and over-time variability in the dependent and explanatory variables.

RE models consider the probability of innovation as the observable outcome of a latent variable, the innovation intensity ($INNOV_{it}^{*}$), which, in turn, depends on some proxies of numerical flexibility and controls. The model can be written as:

$$INNOV_{it} = \begin{cases} 1 \; if \; INNOV^{*}{}_{it} > 0 \\ 0 \; \; else \end{cases} \qquad (1)$$

and

$$INNOV^{*}{}_{it} = \alpha + \boldsymbol{\beta}'\mathbf{NFLEX_{it-1}} + \boldsymbol{\gamma}'\mathbf{X_{it-1}} + \tau_t + \delta_r + \theta_j + \mu_i + u_{it} \qquad (2)$$

where $i\ (firm) = 1, \dots, N$; $t\ (wave) = 2005, 2007, 2010, 2015, 2018$. μ_i is a vector of random effects that captures firm-level unobserved heterogeneity, and it is assumed to be uncorrelated with the observed explanatory variables (Wooldridge, 2010).

Proxies of numerical flexibility ($\mathbf{NFLEX_{it-1}}$) include the share of temporary employees, the share of tenured part-time workers and the proportion of project-, freelance- and agency-workers, all lagged by one wave.

The choice of firm controls ($\mathbf{X_{it-1}}$), which we describe at length in Section A.2.2 (Online Appendix)**,** is based on both the extant literature on the knowledge production function (Pakes and Griliches, 1980; Hausman et al, 1984; Ang, 2011; Bronzini and Piselli, 2016; Franco et al. 2016; Grinza and Quatraro, 2019) and some recent works on the adoption of non-standard employment contracts (Devicienti et al. 2018; Arrighetti et al., 2021b; Berton et al. 2021). Including a large vector of controls at the firm level, $\mathbf{X_{it-1}}$**,** minimizes the risk of endogeneity due to omitted variable bias. In all regressions, we include a vector of time dummies (τ_t) to control for any wave-specific shock, and vectors of fixed effects at the industry- and region/NUTS 2-level (θ_j and δ_r), to control

for time-invariant differences across industries and territories in both the innovation intensity and the use of numerical flexibility.[12]

In Eq. (2), regressors may be correlated with firms' random effects (μ_i), thereby creating an endogeneity problem. Hence, we also estimate some correlated random effects (CRE) probit models. These models specify μ_i as a function of within-firm time averages of the explanatory variables (Mundlak 1978):

$$\mu_i = \boldsymbol{\delta}'\overline{\boldsymbol{NFLEX}}_{\boldsymbol{i}} + \boldsymbol{\vartheta}'\overline{\mathbf{X}}_{\mathbf{i}} + \varepsilon_i; \qquad (3)$$

where ε_i is independent of the covariates. The CRE model has a double advantage compared to the RE model. First, it minimizes the risk of endogeneity due to unobserved heterogeneity (Lin and Wooldridge, 2019). Second, it provides more information, because it estimates both the *within-firm* effects ($\widehat{\boldsymbol{\beta}}$ and $\widehat{\boldsymbol{\gamma}}$ estimates in Eq. 2) and the *between-firm* effects ($\widehat{\boldsymbol{\delta}}$ and $\widehat{\boldsymbol{\vartheta}}$ estimates in Eq. 3; Mundlak, 1978; Schunck, 2013). The within-firm effects show the effect of increasing explanatory variables over their firm-specific time average, and are identified by the sole within-firm variability of the regressors (similar to the coefficients of a linear model with fixed-effects). For this reason, they get closer to causal effects than the estimates of the RE probit model. The between-firm effects show how the probability of innovation varies across firms with different average levels of the explanatory variables, and are based on the between-firm variability of the regressors. When between-firm effects are jointly statistically significant, random effects are correlated with the observed explanatory variables, suggesting that the RE models' coefficients are biased.

The discussion in Section 2 highlighted that the effect of numerical flexibility on innovation may depend on some firms' structural characteristics ('moderators'), particularly the industry technological intensity and firm size. Moreover, numerical flexibility may interact with other types of flexibility, such as wage and functional flexibility. Hence, we extend our baseline model by introducing interactions between the proxies of numerical flexibility and some dummy variables capturing these moderators. We cannot carry out this analysis using CRE models because, given the relatively short time dimension of our dataset, moderators are mostly time-invariant during the observed period.[13] Hence, we investigate the heterogeneous effects of numerical flexibility using RE models. More precisely, we add to Eq. (2) a dummy variable identifying the moderator under investigation (*D*) and its interactions with $\mathbf{NFLEX_{it-1}}$:

[12] These differences are indeed significant, as shown in Table A.5 in the Online Appendix.
[13] By construction (2-digit NACE rev.2 industries are time-invariant; Table A.4 in the Online Appendix), no firms can shift from one group of industries to another, classified in terms of their technological intensity. The proportion of firms that shift from being micro-small to medium-large (or vice versa) is only 3.3%.

$$INNOV^*_{it} = \alpha + \boldsymbol{\beta}'\mathbf{NFLEX_{it-1}} + \pi D + \boldsymbol{\vartheta}'D \cdot \mathbf{NFLEX_{it-1}} + \boldsymbol{\gamma}'\mathbf{X_{it-1}} + \tau_t + \delta_r + \theta_j + \mu_i + u_{it}. \quad (4)$$

The final step of our analysis is to check whether estimates of the CRE model (Equations 2 and 3) and of the extended RE model (Eq. 4) can be interpreted in causal terms, i.e. whether they are robust to various possible sources of endogeneity of numerical flexibility, such as measurement errors and reverse causality. Indeed, firms may anticipate the consequences of introducing some innovations and adjust their workforce accordingly by using more flexible labor contracts. Hence, following Lin and Wooldridge (2019), we combine the CRE model with an instrumental variables approach (IVCRE), and specify the reduced form of $\mathbf{NFLEX_{it-1}}$ as:

$$\mathbf{NFLEX_{it-1}} = \boldsymbol{\varphi} + \boldsymbol{\rho}'\overline{\mathbf{NFLEX_i}} + \boldsymbol{\sigma}'\mathbf{Z_{it-1}} + \boldsymbol{\xi}'\overline{\mathbf{Z}}_i + \omega_{it-1} \quad (5)$$

where the vector $\mathbf{X_{it-1}}$ in Eq. (2) (i.e., the included instruments) is a strict subset of $\mathbf{Z_{it-1}}$ in Eq. (5) (all instruments). The parameters of Equations (2), (3) and (5) can be estimated jointly by using maximum likelihood estimation (Wooldridge, 2015). For the choice of the excluded instruments (i.e. the elements in $\mathbf{Z_{it-1}}$ not included in $\mathbf{X_{it-1}}$), we rely on the strategy proposed by Devicienti et al. (2018) and Berton et al. (2021), and use the means of $\mathbf{NFLEX_{it-1}}$ at the industry, regional, year and firm-size level. These variables should work as valid instruments, as explained in Section A.4.2 and shown in Tables A.8 and A.9 (Online Appendix).

As discussed above, we cannot estimate CRE models with interactions on the entire sample. Hence, we use the results of the heterogeneity analysis in Eq. (4) to identify various subsamples of firms and estimate IVCRE models on each subsample separately. All estimations include cluster-robust standard errors at the firm level to account for within-cluster correlation.

4.2 Results (i): RE and CRE probit models

Results of the RE probit models (Eq. 2) are shown in Table 2. Cols. (1)-(5) refer to the probability of introducing either a product or a process innovation, whereas cols. (6)-(8) refer to the probability of introducing a new product, a new process, or both a new product and a new process, respectively. Finally, col. (9) considers the probability of acquiring or filing patents.

[Insert Table 2 about here]

The first four models in Table 2 show that conditional on year, industry, and region fixed effects, the probability of innovation is positively associated with the share of temporary employees and with the proportion of project-, freelance- and agency workers, whereas it is negatively associated with the share of tenured part-time workers. However, when we include firms' characteristics (col.

5), this latter effect disappears, while the positive association with the share of project-, freelance-, and agency workers remains sizeable and significant.[14] The coefficient associated with the share of temporary contracts remains positive, although smaller and significant only at the 10% level.

Most of the control variables have the expected sign. In particular, larger firms and firms that invested in R&D, ICTs, plants, machinery, and equipment are more likely to introduce new products or processes (Hall et al., 2009; Franco et al., 2016). The probability of innovation is higher in firms with larger shares of trained employees (Leiponen, 2005; Messinis and Ahmedb, 2013), while the shares of managers and middle managers and of female employees have no significant effects (Teruel and Segarra-Blasco, 2022). The use of a second-level wage bargaining scheme (linked to productivity) is positively related to the probability of introducing new products or processes (Haucap and Wey, 2004). Conversely, the presence of a formal union representation in the firm is negatively (and significantly) associated with the probability of innovation. Exporters show a higher probability of innovation (Bugamelli et al. 2012), while belonging to a group has no significant effects.

When we distinguish between different types of innovation (cols. 6-9, Table 2), the share of project-, freelance-and agency workers is positively associated with all the considered metrics of innovation. The share of temporary workers is positively related to the probability of introducing new products and processes, but it does not affect the probability of acquiring or filing patents. The share of tenured part-time workers is not statistically associated with any of the considered metrics of a firm's innovative activity.

These results suggest that innovation is a heterogeneous phenomenon whose various dimensions are related to numerical flexibility in different ways. Innovation that leads to patents (which characterizes mainly scale-intensive and science-based industries; Pavitt, 1984) appears positively associated with larger shares of project and freelance workers but not with larger shares of temporary and part-time employees. Indeed, this type of innovation is characterized by a high degree of novelty (Kato and Zhou, 2018), and it requires specific investments by the firm, as confirmed by the significant role of R&D investments and the share of managers in the firm. In this case, firms may benefit from collaboration with highly skilled external partners but not from other forms of numerical flexibility. In contrast, when we consider innovation in a 'broader' sense, as the introduction of new products or processes, both the shares of temporary employees and of project and freelance workers have positive effects. The share of part-time positions does not affect any

[14] In the Online Appendix (Table A.6), we show the results when introducing controls in the empirical model in a hierarchical fashion.

type of innovation. This could suggest that the use of these contracts does not imply a more effective reallocation of the firm's workforce (with the associated productivity gains) and/or that the lower motivation and commitment of part-time workers offset the potential benefits of the reallocation.

To account for the possible correlation between the explanatory variables and the random effects and to distinguish within-firm and between-firm effects, Table 3 presents the estimates of some CRE models (cols. 2-6). For ease of comparison and interpretation, in col. (1) we report the estimates of the RE probit model (col. 5, Table 2).

[Insert Table 3 about here]

From the estimation of the CRE models, four results emerge. First, Mundlak's terms effects in the lower part of Table 3 (i.e., the firm-specific time averages of the explanatory variables in Eq. 3, which capture between-firm effects) are jointly statistically significant as the Wald test at the bottom of Table 3 confirms. This means that the fundamental hypothesis on which the RE probit model is based (random effects uncorrelated with the observed explanatory variables) is not valid and that the time averages of the explanatory variables must be included in the model. Second, the effects of many control variables estimated in the RE models are actually between-firm effects. Indeed, given the short time dimension of the panel, almost all control variables are dummy variables that seldom change over time for a given firm. Third, the relationship between the various types of non-standard contracts and innovation estimated in the RE models are the result of different within-firm and between-firm effects. Firms with higher shares of temporary employees are less likely to innovate (between-firm effect, lower part of Table 3), but increasing this share for a given firm favors all types of innovation but patents (within-firm effect, upper part of Table 3). In contrast, firms with higher shares of project, freelance- and agency workers are more likely to introduce product innovation and patents (between-firm effect), whereas variations in this share do not affect each firm's probability to innovate (within-firm effect). Finally, firms with higher shares of part-time employees are more likely to introduce process innovation (between-firm effect), but increasing this share for a given firm reduces this probability.

These results deserve some explanations. Higher shares of temporary employees across firms may be associated with a 'bad' signal to workers, which leads to lower effort and commitment and less investment in firm-specific knowledge (offsetting the positive effects of lower adjustment costs and inflow of external knowledge; Posthuma et al. 2005; Berton et al. 2016). However, for a given firm, increasing the share of temporary employees implies having a more considerable inflow of outside knowledge and ideas (Nesheim, 2003; Martínez-Sánchez et al., 2020), or a reallocation of

the workforce, that more than compensate for the negative between-firm effect (indeed, the coefficient in the RE probit models which encompasses between- and within-firm effects is positive). Higher shares of project-, freelance-, and agency workers across firms identify those firms that systematically invest more in collaborations with external partners. Enduring collaborative relationships with external specialists is essential to ensure positive effects on innovation, while too frequent changes may have negative effects (Müller and Peters, 2010). Finally, higher shares of part-time employees may characterize firms that are generally more prone to internal reallocations of workers and, hence, more prone to introduce process innovation. However, for a given firm, part-time positions may go hand in hand with a labor-saving strategy, which is the target of most process innovations. Hence, process innovations and the adoption of part-time positions may be substitutes rather than complements in the short run.

In short, *ceteris paribus*, the within-firm effect of numerical flexibility on innovation is positive and significant when temporary employment intensity is considered, while statistically not significant when either tenured part-time employment or the proportion of project-, freelance- and agency workers are considered.

To get a sense of the economic effect, we computed the average marginal effect of the share of temporary employment on product and process innovation and plotted them in Figure 1. *Ceteris paribus*, a ten percentage point increase in the share of temporary employees leads to about a one percentage point increase (0.85) in the probability of introducing either a product or a process innovation. This effect is somehow larger for product innovation (0.93) than for process innovation (0.63).

[Insert Fig. 1 about here]

4.3 Results (ii): The role of technological intensity, firm size, wage bargaining scheme, and training policy

In the previous subsection, we found no within-firm effects of any proxy of numerical flexibility on firms' patenting activity. Hence, from now on, we focus only on the probability of introducing either a product or a process innovation. Estimates of Eq. (4) for these two types of innovation are shown in Table 4. Cols. (1) and (2) investigate, respectively, the role of the industry technological intensity[15] and firms' size (50 or more employees vs. less than 50) as moderators in the relationship between numerical flexibility and innovation.

[15] See Table A.4 (Online Appendix) for the aggregation of industries in terms of technological intensity.

[Insert Table 4 about here]

As expected, firms that operate in sectors characterized by higher technological intensity are more likely to introduce either a product or a process innovation. However, for these firms, the shares of temporary employees and project-, freelance-, and agency workers have a much lower effect on innovation than for firms operating in medium-low tech manufacturing or less knowledge-intensive services. Similarly, medium and large firms are more likely to introduce a new product or a new process than their counterparts, but again the interaction of this dummy with the share of temporary employment is negative. In contrast, the interaction with the proportion of project-, freelance-and agency workers is almost zero. In Fig. 2 (panel A), we show the average marginal effects of the two proxies of numerical flexibility on innovation for the groups of firms considered so far. Marginal effects are positive and significant for firms active in medium-low tech and less knowledge-intensive services, and for micro and small firms.

[Insert Fig. 2 about here]

We further investigate differences across these types of firms by considering the double interaction of the two proxies of numerical flexibility with the industry technological intensity and the size category of firms. Estimates are presented in Table A.7 (Online Appendix), while the marginal effects are plotted in Fig. 2 (panel B). These marginal effects are positive and significant for micro and small firms that operate in medium-low tech and less knowledge-intensive sectors, whereas they are negative and significant for medium and large firms that operate in industries characterized by higher technological intensity. No effects emerge for micro and small firms operating in high-tech sectors. In contrast, medium and large firms operating in low-tech sectors are more likely to innovate the higher the share of project-, freelance-, and agency workers. In the following subsection, we will check whether these results capture within-firm or between-firm effects and whether they can be interpreted in causal terms.

In the last two columns of Table 4, we examine how numerical flexibility interacts with wage and functional flexibility. In col. (3), we consider whether firms employ a second-level wage bargaining scheme. This may be seen as a mechanism to implement (upward) wage flexibility. In col. (4), we consider whether firms organize training activities for their employees or not. This may be seen as a way to promote functional flexibility. A second-level wage bargaining scheme and on-the-job training are positively associated with innovation. Still, they do not appear to interact with the use of temporary and external workers. In other words, functional flexibility and wage flexibility are positively related to innovation, but they appear neither substitutes nor complements

to numerical flexibility. Hence, our results suggest that firms do not adopt either 'high road' human resource practices (i.e., functional flexibility) or 'low road' practices (i.e., numerical flexibility; Kleinknecht et al., 2014; p. 1213). Rather, they use these practices in different combinations to boost their innovation performance (Atkinson, 1984; European Commission, 2005).

4.4 Results (iii): Instrumental variable estimates and further robustness checks

To check whether the heterogeneous effects presented in the previous section capture within-firm or between-firm effects (and whether they are robust to various sources of endogeneity, such as measurement errors and reverse causality), we estimated IVCRE models on different subsamples of firms. Results are shown in Table A.10 (Online Appendix). Only the share of temporary contracts retains significant within-firm effects. These effects are of opposite sign for micro-small firms in low-tech manufacturing and less knowledge-intensive services (positive, col. 2) and for medium-large firms in high-tech manufacturing and knowledge-intensive services (negative, col. 5).

We also conducted two further robustness checks. First, we included three additional controls in the CRE probit model by exploiting information available only in some waves of RIL: firm age, the share of employees with tertiary education, and the share of employees younger than 35 (Table A.11, Online Appendix). Second, we compared the marginal effects of the CRE probit model (Figure 1) with a linear probability model (LPM) with firm fixed effects (LPMFE; Table A.12, Online Appendix). Both these checks confirm our main results.

Overall, results in Sections 4.2-4.4 help reconcile the findings of previous studies and derive important policy implications. The negative relationship between numerical flexibility and innovation in medium and large firms operating in industries and services with high technological and knowledge intensity is in line with previous works (Kleinknecht et al., 2014; Cetrulo et al., 2019; Grinza and Quatraro, 2019; Reljic et al., 2021). In particular, temporary employment is harmful for firms' innovation in industries whose technology or knowledge require vast and firm-specific investments by both firms and workers, which short-term labor relationships do not favor. In contrast, the use of temporary employees is beneficial for innovation in micro-small firms operating in low-tech industries, which are structurally less likely to innovate. Our interpretation of this result is that these contracts help these firms reduce their adjustment costs and provide access to external knowledge.

5. Concluding remarks and implications for policy and management

This paper contributes to the literature on human resource practices as intangible drivers of firms' innovation by analyzing how the numerical flexibility of a firm's workforce affects its innovative

performance. In particular, we systematically investigate how different forms of numerical flexibility (the use of temporary, part-time, and external workers) affect various types of innovation (product, process, and patents) in various types of firms. We separately identify *between-firm* and *within-firm* effects and provide estimates that can be interpreted in causal terms. Moreover, we examine the interaction between numerical, functional, and wage flexibility.

We find that *ceteris paribus*, the share of temporary employees has a positive and significant within-firm effect on product and process innovation in micro and small firms active in low-tech manufacturing and less knowledge-intensive services, and a negative effect in medium and large firms operating in industries and services with high technological and knowledge intensity. No within-firm effects emerge for the proportion of project-, freelance- and agency workers and tenured part-time employment. For innovation that leads to patents, we only find a positive between-firm effect of the proportion of project-, freelance-, and agency workers.

These results suggest that managers and entrepreneurs may use numerical flexibility as an effective human resource practice to foster innovation if they operate in industries whose technology and knowledge do not require vast and firm-specific investments by both firms and workers. Indeed, short-term, less intensive, and occasional labor relationships do not favor these investments. In contrast, temporary employment may facilitate access to external knowledge and reduce adjustment costs in micro and small firms operating in low-tech sectors. Access to external knowledge is particularly important for these firms because they usually rely on a limited number of workers. Moreover, temporary workers have more incentives to share their knowledge within these firms. Indeed, employers have better information about their effort, and therefore, workers who contribute to the firm's knowledge increase their chances of obtaining a tenured position.

Policymakers may be worried about the documented adverse effects of non-standard labor contracts on job instability, insider-outsider division, and low human capital investments. However, our results highlight possible unintended consequences of changes in the employment protection legislation for firms' innovative performance. In particular, reforms aiming at increasing workers' employment protection would be beneficial also for innovation in medium-large firms operating in medium-high- and high-tech sectors. In contrast, for micro and small firms operating in less knowledge-intensive sectors, a more stringent employment protection legislation should be accompanied by other measures that help these firms access new knowledge and ideas or reduce their adjustment costs.

These results are relevant for all economies that are relatively more populated by micro and small enterprises, more specialized in low-tech industries, and less knowledge-intensive services. In

Europe, Italy is undoubtedly a natural candidate, but also other southern European countries, such as Spain, Portugal, and Greece, may benefit from our findings.

Another important result of our work is that functional flexibility and wage flexibility are positively related to innovation, but they are neither substitutes nor complements to numerical flexibility. This finding suggests that managers and entrepreneurs may use numerical, functional and wage flexibility in different combinations to boost innovation. Thus, policymakers should not expect to face two 'ideal' types of firms, with a clear separation between firms adopting only 'high road' human resource practices (functional flexibility), and firms using only 'low road' practices (numerical flexibility). Italian firms indeed implement a mix of different types of labor flexibility.

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Tables and Figures

Table 1 – Firms' characteristics by the use of non-standard labor contracts

	Unit of measure	Using temporary employees (t-1)	Observations	Not using temporary employees (t-1)	Observations	Test of equality of proportions or means p-value	Using part-time employees (t-1)	Observations	Not using part-time employees (t-1)	Observations	Test of equality of proportions or means p-value	Using project-, freelance-, agency-workers (t-1)	Observations	Not using project-, freelance-, agency-workers (t-1)	Observations	Test of equality of proportions or means p-value
Prod. or proc. innov.	% of firms	0.530	19526	0.409	17912	(0.000)	0.511	21335	0.421	16103	(0.000)	0.544	18444	0.402	18994	(0.000)
Prod. innov.	% of firms	0.456	19526	0.345	17912	(0.000)	0.442	21335	0.351	16103	(0.000)	0.470	18444	0.337	18994	(0.000)
Proc. innov.	% of firms	0.392	19526	0.286	17912	(0.000)	0.376	21335	0.295	16103	(0.000)	0.406	18444	0.279	18994	(0.000)
Prod. & proc. innov.	% of firms	0.318	19526	0.222	17912	(0.000)	0.307	21335	0.225	16103	(0.000)	0.332	18444	0.214	18994	(0.000)
Patents	% of firms	0.066	19621	0.029	17973	(0.000)	0.066	21433	0.026	16161	(0.000)	0.075	18529	0.023	19065	(0.000)
Firm size = # Employees (t-1)	Average value	102.225	19621	19.892	17973	(0.000)	94.725	21433	20.607	16161	(0.000)	95.370	18529	31.270	19065	(0.000)
Investments in R&D (t-1)	% of firms	0.165	19621	0.067	17973	(0.000)	0.157	21433	0.067	16161	(0.000)	0.189	18529	0.050	19065	(0.000)
Investments in ICTs (t-1)	% of firms	0.328	19621	0.184	17973	(0.000)	0.313	21433	0.189	16161	(0.000)	0.363	18529	0.159	19065	(0.000)
Investments in plants, mach. & eq. (t-1)	% of firms	0.449	19621	0.280	17973	(0.000)	0.409	21433	0.314	16161	(0.000)	0.457	18529	0.282	19065	(0.000)
Share of trained employees (t-1)	Average value (%)	0.270	19101	0.219	17625	(0.000)	0.271	20904	0.211	15822	(0.000)	0.282	18010	0.210	18716	(0.000)
Share of managers and middle managers (t-1)	Average value (%)	0.054	19611	0.053	17961	(0.282)	0.049	21418	0.060	16154	(0.000)	0.053	18516	0.054	19056	(0.528)
Share of female employees (t-1)	Average value (%)	0.381	19580	0.358	17938	(0.000)	0.418	21373	0.307	16145	(0.000)	0.363	18481	0.378	19037	(0.000)
Second-level wage barg. (t-1)	% of firms	0.121	19621	0.041	17973	(0.000)	0.118	21433	0.036	16161	(0.000)	0.135	18529	0.032	19065	(0.000)
Union representation (RSA/RSU) (t-1)	% of firms	0.297	18829	0.126	16856	(0.000)	0.289	20516	0.118	15169	(0.000)	0.324	17777	0.110	17908	(0.000)
Exporter (t-1)	% of firms	0.339	19621	0.226	17973	(0.000)	0.333	21433	0.222	16161	(0.000)	0.379	18529	0.193	19065	(0.000)
National group (t-1)	% of firms	0.138	19621	0.067	17973	(0.000)	0.131	21433	0.068	16161	(0.000)	0.151	18529	0.059	19065	(0.000)
Foreign group (t-1)	% of firms	0.143	19621	0.083	17973	(0.000)	0.116	21433	0.112	16161	(0.245)	0.127	18529	0.102	19065	(0.000)
Independent (no group) firm (t-1)	% of firms	0.719	19621	0.850	17973	(0.000)	0.753	21433	0.819	16161	(0.000)	0.722	18529	0.839	19065	(0.000)

Table 2 - RE probit model estimates (Eq. 2)

	(1) (Prod. or proc. inn., RE)	(2) (Prod. or proc. inn., RE)	(3) (Prod. or proc. inn., RE)	(4) (Prod. or proc. inn., RE)	(5) (Prod. or proc. inn., RE)	(6) (Prod. inn., RE)	(7) (Proc. inn., RE)	(8) (Prod. & proc. inn., RE)	(9) (Patents, RE)
Share of temporary employees (t-1)	0.215***			0.182***	0.099*	0.112**	0.108*	0.126**	-0.114
	(0.052)			(0.056)	(0.055)	(0.056)	(0.057)	(0.059)	(0.139)
Share of (tenured) part-time employees (t-1)		-0.208***		-0.260***	-0.003	0.059	-0.027	0.047	-0.153
		(0.053)		(0.057)	(0.057)	(0.059)	(0.060)	(0.063)	(0.160)
Prop. of project-, freelance-, agency-workers (t-1)			0.444***	0.399***	0.249***	0.246***	0.212***	0.223***	0.377***
			(0.045)	(0.046)	(0.046)	(0.046)	(0.046)	(0.048)	(0.095)
Firm size = # Employees (log, +1) (t-1)					0.161***	0.150***	0.175***	0.174***	0.316***
					(0.010)	(0.010)	(0.010)	(0.010)	(0.022)
Investments in R&D (t-1)					0.288***	0.347***	0.205***	0.286***	0.470***
					(0.031)	(0.031)	(0.030)	(0.030)	(0.049)
Investments in ICTs (t-1)					0.080***	0.079***	0.048**	0.052**	0.026
					(0.024)	(0.024)	(0.024)	(0.025)	(0.049)
Investments in plants, mach. & eq. (t-1)					0.191***	0.151***	0.216***	0.186***	-0.019
					(0.021)	(0.021)	(0.021)	(0.022)	(0.044)
Share of trained employees (t-1)					0.237***	0.191***	0.238***	0.206***	-0.002
					(0.025)	(0.026)	(0.025)	(0.027)	(0.056)
Share of managers and middle managers (t-1)					0.072	0.185***	-0.091	0.045	0.805***
					(0.069)	(0.070)	(0.074)	(0.076)	(0.149)
Share of female employees (t-1)					-0.027	-0.005	-0.044	-0.019	0.121
					(0.037)	(0.037)	(0.039)	(0.040)	(0.089)
Second-level wage barg. (t-1)					0.066*	0.093**	0.043	0.078**	0.107*
					(0.038)	(0.038)	(0.037)	(0.037)	(0.061)
Union representation (RSA/RSU) (t-1)					-0.125***	-0.132***	-0.106***	-0.119***	-0.140***
					(0.028)	(0.029)	(0.028)	(0.029)	(0.054)
Exporter (t-1)					0.352***	0.369***	0.273***	0.313***	0.519***
					(0.023)	(0.023)	(0.023)	(0.024)	(0.047)
National group (t-1)					-0.017	-0.021	-0.005	-0.013	0.002
					(0.031)	(0.031)	(0.031)	(0.032)	(0.056)
Foreign group (t-1)					0.014	-0.002	-0.010	-0.030	-0.032
					(0.031)	(0.031)	(0.031)	(0.032)	(0.065)
Constant	-0.134*	-0.133*	-0.172**	-0.171**	-0.798***	-1.148***	-1.056***	-1.447***	-4.340***
	(0.072)	(0.072)	(0.074)	(0.075)	(0.076)	(0.082)	(0.075)	(0.083)	(0.246)
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region/NUTS2 FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
#Observations	42697	41976	39898	37438	34614	34614	34614	34614	34761
#Firms	26925	26525	25630	24211	23469	23469	23469	23469	23553
Log-likelihood	-27085.35	-26701.03	-25279.49	-23737.93	-21169.93	-20819.24	-19480.77	-17862.19	-5046.95
Prop. variance by the panel component	0.419	0.415	0.407	0.407	0.310	0.326	0.284	0.298	0.467

Notes: All regressions include year-, industry- and region/NUTS2-fixed effects, where industries are defined in Table A.1 in the Online Appendix. Coefficients of year, industry, and region/NUTS2 dummies are not reported to save space. Full tables are available from authors upon request. Cluster (firm) - robust standard errors are reported in parentheses. Statistical significance at the 10%, 5%, and 1% levels is indicated by *,**, and ***, respectively.

Table 3 - CRE probit model estimates (Equations 2 and 3)

	(1) (Prod. or proc. inn., RE)	(2) (Prod. or proc. inn., CRE)	(3) (Prod. inn., CRE)	(4) (Proc. inn., CRE)	(5) (Prod. & proc. inn., CRE)	(6) (Patents, CRE)
Share of temporary employees (t-1)	0.099*	0.295***	0.332***	0.234**	0.283**	-0.025
	(0.055)	(0.109)	(0.110)	(0.115)	(0.121)	(0.288)
Share of (tenured) part-time employees (t-1)	-0.003	-0.138	-0.033	-0.273**	-0.171	0.148
	(0.057)	(0.129)	(0.132)	(0.134)	(0.143)	(0.361)
Prop. of project-, freelance-, agency-workers (t-1)	0.249***	-0.033	-0.018	0.054	0.081	-0.110
	(0.046)	(0.083)	(0.085)	(0.084)	(0.089)	(0.180)
Firm size = # Employees (log, +1) (t-1)	0.161***	0.057	0.017	0.017	-0.029	0.168*
	(0.010)	(0.042)	(0.043)	(0.043)	(0.045)	(0.090)
Investments in R&D (t-1)	0.288***	0.016	0.055	0.021	0.065	-0.012
	(0.031)	(0.049)	(0.048)	(0.049)	(0.050)	(0.081)
Investments in ICTs (t-1)	0.080***	-0.032	-0.021	-0.067*	-0.057	-0.069
	(0.024)	(0.039)	(0.039)	(0.040)	(0.041)	(0.080)
Investments in plants, mach. & eq. (t-1)	0.191***	-0.017	-0.008	-0.057	-0.057	-0.067
	(0.021)	(0.035)	(0.035)	(0.036)	(0.037)	(0.077)
Share of trained employees (t-1)	0.237***	-0.098**	-0.113**	-0.036	-0.057	-0.111
	(0.025)	(0.043)	(0.045)	(0.044)	(0.047)	(0.099)
Share of managers and middle managers (t-1)	0.072	0.143	0.199	-0.082	-0.026	1.203***
	(0.069)	(0.141)	(0.145)	(0.156)	(0.166)	(0.360)
Share of female employees (t-1)	-0.027	-0.015	-0.084	0.183	0.116	0.178
	(0.037)	(0.106)	(0.107)	(0.113)	(0.120)	(0.264)
Second-level wage barg. (t-1)	0.066*	-0.008	0.104	-0.026	0.093	0.377***
	(0.038)	(0.068)	(0.066)	(0.066)	(0.067)	(0.108)
Union representation (RSA/RSU) (t-1)	-0.125***	-0.123**	-0.142**	-0.059	-0.083	-0.270**
	(0.028)	(0.063)	(0.062)	(0.063)	(0.066)	(0.121)
Exporter (t-1)	0.352***	0.040	0.042	-0.015	-0.014	-0.218**
	(0.023)	(0.052)	(0.051)	(0.052)	(0.053)	(0.107)
National group (t-1)	-0.017	0.034	0.069	-0.013	0.021	0.003
	(0.031)	(0.062)	(0.062)	(0.062)	(0.064)	(0.115)
Foreign group (t-1)	0.014	0.144***	0.128**	0.129**	0.123**	0.023
	(0.031)	(0.051)	(0.051)	(0.051)	(0.053)	(0.112)
Share of temporary employees (t-1, id mean)		-0.254**	-0.282**	-0.153	-0.186	-0.117
		(0.127)	(0.129)	(0.134)	(0.141)	(0.332)
Share of (tenured) part-time employees (t-1, id mean)		0.178	0.124	0.312**	0.280*	-0.347
		(0.144)	(0.147)	(0.149)	(0.159)	(0.402)
Prop. of project-, freelance-, agency-workers (t-1, id mean)		0.373***	0.348***	0.189*	0.165	0.662***
		(0.099)	(0.101)	(0.100)	(0.106)	(0.215)
Firm size = # Employees (log, +1) (t-1, id mean)		0.077*	0.110**	0.135***	0.185***	0.129
		(0.044)	(0.044)	(0.044)	(0.046)	(0.093)
Investments in R&D (t-1, id mean)		0.428***	0.466***	0.282***	0.344***	0.809***
		(0.063)	(0.063)	(0.063)	(0.064)	(0.105)
Investments in ICTs (t-1, id mean)		0.164***	0.147***	0.170***	0.161***	0.131
		(0.050)	(0.050)	(0.050)	(0.052)	(0.105)
Investments in plants, mach. & eq. (t-1, id mean)		0.331***	0.254***	0.433***	0.387***	0.089
		(0.044)	(0.044)	(0.045)	(0.047)	(0.099)
Share of trained employees (t-1, id mean)		0.494***	0.451***	0.400***	0.384***	0.167
		(0.053)	(0.054)	(0.054)	(0.057)	(0.117)
Share of managers and middle managers (t-1, id mean)		-0.075	0.009	0.004	0.127	-0.483
		(0.162)	(0.167)	(0.178)	(0.189)	(0.413)
Share of female employees (t-1, id mean)		0.002	0.104	-0.243**	-0.140	-0.057
		(0.113)	(0.114)	(0.120)	(0.127)	(0.278)
Second-level wage barg. (t-1, id mean)		0.084	-0.044	0.077	-0.048	-0.431***
		(0.082)	(0.081)	(0.080)	(0.081)	(0.133)
Union representation (RSA/RSU) (t-1, id mean)		-0.027	-0.006	-0.086	-0.069	0.148
		(0.070)	(0.070)	(0.070)	(0.074)	(0.135)
Exporter (t-1, id mean)		0.383***	0.402***	0.352***	0.399***	0.938***
		(0.058)	(0.058)	(0.058)	(0.059)	(0.122)
National group (t-1, id mean)		-0.086	-0.138*	-0.006	-0.065	-0.019
		(0.072)	(0.072)	(0.072)	(0.074)	(0.135)
Foreign group (t-1, id mean)		-0.204***	-0.205***	-0.219***	-0.240***	-0.097
		(0.060)	(0.060)	(0.061)	(0.063)	(0.131)
Constant	-0.798***	-0.847***	-1.196***	-1.125***	-1.523***	-4.542***
	(0.076)	(0.078)	(0.084)	(0.077)	(0.086)	(0.270)
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes	Yes	Yes	Yes
Region/NUTS2 FEs	Yes	Yes	Yes	Yes	Yes	Yes
#Observations	34614	34614	34614	34614	34614	34761
#Firms	23469	23469	23469	23469	23469	23553
Log-likelihood	-21169.93	-20958.8	-20632.53	-19273.33	-17669.85	-4940.134
Prop. variance by the panel component	0.310	0.323	0.338	0.299	0.313	0.509
Wald test; H0: Mundlak's terms jointly = 0 (p-value)		0.000	0.000	0.000	0.000	0.000

Notes: For ease of comparison and interpretation, col (1) reports the estimates of the RE probit model (col. 5, Table 2). All regressions include year-, industry- and region/NUTS2-fixed effects, where industries are defined in Table A.1 in the Online Appendix. Coefficients of year, industry, and region/NUTS2 dummies are not reported to save space. Full tables are available from authors upon request. Cluster (firm) - robust standard errors are reported in parentheses. Statistical significance at the 10%, 5%, and 1% levels is indicated by *,**, and ***, respectively.

Table 4 - Extended RE probit model estimates (Eq. 4); selected coefficients

	(1) (Prod. or proc. inn., RE)	(2) (Prod. or proc. inn., RE)	(3) (Prod. or proc. inn., RE)	(4) (Prod. or proc. inn., RE)
Share of temporary employees (t-1)	0.143*	0.188***	0.090	0.115*
	(0.075)	(0.058)	(0.056)	(0.067)
Share of (tenured) part-time employees (t-1)	-0.106	0.051	0.011	-0.041
	(0.075)	(0.060)	(0.058)	(0.068)
Prop. of project-, freelance-, agency-workers (t-1)	0.340***	0.259***	0.250***	0.210***
	(0.067)	(0.048)	(0.047)	(0.059)
Medium-high-, High-tech manuf., Knowledge-intensive serv. (t-1)=1	0.236***			
	(0.035)			
Medium-high-, High-tech manuf., Knowledge-intensive serv. (t-1)=1 # Share of temporary employees (t-1)	-0.210			
	(0.141)			
Medium-high-, High-tech manuf., Knowledge-intensive serv. (t-1)=1 # Share of (tenured) part-time employees (t-1)	0.079			
	(0.122)			
Medium-high-, High-tech manuf., Knowledge-intensive serv. (t-1)=1 # Prop. of project-, freelance-, agency-workers (t-1)	-0.249**			
	(0.109)			
Medium-large firms [50:.) (t-1)=1		0.339***		
		(0.041)		
Medium-large firms [50:.) (t-1)=1 # Share of temporary employees (t-1)		-0.321**		
		(0.154)		
Medium-large firms [50:.) (t-1)=1 # Share of (tenured) part-time employees (t-1)		-0.426***		
		(0.151)		
Medium-large firms [50:.) (t-1)=1 # Prop. of project-, freelance-, agency-workers (t-1)		-0.029		
		(0.143)		
Second-level wage barg. (t-1)=1			0.097*	
			(0.054)	
Second-level wage barg. (t-1)=1 # Share of temporary employees (t-1)			0.230	
			(0.286)	
Second-level wage barg. (t-1)=1 # Share of (tenured) part-time employees (t-1)			-0.757**	
			(0.352)	
Second-level wage barg. (t-1)=1 # Prop. of project-, freelance-, agency-workers (t-1)			-0.001	
			(0.181)	
Training activities (t-1)=1				0.171***
				(0.027)
Training activities (t-1)=1 # Share of temporary employees (t-1)				-0.072
				(0.106)
Training activities (t-1)=1 # Share of (tenured) part-time employees (t-1)				0.072
				(0.103)
Training activities (t-1)=1 # Prop. of project-, freelance-, agency-workers (t-1)				0.073
				(0.089)
Constant	-0.365***	-0.479***	-0.802***	-0.777***
	(0.056)	(0.073)	(0.076)	(0.075)
Firm controls ($\mathbf{X}_{it-1}$)	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes
Industry FEs	No	Yes	Yes	Yes
Region/NUTS2 FEs	Yes	Yes	Yes	Yes
#Observations	25973	34614	34614	35447
#Firms	16749	23469	23469	23853
Log-likelihood	-16046.41	-21263.53	-21167.19	-21675.31
Prop. variance by the panel component	0.328	0.307	0.310	0.310

Notes: All regressions include firm controls ($\mathbf{X}_{it-1}$) and year-, industry- and region/NUTS2-fixed effects, where industries are defined in Table A.1 in the Online Appendix. Coefficients of the control variables, year, industry, and region/NUTS2 dummies are not reported to save space. Full tables are available from authors upon request. Cluster (firm) - robust standard errors are reported in parentheses. Statistical significance at the 10%, 5%, and 1% levels is indicated by *,**, and ***, respectively.

Figures

Fig. 1 – Average marginal effect of the share of temporary employees on different proxies of firm innovation

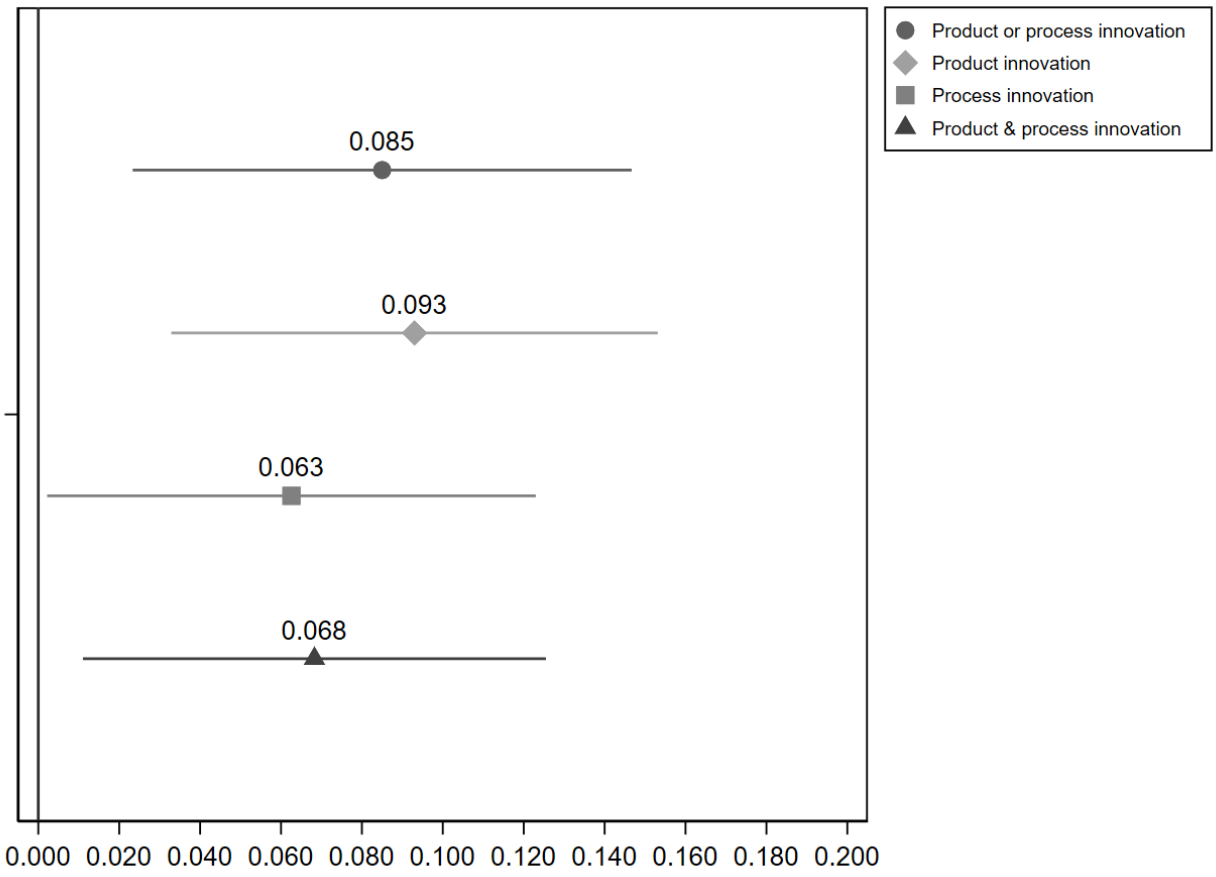
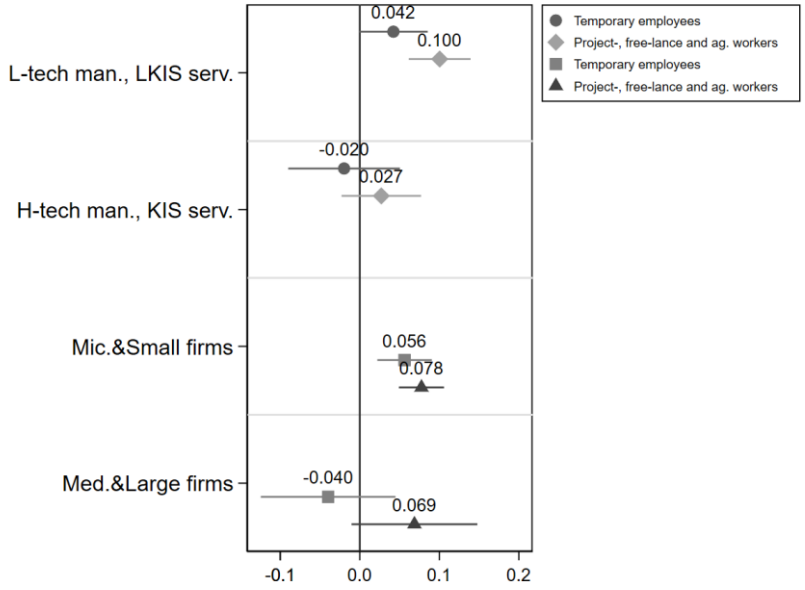
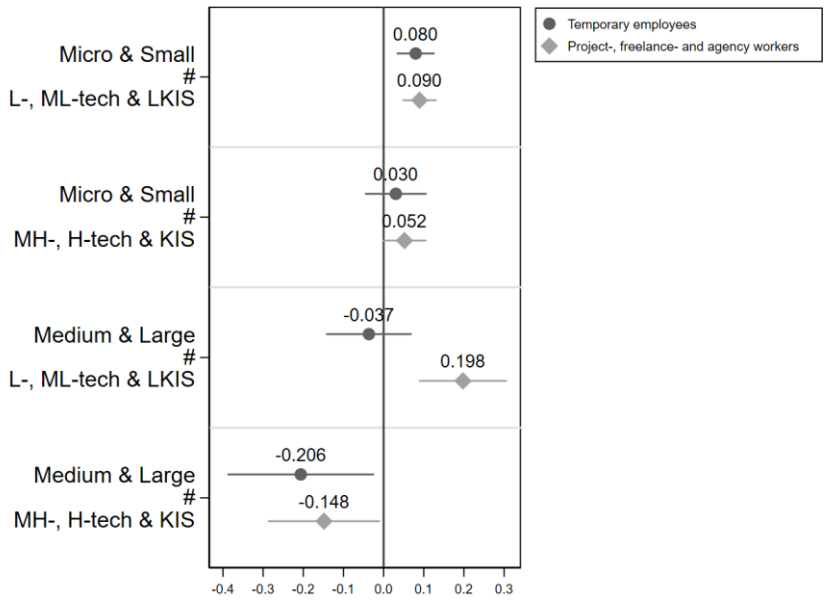


Fig. 2 – Average marginal effects of temporary employees and external workers on innovation in different types of firms

Panel A



Panel B



Labor flexibility and innovation: the importance of firms' heterogeneity

Supplementary material - Online Appendix

A.1 Institutional background

In 2005, the Italian Labor Law was the result of three major reforms that introduced and regulated the use of non-standard labor contracts,[16] making it easier for firms to use these contracts. Indeed, firms could sign fixed-term contracts (*Contratto a tempo determinato*) in case of productive, organizational or technical reasons, as long as they respected the maximum duration of 36 months and the quantitative limits identified by the centralized collective bargaining agreements (CCBAs, *Contratti collettivi nazionali di lavoro*).[17] At the same time, firms adopting part-time work could enjoy a specific tax relief. Finally, firms could also use a variety of other non-standard labor contracts, such as project-workers arrangement (*co.co.pro*), job on call (*Lavoro intermittente, Lavoro a chiamata*), job sharing (*Contratto di lavoro ripartito*), placement contracts (*Contratto di inserimento*), and agency-workers (*Lavoro interinale*).[18]

This system of non-standard labor contracts remained almost unchanged until the introduction of the Law 92/2012 (the 'Fornero reform'). The use of non-standard employment was made more difficult, by higher costs and a more complex procedure to set them up. In addition, some typologies of contracts (i.e. placement contracts) were abrogated. Apprenticeship (*Contratto di apprendistato*) was amended, by putting on employers a new obligation to hire half of the apprentices active in the firm. However, this reform facilitated the use of fixed-term contracts shorter than 12 months, by not requiring the existence of productive, organizational or technical reasons to set them up (i.e., the 'a causality' principle; Consiglio and Moschera, 2016). A subsequent Law Decree (76/2013) provided new fiscal incentives to hire young people through tenured contracts and, at the same time, it enlarged the application of the 'a causality' principle beyond the 12-month limit.

[16] These interventions were: (i) the 'Treu package', made up by the Law 196/1997 and the Legislative Decrees 280/1997 and 468/1997; (ii) the Legislative Decree 368/2001; (iii) the 'Biagi reform', which corresponds to the Legislative Decree 276/2003. According to ILO (2016), non-standard labor contracts can be grouped into four classes: (i) temporary employment (which includes, among others, fixed-term contracts and apprenticeships); (ii) part-time work; (iii) temporary agency work and other forms of employment involving multiple parties (usually three: the agency, the user –a firm-- and the administered employee); (iv) disguised employment relationship and self-employment. The Italian regulation includes categories (i), (ii) and (iii) into the broad set of non-standard labor contracts, while considering (iv) self-employment as a stand-alone class.

[17] Exceptions were: (i) the launch of a new business, within the periods defined by the CCBAs; (ii) seasonal activities; (iii) positive demand dynamics in specific periods of the year.

[18] CCBAs also identify the quantitative limitations for temporary-agency workers.

In 2014, the regulation of labor contracts changed once more with the 'Jobs Act' (the Legislative Decree 81/2015). Fixed-term contracts were further liberalized (no indication of any motivation for the entire duration of the contract),[19] whereas rules for part-time work changed in terms of: (i) the limits to increase hours of work; (ii) the opportunity to ask for part-time schedule in the presence of specific events. Moreover, the list of non-standard labor contracts was re-organized. Project-workers and job sharing (*Contratto di lavoro ripartito*) were abrogated, and quantitative limits were set for job-on-call contracts. Additionally, the 'Jobs Act' introduced substantial novelties in terms of employment protection. For unfair dismissals due to economic reasons (*motivo oggettivo*), workers have the right to receive a monetary compensation instead of a job reinstatement.[20] The monetary compensation is proportional to tenure (*tutele crescenti*). The 'Jobs Act' also established the opportunity to set up an extrajudicial proceeding to disfavor workers' appeals to court against dismissals. Finally, the Stability Law in 2015 granted a generous tax relief to all employers who hired through permanent contracts in 2015.[21]

Overall, the regulation regarding the use of non-standard labor contracts remained substantially unchanged in the period considered in our analysis (i.e., 2005-2018). Only the last two waves of the RIL survey (2015, 2018) may be affected by the changes introduced by the 'Jobs Act' and the 'Stability Law'. We include a vector of year- fixed effects to normalize the intensity in the use of non-standard labor contracts across years. This strategy controls for any wave-specific shock in the use of both these contracts and innovation.

[19] The article 23 established a maximum share of temporary employees equal to 20% of permanent workers, but with exceptions that refer to (i) firms up to five employees; (ii) the launch of new activities; (iii) innovative start-ups; (iv) seasonal activities.
[20] The monetary compensation is limited to those workers who have been hired after the enforcement of the 'Jobs Act'.
[21] The Legislative Decree 87/2018 ('Decreto Dignità') placed a limitation in the use of non-standard labor contracts and changed again the regulatory framework.

A.2 The RIL survey and descriptive statistics

A.2.1 The RIL survey

This work exploits data from the *Rilevazione Longitudinale Imprese e Lavoro* (RIL), a mandatory survey conducted by the *Istituto Nazionale per l'Analisi delle Politiche Pubbliche* (INAPP).[22] The RIL survey is carried out on a representative sample of Italian partnerships and limited liability companies of all size classes that operate in the non-agricultural private sectors. The sample is stratified by firm size, industry, geographical area and the legal form of firms. Inclusion (probability of extraction) is proportional to firm size (measured by the total number of employees). The reference population is provided by the Italian Statistical Institute (ISTAT) in the *Registro statistico delle imprese attive* (ASIA) database.

INAPP conducted five waves of the survey in 2005, 2007, 2010, 2015 and 2018, interviewing altogether 74843 partnerships and limited liability companies. Each wave covers from about 21000 to 30000 firms. A sub-sample of 33550 firms (45% of the firms) is observed in at least two waves. After the data cleaning steps detailed in Section 3 of the main text of the paper, our final sample includes 23469 firms.

In RIL, the taxonomy of industries is based on the NACE rev. 1.1 (waves 2005 and 2007) and NACE rev. 2 (waves from 2010 onwards) statistical classifications of economic activities for Europe. Using the conversion matrix proposed by Perani and Cirillo (2015), 2-digit industry codes in the third, fourth and fifth wave of RIL have been converted into NACE Rev. 1.1 and then aggregated into a consistent taxonomy of 16 sectors. Table A.1 describes the distribution of firms across these sectors. Geographical location of firms is available at the NUTS 2 level:[23] Table A.2 presents the distribution of firms across Italian regions.

[22] INAPP is part of the Italian National Statistical System (SISTAN). RIL has been recently used in a number of scientific papers such as Pompei et al. (2019); Berton et al. (2021); Dosi et al. (2021). For more details on RIL questionnaire, sample design and methodological issues, see: https://www.inapp.org/it/dati/ril.

[23] In Italy, the NUTS 2 degree of aggregation corresponds to regions. More information on the classification can be retrieved from: https://ec.europa.eu/eurostat/web/nuts/background.

Table A. 1- RIL database; distribution of firms by industry

	RIL database - number of firms	%	Our sample - number of firms	%
Mining and quarrying	1110	1,51	496	2,11
Manufacture of Food; beverages; tobacco	4133	5,63	1491	6,35
Manufacture of Textile and wearing; Wood; Paper and reproduction	5260	7,16	1989	8,48
Manufacture of Coke; Chemicals; Metals	5971	8,13	2548	10,86
Manufacture of Machinery and equipment	5477	7,46	2038	8,68
Other manufacturing	3174	4,32	1336	5,69
Supply and distribution of electricity, gas, steam	2370	3,23	630	2,68
Construction	9796	13,34	2804	11,95
Wholesale and retail trade	9294	12,66	2658	11,33
Accommodation and food service	5013	6,83	1187	5,06
Transport and telecommunication	4070	5,54	1440	6,14
Financial and insurance	3083	4,20	809	3,45
Other business services	7763	10,57	2027	8,64
Education	1533	2,09	349	1,49
Health and social work	2630	3,58	892	3,80
Other services	2758	3,76	775	3,30
# Firms (Total)	73435	100	23469	100

Notes: Cols. (2) and (3) refer to all firms contained in the RIL database, excluding firms that declared not being active and firms that changed their location (NUTS 2 region) across waves. Cols. (4) and (5) refer to the final sample (i.e. the sample in columns 1 and 2, Table 3 in the main text of the paper).

Table A. 2- RIL database; distribution of firms by NUTS 2 regions

	RIL database - number of firms	%	Our sample - number of firms	%
Piemonte	4783	6,51	1724	7,35
Valle d'Aosta	1331	1,81	347	1,48
Lombardia	10887	14,83	4128	17,59
Trentino Alto-Adige	2923	3,98	840	3,58
Veneto	6163	8,39	2343	9,98
Friuli V.G.	2926	3,98	982	4,18
Liguria	2959	4,03	821	3,50
Emilia Romagna	5515	7,51	2012	8,57
Toscana	5234	7,13	1752	7,47
Umbria	2445	3,33	718	3,06
Marche	3138	4,27	1020	4,35
Lazio	4668	6,36	1262	5,38
Abruzzo	2642	3,60	705	3,00
Molise	1528	2,08	389	1,66
Campania	3786	5,16	1079	4,60
Puglia	3057	4,16	860	3,66
Basilicata	1965	2,68	575	2,45
Calabria	2110	2,87	511	2,18
Sicilia	2989	4,07	740	3,15
Sardegna	2386	3,25	661	2,82
# Firms (Total)	73435	100	23469	100

Notes: Cols. (2) and (3) refer to all firms contained in the RIL database, excluding firms that declared not being active and firms that changed their location (NUTS 2 region) across waves. Cols. (4) and (5) refer to the final sample (i.e. the sample in columns 1 and 2, Table 3 in the main text of the paper).

A.2.2 Definition of variables and descriptive statistics

The control variables used in the empirical analysis are defined as follows. Firm size is proxied by the total number of employees. Three dummy variables indicate, respectively, whether the firm has invested in research and development (R&D), in information and communication technologies (ICTs) and in plants, machinery and equipment in the year before the interview. In terms of workforce composition, we consider the share of employees who participated in training activities, the share of managers and middle managers, and the share of female employees. We also constructed two indicators of industrial relations: (i) the use of a second-level wage bargaining scheme (linked to productivity) in addition to the one defined by the CCBAs, and (ii) the presence of workers' union representations. Finally, we constructed some dummy variables indicating whether firms are exporters and whether they belong to a national group or a foreign group.

Table A. 3 summarizes these definitions and provides some descriptive statistics of these variables in the RIL sample. About half of firms (47.5%) introduced at least one product or one process innovation in the 3 years before the interview (40% at least one product, 34% at least one process, 26% both types of innovation). Only 4.6% of firms filed or purchased a patent (in line with the evidence provided by Lotti and Marin, 2013; Succurro and Costanzo, 2019; among others).

The average shares of temporary and tenured part-time employees are about 12% and 16%, respectively. About 80% of firms show a share of temporary employees lower than 20%, which is reasonable given the current legal limits (Section A.1). The average proportion of project-, freelance and agency-workers to total employees is about 13%, with only 10% of having a share equal or higher than 50%.

In the empirical analysis we also classified industries in terms of their technology and knowledge intensity (R&D expenditures/value added). To this end, we followed Eurostat's definition[24], which is based on the NACE Rev.2 classification at the 2-digit level. Since the latter is available only in the last three waves of RIL, a lower number of observations are included in the regressions when exploiting this taxonomy on the technology and knowledge intensity of industries. The detailed composition of our sample in terms of industries and technological intensity is reported in Table A.4.

[24] See https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:High-tech_classification_of_manufacturing_industries and https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Knowledge-intensive_services_(KIS).

Table A. 3- Firm characteristics: definitions and descriptive statistics

Variable	Definition	Mean	SD	Min	p10	p25	p50	p75	p90	Max
Prod. or proc. inn.	The firm has introduced at least one product or one process innovation in the current year and/or in the past two years; dummy	0.475	0.499	0	0.000	0.000	0.000	1.000	1.000	1
Prod. inn.†	The firm has introduced at least one product innovation in the current year and/or in the past two years; dummy	0.400	0.490	0	0.000	0.000	0.000	1.000	1.000	1
Proc. inn. ‡	The firm has introduced at least one process innovation in the current year and/or in the past two years; dummy	0.336	0.472	0	0.000	0.000	0.000	1.000	1.000	1
Prod. & proc. inn.	The firm has introduced at least one product and one process innovation in the current year and/or in the past two years; dummy	0.261	0.439	0	0.000	0.000	0.000	1.000	1.000	1
Patents	The firm has acquired or filed patents in the current year and/or in the past two years; dummy	0.046	0.209	0	0.000	0.000	0.000	0.000	0.000	1
Share of temporary employees	Share of employees with the following types of contracts in the firm's total employees. Fixed-term contracts (*Contratto a tempo determinato*), apprenticeships (*Contratto di apprendistato*), training contracts (*Contratto di formazione e lavoro*) and placement contracts (*Contratto di inserimento*); share	0.122	0.215	0	0.000	0.000	0.008	0.154	0.373	1
Share of (tenured) part-time employees	Share of employees with (tenured) part-time contracts in the firm's total employees; share	0.159	0.264	0	0.000	0.000	0.036	0.188	0.500	1
Prop. of project-, freelance-, agency-workers	Share of employees with the following types of contracts in the firm's total employees. Employer-coordinated freelance workers (*co.co.co*), project-workers *(Lavoratori a progetto*), voucher-based workers (*Collaboratori occasionali*), family workers (*Coadiuvanti familiari*) and agency-workers (*Lavoratori interinali, dipendenti di imprese appaltatrici di servizi*); share	0.132	0.232	0	0.000	0.000	0.000	0.167	0.469	1
Firm size = # Employees	Total number of employees	62.185	776.837	1	2.000	4.000	11.000	32.000	100.000	148220
Investments in R&D	The firm has invested in research and development, certifications and patents, licenses, trademarks and software in the current year; dummy	0.106	0.308	0	0.000	0.000	0.000	0.000	1.000	1
Investments in ICTs	The firm has invested in IT equipment (i.e., computer, process automation) in the current year; dummy	0.222	0.416	0	0.000	0.000	0.000	0.000	1.000	1
Investments in plants, mach. & eq.	The firm has invested in plants, machinery and industrial equipment in the current year; dummy	0.334	0.472	0	0.000	0.000	0.000	1.000	1.000	1
Share of trained employees	Share of employees who have participated in training activities organized by the firm in the firm's total employees; share	0.279	0.387	0	0.000	0.000	0.000	0.571	1.000	1
Share of managers and middle managers	Share of managers and middle managers in the firm's total employees; share	0.049	0.129	0	0.000	0.000	0.000	0.034	0.147	1
Share of female employees	Share of female employees in the firm's total employees; share	0.386	0.329	0	0.000	0.105	0.301	0.625	1.000	1
Second-level wage barg.	The firm has activated a second-level bargaining scheme, linked to levels of production or productivity in the current year; dummy	0.071	0.258	0	0.000	0.000	0.000	0.000	0.000	1
Union representation (RSA/RSU)	Trade (workers') unions (either Company Union Representation --*RSA*--, or Unitary Representation Bodies –*RSU*--) are active in the firm in the current year; dummy	0.206	0.404	0	0.000	0.000	0.000	0.000	1.000	1
Exporter	The firm has exported (in whole or in part) its products and services in the current year; dummy	0.254	0.435	0	0.000	0.000	0.000	1.000	1.000	1
National group	The firm belongs to an Italian industrial group in the current year; dummy	0.109	0.311	0	0.000	0.000	0.000	0.000	1.000	1
Foreign group	The firm belongs to an foreign industrial group in the current year; dummy	0.084	0.277	0	0.000	0.000	0.000	0.000	0.000	1
Independent (no group) firm	The firms does not belong to any industrial group in the current year; dummy	0.808	0.394	0	0.000	1.000	1.000	1.000	1.000	1

Notes:†Product innovation refers to the introduction in the market of a new product (or service) either technologically new or significantly improved in terms of performance, technical and functional characteristics, easiness of use with respect to previous products (or services) sold by the firm. ‡ Process innovation refers to the adoption of production processes, production management activities or production support activities either technologically new or significantly improved with respect to those previously adopted by the firm.

Table A. 4 - Distribution of observations by 2-digit industry (NACE rev.2 classification) and technological intensity

	Medium-low-, Low-tech manuf., Less knowledge-intensive serv.	Medium-high-, High-tech manuf., Knowledge-intensive serv.	Total
Manufacture of food products	2008	0	2008
Manufacture of beverages	206	0	206
Manufacture of textiles	654	0	654
Manufacture of wearing apparel	442	0	442
Manufacture of leather and related products	418	0	418
Manufacture of wood and of products of wood and cork, ...	574	0	574
Manufacture of paper and paper products	267	0	267
Printing and reproduction of recorded media	386	0	386
Manufacture of coke and refined petroleum products	212	0	212
Manufacture of chemicals and chemical products	0	231	231
Manufacture of basic pharmaceutical products and pharmaceutical ...	0	49	49
Manufacture of rubber and plastic products	537	0	537
Manufacture of other non-metallic mineral products	744	0	744
Manufacture of basic metals	248	0	248
Manufacture of fabricated metal products, except machinery and equipment	1949	0	1949
Manufacture of computer, electronic and optical products	0	506	506
Manufacture of electrical equipment	0	453	453
Manufacture of machinery and equipment n.e.c.	0	1412	1412
Manufacture of motor vehicles, trailers and semi-trailers	0	194	194
Manufacture of other transport equipment	0	107	107
Manufacture of furniture	1370	0	1370
Other manufacturing	616	0	616
Repair and installation of machinery and equipment	449	0	449
Wholesale and retail trade and repair of motor vehicles and motorcycles	868	0	868
Wholesale trade, except of motor vehicles and motorcycles	1710	0	1710
Retail trade, except of motor vehicles and motorcycles	1141	0	1141
Land transport and transport via pipelines	1225	0	1225
Water transport	0	44	44
Air transport	0	4	4
Warehousing and support activities for transportation	584	0	584
Postal and courier activities	9	0	9
Accommodation	738	0	738
Food and beverage service activities	764	0	764
Publishing activities	0	100	100
Motion picture, video and television programme production, sound recording ...	0	169	169
Programming and broadcasting activities	0	65	65
Telecommunications	0	15	15
Computer programming, consultancy and related activities	0	481	481
Information service activities	0	493	493
Financial service activities, except insurance and pension funding	0	396	396
Insurance, reinsurance and pension funding, except compulsory social security	0	37	37
Activities auxiliary to financial services and insurance activities	0	738	738
Real estate activities	123	0	123
Legal and accounting activities	0	417	417
Activities of head offices; management consultancy activities	0	147	147
Architectural and engineering activities; technical testing and analysis	0	269	269
Scientific research and development	0	24	24
Advertising and market research	0	97	97
Other professional, scientific and technical activities	0	175	175
Veterinary activities	0	8	8
Rental and leasing activities	62	0	62
Employment activities	0	20	20
Travel agency, tour operator and other reservation service and related activities	235	0	235
Security and investigation activities	0	75	75
Services to buildings and landscape activities	241	0	241
Office administrative, office support and other business support activities	186	0	186
Education	0	436	436
Human health activities	0	1161	1161
Residential care activities	0	111	111
Social work activities without accommodation	0	17	17
Creative, arts and entertainment activities	0	38	38
Libraries, archives, museums and other cultural activities	0	6	6
Gambling and betting activities	0	37	37
Sports activities and amusement and recreation activities	0	80	80
Repair of computers and personal and household goods	48	0	48
Other personal service activities	649	0	649
Total	19663	8612	28275

A.3 Non-standard labor contracts across industries and (NUTS 2) regions

Table A.5 provides a description of the use of non-standard labor contracts across industries and NUTS 2 regions in Italy. Differences in the use of numerical flexibility are indeed significant across both industries and territories.

Table A.5 - The use of non-standard labor contracts across industries and NUTS 2 regions

	Using temporary employees (t-1)		Not using temporary employees (t-1)		Test of equality of proportions	Using part-time employees (t-1)		Not using part-time employees (t-1)		Test of equality of proportions	Using project-, freelance-, agency-workers (t-1)		Not using project-, freelance-, agency-workers (t-1)		Test of equality of proportions
	Share of firms	Observations	Share of firms	Observations	p-value	Share of firms	Observations	Share of firms	Observations	p-value	Share of firms	Observations	Share of firms	Observations	p-value
Mining and quarrying	0.015	19621	0.031	17973	(0.000)	0.016	21433	0.031	16161	(0.000)	0.021	18529	0.024	19065	(0.068)
Manufacture of Food; beverages; tobacco	0.070	19621	0.060	17973	(0.000)	0.066	21433	0.064	16161	(0.391)	0.069	18529	0.062	19065	(0.003)
Manufacture of Textile and wearing; Wood; Paper and reproduction	0.082	19621	0.088	17973	(0.044)	0.088	21433	0.080	16161	(0.004)	0.084	18529	0.086	19065	(0.442)
Manufacture of Coke; Chemicals; Metals	0.111	19621	0.118	17973	(0.042)	0.105	21433	0.126	16161	(0.000)	0.117	18529	0.111	19065	(0.079)
Manufacture of Machinery and equipment	0.099	19621	0.081	17973	(0.000)	0.092	21433	0.088	16161	(0.150)	0.108	18529	0.073	19065	(0.000)
Other manufacturing	0.057	19621	0.064	17973	(0.002)	0.063	21433	0.057	16161	(0.025)	0.061	18529	0.060	19065	(0.707)
Supply and distribution of electricity, gas, steam	0.026	19621	0.027	17973	(0.416)	0.024	21433	0.028	16161	(0.019)	0.030	18529	0.022	19065	(0.000)
Construction	0.122	19621	0.120	17973	(0.658)	0.103	21433	0.145	16161	(0.000)	0.101	18529	0.140	19065	(0.000)
Wholesale and retail trade	0.099	19621	0.118	17973	(0.000)	0.105	21433	0.113	16161	(0.011)	0.099	18529	0.117	19065	(0.000)
Accommodation and food service	0.058	19621	0.034	17973	(0.000)	0.046	21433	0.048	16161	(0.378)	0.034	18529	0.058	19065	(0.000)
Transport and telecommunication	0.062	19621	0.063	17973	(0.632)	0.054	21433	0.073	16161	(0.000)	0.058	18529	0.066	19065	(0.000)
Financial and insurance	0.031	19621	0.038	17973	(0.000)	0.041	21433	0.025	16161	(0.000)	0.041	18529	0.027	19065	(0.000)
Other business services	0.082	19621	0.081	17973	(0.719)	0.096	21433	0.061	16161	(0.000)	0.087	18529	0.076	19065	(0.000)
Education	0.014	19621	0.013	17973	(0.430)	0.015	21433	0.011	16161	(0.006)	0.011	18529	0.015	19065	(0.000)
Health and social work	0.037	19621	0.038	17973	(0.518)	0.052	21433	0.019	16161	(0.000)	0.050	18529	0.025	19065	(0.000)
Other services	0.038	19621	0.028	17973	(0.000)	0.034	21433	0.032	16161	(0.446)	0.028	18529	0.037	19065	(0.000)
Piemonte	0.082	19621	0.072	17973	(0.001)	0.079	21433	0.076	16161	(0.350)	0.083	18529	0.072	19065	(0.000)
Valle d'Aosta	0.014	19621	0.019	17973	(0.001)	0.012	21433	0.022	16161	(0.000)	0.010	18529	0.022	19065	(0.000)
Lombardia	0.184	19621	0.187	17973	(0.440)	0.201	21433	0.165	16161	(0.000)	0.216	18529	0.155	19065	(0.000)
Trentino Alto-Adige	0.036	19621	0.032	17973	(0.083)	0.035	21433	0.033	16161	(0.338)	0.027	18529	0.041	19065	(0.000)
Veneto	0.113	19621	0.096	17973	(0.000)	0.118	21433	0.087	16161	(0.000)	0.119	18529	0.091	19065	(0.000)
Friuli V.G.	0.043	19621	0.041	17973	(0.293)	0.045	21433	0.038	16161	(0.001)	0.044	18529	0.040	19065	(0.062)
Liguria	0.035	19621	0.034	17973	(0.810)	0.035	21433	0.033	16161	(0.327)	0.033	18529	0.035	19065	(0.274)
Emilia Romagna	0.107	19621	0.077	17973	(0.000)	0.102	21433	0.081	16161	(0.000)	0.105	18529	0.081	19065	(0.000)
Toscana	0.080	19621	0.072	17973	(0.005)	0.078	21433	0.073	16161	(0.038)	0.076	18529	0.076	19065	(0.775)
Umbria	0.032	19621	0.025	17973	(0.000)	0.026	21433	0.032	16161	(0.002)	0.022	18529	0.035	19065	(0.000)
Marche	0.046	19621	0.036	17973	(0.000)	0.043	21433	0.038	16161	(0.022)	0.037	18529	0.044	19065	(0.000)
Lazio	0.052	19621	0.047	17973	(0.032)	0.052	21433	0.047	16161	(0.056)	0.054	18529	0.046	19065	(0.001)
Abruzzo	0.022	19621	0.032	17973	(0.000)	0.022	21433	0.032	16161	(0.000)	0.021	18529	0.032	19065	(0.000)
Molise	0.013	19621	0.020	17973	(0.000)	0.012	21433	0.022	16161	(0.000)	0.011	18529	0.022	19065	(0.000)
Campania	0.035	19621	0.049	17973	(0.000)	0.035	21433	0.051	16161	(0.000)	0.038	18529	0.046	19065	(0.000)
Puglia	0.032	19621	0.041	17973	(0.000)	0.029	21433	0.046	16161	(0.000)	0.031	18529	0.042	19065	(0.000)
Basilicata	0.018	19621	0.029	17973	(0.000)	0.016	21433	0.032	16161	(0.000)	0.015	18529	0.031	19065	(0.000)
Calabria	0.014	19621	0.026	17973	(0.000)	0.015	21433	0.026	16161	(0.000)	0.013	18529	0.026	19065	(0.000)
Sicilia	0.023	19621	0.035	17973	(0.000)	0.026	21433	0.032	16161	(0.000)	0.024	18529	0.033	19065	(0.000)
Sardegna	0.022	19621	0.029	17973	(0.000)	0.019	21433	0.033	16161	(0.000)	0.021	18529	0.030	19065	(0.000)

A. 4 Further econometric results

In this section, we provide some further econometric results, which we have not reported in the main text of the paper.

A.4.1 RE probit models

In Table A.6, we show the results of the RE probit, including controls in a hierarchical fashion.

Table A.6 – RE probit model estimates (Eq. 2); including controls hierarchically

	(1) (Prod. or proc. inn., RE)	(2) (Prod. or proc. inn., RE)	(3) (Prod. or proc. inn., RE)	(4) (Prod. or proc. inn., RE)	(5) (Prod. or proc. inn., RE, c1)	(6) (Prod. or proc. inn., RE, c2)	(7) (Prod. or proc. inn., RE, c3)	(8) (Prod. or proc. inn., RE, c4)	(9) (Prod. or proc. inn., RE, c5)	(10) (Prod. or proc. inn., RE, c6)	(11) (Prod. or proc. inn., RE, c7)	(12) (Prod. or proc. inn., RE, c8)	(13) (Prod. or proc. inn., RE, c9)	(14) (Prod. or proc. inn., RE, c10)	(15) (Prod. or proc. inn., RE)	(16) (Prod. inn., RE)	(17) (Proc. inn., RE)	(18) (Prod. & proc. inn., RE)	(19) (Patents, RE)
Share of temporary employees (t-1)	0.215***			0.182***	0.120**	0.123**	0.119**	0.110**	0.118**	0.122**	0.121**	0.123**	0.078	0.100*	0.099*	0.112**	0.108*	0.126**	-0.114
	(0.052)			(0.056)	(0.054)	(0.054)	(0.053)	(0.053)	(0.053)	(0.054)	(0.054)	(0.054)	(0.056)	(0.055)	(0.055)	(0.056)	(0.057)	(0.059)	(0.139)
Share of (tenured) part-time employees (t-1)		-0.208***		-0.260***	-0.092	-0.072	-0.065	-0.054	-0.037	-0.032	-0.036	-0.036	-0.052	-0.002	-0.003	0.059	-0.027	0.047	-0.153
		(0.053)		(0.057)	(0.056)	(0.055)	(0.055)	(0.054)	(0.054)	(0.055)	(0.057)	(0.057)	(0.058)	(0.057)	(0.057)	(0.059)	(0.060)	(0.063)	(0.160)
Prop. of project-, freelance-, agency-workers (t-1)			0.444***	0.399***	0.381***	0.333***	0.308***	0.306***	0.297***	0.297***	0.298***	0.299***	0.307***	0.249***	0.249***	0.246***	0.212***	0.223***	0.377***
			(0.045)	(0.046)	(0.045)	(0.045)	(0.045)	(0.045)	(0.045)	(0.045)	(0.045)	(0.045)	(0.046)	(0.046)	(0.046)	(0.046)	(0.046)	(0.048)	(0.095)
Firm size = # Employees (log, +1) (t-1)					0.242***	0.210***	0.198***	0.185***	0.178***	0.177***	0.177***	0.175***	0.188***	0.161***	0.161***	0.150***	0.175***	0.174***	0.316***
					(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.009)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.022)
Investments in R&D (t-1)						0.420***	0.340***	0.318***	0.314***	0.312***	0.313***	0.313***	0.315***	0.287***	0.288***	0.347***	0.205***	0.286***	0.470***
						(0.029)	(0.030)	(0.030)	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)	(0.030)	(0.030)	(0.049)
Investments in ICTs (t-1)							0.172***	0.088***	0.083***	0.084***	0.085***	0.084***	0.092***	0.080***	0.080***	0.079***	0.048**	0.052**	0.026
							(0.021)	(0.023)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.025)	(0.049)
Investments in plants, mach. & eq. (t-1)								0.189***	0.180***	0.181***	0.182***	0.182***	0.193***	0.192***	0.191***	0.151***	0.216***	0.186***	-0.019
								(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.022)	(0.044)
Share of trained employees (t-1)									0.214***	0.214***	0.216***	0.215***	0.227***	0.237***	0.237***	0.191***	0.238***	0.206***	-0.002
									(0.025)	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)	(0.026)	(0.025)	(0.027)	(0.056)
Share of managers and middle managers (t-1)										0.064	0.062	0.060	0.071	0.073	0.072	0.185***	-0.091	0.045	0.805***
										(0.066)	(0.067)	(0.067)	(0.069)	(0.069)	(0.069)	(0.070)	(0.074)	(0.076)	(0.149)
Share of female employees (t-1)											0.008	0.009	0.004	-0.027	-0.027	-0.005	-0.044	-0.019	0.121
											(0.037)	(0.037)	(0.037)	(0.037)	(0.037)	(0.037)	(0.039)	(0.040)	(0.089)
Second-level wage barg. (t-1)												0.033	0.077**	0.065*	0.066*	0.093**	0.043	0.078**	0.107*
												(0.037)	(0.038)	(0.038)	(0.038)	(0.038)	(0.037)	(0.037)	(0.061)
Union representation (RSA/RSU) (t-1)													-0.120***	-0.126***	-0.125***	-0.132***	-0.106***	-0.119***	-0.140***
													(0.028)	(0.028)	(0.028)	(0.029)	(0.028)	(0.029)	(0.054)
Exporter (t-1)														0.352***	0.352***	0.369***	0.273***	0.313***	0.519***
														(0.023)	(0.023)	(0.023)	(0.023)	(0.024)	(0.047)
National group (t-1)															-0.017	-0.021	-0.005	-0.013	0.002
															(0.031)	(0.031)	(0.031)	(0.032)	(0.056)
Foreign group (t-1)															0.014	-0.002	-0.010	-0.030	-0.032
															(0.031)	(0.031)	(0.031)	(0.032)	(0.065)
Constant	-0.134*	-0.133*	-0.172**	-0.171**	-0.794***	-0.737***	-0.730***	-0.768***	-0.786***	-0.793***	-0.797***	-0.794***	-0.796***	-0.794***	-0.798***	-1.148***	-1.056***	-1.447***	-4.340***
	(0.072)	(0.072)	(0.074)	(0.075)	(0.075)	(0.074)	(0.074)	(0.073)	(0.073)	(0.073)	(0.074)	(0.074)	(0.076)	(0.075)	(0.076)	(0.082)	(0.075)	(0.083)	(0.246)
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region/NUTS2 FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
#Observations	42697	41976	39898	37438	37438	37438	37438	37438	36571	36551	36482	36482	34615	34615	34614	34614	34614	34614	34761
#Firms	26925	26525	25630	24211	24211	24211	24211	24211	23829	23825	23790	23790	23469	23469	23469	23469	23469	23469	23553
Log-likelihood	-2.71e+04	-2.67e+04	-2.53e+04	-2.37e+04	-2.32e+04	-2.31e+04	-2.31e+04	-2.30e+04	-2.24e+04	-2.24e+04	-2.24e+04	-2.24e+04	-2.13e+04	-2.12e+04	-2.12e+04	-2.08e+04	-1.95e+04	-1.79e+04	-5046.950
Prop. variance by the panel component	0.419	0.415	0.407	0.407	0.374	0.356	0.349	0.340	0.331	0.331	0.330	0.330	0.322	0.310	0.310	0.326	0.284	0.298	0.467

Notes: All regressions include year-, industry- and region/NUTS2-fixed effects, where industries are defined as in Table A.1. Coefficients of year, industry and region/NUTS2 dummies are not reported to save space. Full tables are available from authors upon request. Cluster (firm) - robust standard errors are reported in parentheses. Statistical significance at the 10%, 5% and 1% level is indicated by *,** and ***, respectively.

Table A.7 reports the estimates of the double interaction of each proxy of numerical flexibility with the industry technological intensity and the size category of firms.

Table A.7 – Extended RE probit model estimates (Eq. 4) with double interactions

	(1) (Prod. or proc. inn., RE)
Share of temporary employees (t-1)	0.264***
	(0.080)
Share of (tenured) part-time employees (t-1)	0.048
	(0.082)
Prop. of project-, freelance-, agency-workers (t-1)	0.297***
	(0.072)
Medium-large firms [50:.) (t-1)=1	0.307***
	(0.055)
Medium-large firms [50:.) (t-1)=1 # Share of temporary employees (t-1)	-0.388*
	(0.198)
Medium-large firms [50:.) (t-1)=1 # Share of (tenured) part-time employees (t-1)	-0.697***
	(0.186)
Medium-large firms [50:.) (t-1)=1 # Prop. of project-, freelance-, agency-workers (t-1)	0.370*
	(0.203)
Medium-high-, High-tech manuf., Knowledge-intensive serv. (t-1)=1	0.234***
	(0.040)
Medium-high-, High-tech manuf., Knowledge-intensive serv. (t-1)=1 # Share of temporary employees (t-1)	-0.164
	(0.151)
Medium-high-, High-tech manuf., Knowledge-intensive serv. (t-1)=1 # Share of (tenured) part-time employees (t-1)	-0.119
	(0.130)
Medium-high-, High-tech manuf., Knowledge-intensive serv. (t-1)=1 # Prop. of project-, freelance-, agency-workers (t-1)	-0.126
	(0.116)
Medium-large firms [50:.) (t-1)=1 # Medium-high-, High-tech manuf., Knowledge-intensive serv. (t-1)=1	0.086
	(0.085)
Medium-large firms [50:.) (t-1)=1 # Medium-high-, High-tech manuf., Knowledge-intensive serv. (t-1)=1 # Share of temporary employees (t-1)	-0.413
	(0.394)
Medium-large firms [50:.) (t-1)=1 # Medium-high-, High-tech manuf., Knowledge-intensive serv. (t-1)=1 # Share of (tenured) part-time employees (t-1)	0.771*
	(0.403)
Medium-large firms [50:.) (t-1)=1 # Medium-high-, High-tech manuf., Knowledge-intensive serv. (t-1)=1 # Prop. of project-, freelance-, agency-workers (t-1)	-1.046***
	(0.330)
Constant	-0.069
	(0.052)
Firm controls ($\boldsymbol{X_{it-1}}$)	Yes
Year FEs	Yes
Region/NUTS2 FEs	Yes
#Observations	25973
#Firms	16749
Log-likelihood	-16101.77
Prop. variance by the panel component	0.325

Notes: The regression includes the vector of firm controls ($\mathbf{X_{it-1}}$), year-, and region/NUTS2-fixed effects. Coefficients of the control variables, year and region/NUTS2 dummies are not reported to save space. Full tables are available from authors upon request. Cluster (firm) - robust standard errors are reported in parentheses. Statistical significance at the 10%, 5% and 1% level is indicated by *,** and ***, respectively.

A.4.2 Instrumental variable estimates

In order to estimate CRE models with instrumental variables (IVCRE), we need to identify some excluded instruments (i.e. elements in $\mathbf{Z_{it-1}}$ not included in $\mathbf{X_{it-1}}$). To this end, we rely on the strategy proposed by Devicienti et al. (2018) and Berton et al. (2021), and use the means of $\mathbf{NFLEX_{it-1}}$ at the industry, regional, year and firm-size level. These variables should be valid instruments. First, the innovative activity of firms is mainly episodic in nature. Hence, once (lagged) firm-specific numerical flexibility is controlled for, the (lagged) average propensity of using it at the industry/region/year/firm size level should not have any direct effect on innovation. We provide some suggestive evidence that this is indeed the case in Table A.8, where we introduce the excluded instruments in the structural equation and none of them is significant. Second, the excluded instruments are strong predictors of the current shares of temporary employees, project-, freelance-and agency workers, and part-time employees (as shown by the estimates of the reduced form of $\mathbf{NFLEX_{it-1}}$ in Table A.9).

Results of the CRE model with instrumental variable (IVCRE) are shown in Table A.10.[25] In col. (1) we present the estimates on the entire sample. In cols. (2)-(5), we report estimates of the IVCRE model on four different groups of firms, defined in terms of industry technological intensity and size category.[26] Estimates of the IVCRE baseline model (col. 1) are very similar to those of the CRE model (col. 2 of Table 3 in the main text of the paper) in terms of sign and significance level. In particular, the positive effect of the share of temporary employees on innovation is confirmed: by raising the share of temporary employees, a firm can increase the probability to introduce a new product or a new process. The Wald test, reported at the bottom of Table A.10, clearly rejects the null hypothesis of exogeneity of the potential endogenous variables, suggesting that the IVCRE estimation is more appropriate.

When considering the four groups of firms, a positive effect of the share of temporary employees on innovation is estimated for micro-small firms in low-tech manufacturing and less-knowledge intensive services (col. 2). In contrast, temporary employment has a negative effect for medium-large firms active in high-tech manufacturing and knowledge intensive services (col. 5).

The Wald tests, reported at the bottom of Table A.10, does not reject the null hypothesis of exogeneity of the potential endogenous variables at standard significance level (probably because of

[25] We employ the Stata command `ivprobit` (`mle` option) to estimate the CRE probit model with endogenous variables.

[26] The four groups are: micro-small firms in low-tech manufacturing and less-knowledge intensive services; micro-small firms in high-tech manufacturing and knowledge intensive services; medium-large firms in low-tech manufacturing and less-knowledge intensive service; medium-large firms in high-tech manufacturing and knowledge intensive services.

the lower number of observations). For this reason, IVCRE estimates in Table A.10 can be considered as a robustness check, and results contained in Tables 3 and 4 in the paper remain the reference point.

Table A.8 – CRE probit model estimates (Equations 2 and 3) with excluded instruments in the structural equation

	(1) (Prod. or proc. inn., CRE, check on IV)
Share of temporary employees (t-1)	0.264**
	(0.113)
Share of (tenured) part-time employees (t-1)	-0.137
	(0.133)
Prop. of project-, freelance-, agency-workers (t-1)	-0.061
	(0.085)
Sh. temporary employees (by: reg, ind, year, size; t-1)	0.275
	(0.308)
Sh. (tenured) part-time employees (by: reg, ind, year, size; t-1)	0.133
	(0.343)
Sh. project-, freelance-, agency-workers (by: reg, ind, year, size; t-1)	0.312
	(0.292)
Constant	-0.822***
	(0.085)
Firm controls ($\boldsymbol{X}_{it-1}$)	Yes
Mundlak's terms ($\overline{\text{NFLEX}}_i$, $\bar{Z}_i$)	Yes
Year FEs	Yes
Industry FEs	Yes
Region/NUTS2 FEs	Yes
#Observations	34614
#Firms	23469
Log-likelihood	-20948.97
Prop. variance by the panel component	0.322

Notes: The regression includes the vector of firm controls ($\boldsymbol{X}_{it-1}$), the vector of Mundlak's terms ($\overline{\text{NFLEX}}_i$, $\bar{Z}_i$), year-, industry- and region/NUTS2-fixed effects, where industries are defined as in Table A.1. Coefficients of control variables, Mundlak's terms, year, industry and region/NUTS2 dummies are not reported to save space. Full tables are available from authors upon request. Cluster (firm) - robust standard errors are reported in parentheses. Statistical significance at the 10%, 5% and 1% level is indicated by *,** and ***, respectively.

Table A.9 – IVCRE probit model estimates (Equations 2, 3 and 5); reduced form of $\mathbf{NFLEX_{it-1}}$ (Eq. 5)

	Share of temporary employees (t-1)	Share of (tenured) part-time employees (t-1)	Prop. of project-, freelance-, agency-workers (t-1)	Share of temporary employees (t-1, id mean)	Share of (tenured) part-time employees (t-1, id mean)	Prop. of project-, freelance-, agency-workers (t-1, id mean)
Sh. temporary employees (by: reg, ind, year, size; t-1)	0.737***	-0.060**	0.033	0.015	-0.008	0.003
	(0.035)	(0.025)	(0.030)	(0.009)	(0.008)	(0.009)
Sh. (tenured) part-time employees (by: reg, ind, year, size; t-1)	-0.042	0.574***	0.032	-0.013	-0.017	0.012
	(0.034)	(0.038)	(0.036)	(0.010)	(0.011)	(0.011)
Sh. project-, freelance-, agency-workers (by: reg, ind, year, size; t-1)	0.007	-0.024	0.815***	-0.002	-0.019**	-0.002
	(0.024)	(0.023)	(0.035)	(0.009)	(0.010)	(0.011)
Sh. temporary employees (by: reg, ind, year, size; t-1, id mean)	0.299***	0.017	-0.034	1.023***	-0.043**	-0.001
	(0.042)	(0.033)	(0.036)	(0.027)	(0.022)	(0.022)
Sh. (tenured) part-time employees (by: reg, ind, year, size; t-1, id mean)	-0.001	0.418***	0.048	-0.032	1.011***	0.065***
	(0.039)	(0.045)	(0.042)	(0.021)	(0.027)	(0.023)
Sh. project-, freelance-, agency-workers (by: reg, ind, year, size; t-1, id mean	-0.004	0.023	0.212***	0.007	0.007	1.036***
	(0.030)	(0.030)	(0.041)	(0.020)	(0.021)	(0.026)
Constant	-0.034***	-0.018***	-0.024***	-0.033***	-0.017***	-0.024***
	(0.007)	(0.006)	(0.009)	(0.006)	(0.006)	(0.009)
Firm controls ($\boldsymbol{X}_{it-1}$)	Yes	Yes	Yes	Yes	Yes	Yes
Mundlak's terms ($\overline{\text{NFLEX}}_i$,$\bar{X}_i$)	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes	Yes	Yes	Yes
Region/NUTS2 FEs	Yes	Yes	Yes	Yes	Yes	Yes
#Observations	34614	34614	34614	34614	34614	34614
#Firms	23469	23469	23469	23469	23469	23469

Notes: All regressions include the vector of firm controls ($\mathbf{X}_{it-1}$), the vector of Mundlak's terms ($\overline{\text{NFLEX}}_i$,$\bar{X}_i$), year-, industry- and region/NUTS2-fixed effects, where industries are defined as in Table A.1. Coefficients of control variables, Mundlak's terms, year, industry and region/NUTS2 dummies are not reported to save space. Full tables are available from authors upon request. Cluster (firm) - robust standard errors are reported in parentheses. Statistical significance at the 10%, 5% and 1% level is indicated by *,** and ***, respectively.

Table A.10 – IVCRE probit model estimates (Equations 2, 3 and 5); structural equation estimates (Eq. 2)

	(1) (Prod. or proc. inn., IVCRE probit mle)	(2) (Prod. or proc. inn., IVCRE probit mle; micro-small and low-tech lkis)	(3) (Prod. or proc. inn., IVCRE probit mle; micro-small and high-tech kis)	(4) (Prod. or proc. inn., IVCRE probit mle; medium-large and low-tech lkis)	(5) (Prod. or proc. inn., IVCRE probit mle; medium-large and high-tech kis)
Share of temporary employees (t-1)	0.569*	0.757**	-0.097	0.089	-1.996**
	(0.343)	(0.378)	(0.449)	(0.874)	(0.782)
Share of (tenured) part-time employees (t-1)	0.038	-0.815*	0.438	-0.139	-1.231
	(0.471)	(0.462)	(0.491)	(0.716)	(1.642)
Prop. of project-, freelance-, agency-workers (t-1)	0.253	0.292	0.222	0.665	-0.665
	(0.285)	(0.287)	(0.318)	(0.693)	(0.706)
Firm size = # Employees (log, +1) (t-1)	0.037	0.035	0.146	-0.004	0.284**
	(0.044)	(0.064)	(0.109)	(0.097)	(0.127)
Investments in R&D (t-1)	0.011	-0.037	0.041	0.139	0.092
	(0.040)	(0.072)	(0.091)	(0.093)	(0.133)
Investments in ICTs (t-1)	-0.036	0.034	-0.038	-0.079	-0.265*
	(0.033)	(0.050)	(0.072)	(0.095)	(0.137)
Investments in plants, mach. & eq. (t-1)	-0.012	0.001	-0.037	-0.108	-0.196
	(0.029)	(0.041)	(0.072)	(0.095)	(0.150)
Share of trained employees (t-1)	-0.073**	-0.098*	-0.166**	0.113	-0.034
	(0.036)	(0.054)	(0.083)	(0.124)	(0.186)
Share of managers and middle managers (t-1)	0.140	0.049	0.129	0.288	-0.562
	(0.125)	(0.163)	(0.245)	(1.157)	(0.792)
Share of female employees (t-1)	-0.077	-0.158	0.252	-0.167	1.131**
	(0.117)	(0.137)	(0.207)	(0.396)	(0.543)
Second-level wage barg. (t-1)	-0.005	0.142	0.159	0.019	-0.095
	(0.056)	(0.120)	(0.166)	(0.107)	(0.144)
Union representation (RSA/RSU) (t-1)	-0.099*	0.011	-0.243	-0.116	-0.200
	(0.052)	(0.088)	(0.149)	(0.122)	(0.179)
Exporter (t-1)	0.029	-0.013	0.097	-0.053	0.108
	(0.043)	(0.059)	(0.103)	(0.119)	(0.206)
National group (t-1)	0.016	0.096	-0.069	-0.039	-0.157
	(0.052)	(0.090)	(0.119)	(0.116)	(0.171)
Foreign group (t-1)	0.093**	0.159**	-0.020	-0.144	-0.408**
	(0.044)	(0.065)	(0.102)	(0.147)	(0.188)
Constant	-0.690***	-0.365***	0.115	0.026	-0.007
	(0.068)	(0.080)	(0.209)	(0.225)	(0.442)
Mundlak's terms ($\overline{\boldsymbol{NFLEX}}_{\boldsymbol{i}}$, $\overline{\boldsymbol{X}}_{\boldsymbol{i}}$)	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes
Industry FEs	Yes	Yes	Yes	Yes	Yes
Region/NUTS2 FEs	Yes	Yes	Yes	Yes	Yes
#Observations	34614	14392	5956	3655	1970
#Firms	23469	9266	3999	2499	1320
Log-likelihood	161255.8	65581.68	26435.57	26924.16	17868.13
Prop. variance by the panel component					
Wald test; H0: no endogeneity (Chi2)	19.083	9.833	23.916	2.209	9.588
Wald test; H0: no endogeneity (p-value)	0.004	0.132	0.001	0.900	0.143

Notes. All regressions include the vector of Mundlak's terms ($\overline{\text{NFLEX}}_{\text{i}}$, $\overline{\text{X}}_{\text{i}}$), year-, industry- and region/NUTS2-fixed effects, where industries are defined as in Table A.1. Coefficients of control variables, Mundlak's terms, year, industry and region/NUTS2 dummies are not reported to save space. Full tables are available from authors upon request. Cluster (firm) - robust standard errors are reported in parentheses. Statistical significance at the 10%, 5% and 1% level is indicated by *,** and ***, respectively.

A.4.3 Other robustness checks

We conducted two further robustness checks. First, we included three additional controls in the CRE probit model, by exploiting the information available in only some of the waves of RIL. In particular, we included a proxy for firms' age (available in 2015 and 2018), the share of employees with a University degree and the share of employees younger than 35 years old (available in 2010, 2015 and 2018). Indeed, there is evidence that young firms may use more non-standard labor contracts than their older counterparts to compensate for the higher risk of their business; at the same time, young firms may be more innovative. Moreover, in Italy, younger workers tend to be

more educated and often employed on a temporary basis. Table A.11 reports the estimates of CRE models, including these additional controls.

Ceteris paribus, older firms and firms with a higher share of young workers innovate more (*between-firm* effects, lower part of Table A.11). However, each firm's probability to innovate diminishes as it becomes older, while it increases with the share of highly educated workers (*within-firm* effects, upper part of Table A.11). The positive relationship between the share of temporary employees and innovation is confirmed, although in col. (2) the coefficient is poorly estimated (probably because of the huge drop in the number of observations).

A second robustness check is performed by estimating linear probability models (LPM) with firm fixed effects (FE). Indeed, in a linear model, the CRE *within-firm* effects are equivalent to the FE estimates, because both are based on the sole within-firm variability in the variables. Results reported in Table A.12 are well in line with the marginal effects obtained from the CRE probit model estimates (Figure 1 in the paper).

Table A.11 – CRE probit model estimates (Equations 2 and 3) with additional controls

	(1) (Prod. or proc. inn., CRE)	(2) (Prod. or proc. inn., CRE)
Share of temporary employees (t-1)	0.290**	0.259
	(0.124)	(0.211)
Share of (tenured) part-time employees (t-1)	-0.126	-0.366*
	(0.145)	(0.218)
Prop. of project-, freelance-, agency-workers (t-1)	-0.072	0.085
	(0.094)	(0.154)
Firm age = # Years since firm establishment (log, +1) (t-1)	-0.240***	-0.320**
	(0.090)	(0.129)
Share of employees with a University degree (t-1)		0.664*
		(0.359)
Share of employees younger than 35 y.o. (t-1)		-0.121
		(0.170)
Share of temporary employees (t-1, id mean)	-0.241	-0.414*
	(0.150)	(0.234)
Share of (tenured) part-time employees (t-1, id mean)	0.130	0.335
	(0.163)	(0.240)
Prop. of project-, freelance-, agency-workers (t-1, id mean)	0.489***	0.404**
	(0.118)	(0.178)
Firm age = # Years since firm establishment (log, +1) (t-1, id mean)	0.219**	0.321**
	(0.092)	(0.127)
Share of employees with a University degree (t-1, id mean)		-0.186
		(0.371)
Share of employees younger than 35 y.o. (t-1, id mean)		0.431**
		(0.180)
Constant	-0.772***	-1.477***
	(0.125)	(0.166)
Firm controls ($\boldsymbol{X}_{it-1}$)	Yes	Yes
Mundlak terms ($\overline{\boldsymbol{NFLEX}}_{\boldsymbol{i}}, \bar{\boldsymbol{X}}_{\boldsymbol{i}}$)	Yes	Yes
Year FEs	Yes	Yes
Industry FEs	Yes	Yes
Region/NUTS2 FEs	Yes	Yes
#Observations	25062	15884
#Firms	15804	13529
Log-likelihood	-14817.38	-9358.983
Prop. variance by the panel component	0.327	0.378

Notes. All regressions include the vector of firm controls ($\boldsymbol{X}_{it-1}$), the vector of Mundlak's terms ($\overline{\boldsymbol{NFLEX}}_{\boldsymbol{i}}, \bar{\boldsymbol{X}}_{\boldsymbol{i}}$) year-, industry- and region/NUTS2-fixed effects, where industries are defined as in Table A.1. Coefficients of control variables, Mundlak's terms, year, industry and region/NUTS2 dummies are not reported to save space. Full tables are available from authors upon request. Cluster (firm) - robust standard errors are reported in parentheses. Statistical significance at the 10%, 5% and 1% level is indicated by *,** and ***, respectively.

Table A.12 – Linear probability models with firm fixed effects

	(1) (Prod. or proc. inn., LPMFE)	(2) (Prod. inn., LPMFE)	(3) (Proc. inn., LPMFE)	(4) (Prod. & proc inn., LPMFE)	(5) (Patents, LPMFE)
Share of temporary employees (t-1)	0.078**	0.086***	0.057*	0.065**	-0.003
	(0.034)	(0.033)	(0.032)	(0.030)	(0.011)
Share of (tenured) part-time employees (t-1)	-0.028	0.002	-0.055	-0.025	0.007
	(0.040)	(0.038)	(0.035)	(0.033)	(0.011)
Prop. of project-, freelance-, agency-workers (t-1)	-0.010	-0.008	0.009	0.011	-0.008
	(0.025)	(0.025)	(0.024)	(0.023)	(0.011)
Firm size = # Employees (log, +1) (t-1)	0.018	0.005	0.002	-0.011	0.011*
	(0.013)	(0.012)	(0.012)	(0.012)	(0.006)
Investments in R&D (t-1)	0.003	0.017	0.002	0.016	-0.003
	(0.014)	(0.014)	(0.015)	(0.015)	(0.009)
Investments in ICTs (t-1)	-0.011	-0.009	-0.022*	-0.020*	-0.007
	(0.012)	(0.012)	(0.011)	(0.011)	(0.005)
Investments in plants, mach. & eq. (t-1)	-0.005	-0.001	-0.018*	-0.015	-0.003
	(0.011)	(0.010)	(0.011)	(0.010)	(0.004)
Share of trained employees (t-1)	-0.018	-0.023*	-0.001	-0.005	-0.006
	(0.013)	(0.013)	(0.013)	(0.012)	(0.005)
Share of managers and middle managers (t-1)	0.031	0.047	-0.047	-0.032	0.041***
	(0.043)	(0.043)	(0.041)	(0.039)	(0.015)
Share of female employees (t-1)	0.002	-0.021	0.051*	0.028	0.013
	(0.032)	(0.032)	(0.031)	(0.029)	(0.011)
Second-level barg. to prod. (t-1)	-0.006	0.024	-0.008	0.022	0.036***
	(0.019)	(0.019)	(0.020)	(0.019)	(0.012)
Union representation (RSA/RSU) (t-1)	-0.030*	-0.038**	-0.014	-0.022	-0.020**
	(0.018)	(0.018)	(0.018)	(0.018)	(0.009)
Exporter (t-1)	0.013	0.010	-0.006	-0.009	-0.013*
	(0.016)	(0.016)	(0.016)	(0.014)	(0.007)
National group (t-1)	0.006	0.012	-0.010	-0.005	0.002
	(0.018)	(0.018)	(0.018)	(0.017)	(0.009)
Foreign group (t-1)	0.024	0.018	0.018	0.012	-0.000
	(0.016)	(0.016)	(0.016)	(0.015)	(0.007)
Constant	0.445***	0.410***	0.360***	0.325***	0.025
	(0.037)	(0.037)	(0.036)	(0.035)	(0.017)
Year FEs	Yes	Yes	Yes	Yes	Yes
Firm FEs	Yes	Yes	Yes	Yes	Yes
Adj.R-squared	0.324	0.323	0.308	0.303	0.360
#Observations	19020	19020	19020	19020	19119
#Firms	7875	7875	7875	7875	7911

Notes. All regressions include year- and firm-fixed effects. Coefficients of year and firm dummies are not reported to save space. Full tables are available from authors upon request. Cluster (firm) - robust standard errors are reported in parentheses. Statistical significance at the 10%, 5% and 1% level is indicated by *,** and ***, respectively.

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