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Abstract

In this paper, we empirically assess whether the perceived implications of technological innovations on the probability of job loss vary according to the innovation-related strategies adopted by firms. We take advantage of a unique dataset based on a large and representative cross-sectional survey covering several characteristics of Italian workers and their firms. We find that the relationship between technological innovations and job insecurity is moderated by firms' technology-specific training programs, their dismissal plans, and the impact of innovations on the tasks and activities performed by workers. Thus, workers' perceptions of job insecurity vary significantly across innovative firms and the adoption of technological innovations in the workplace has a multifaceted impact on the perceptions of job insecurity of the affected workers.

JEL-Codes: J280, O330.

Keywords: job insecurity, technology, innovation, firms.

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The views expressed in this paper are those of the authors and do not necessarily reflect those of INAPP. All errors are our own.

1 Introduction

The economic literature has long established that technological progress and firm innovation are fundamental sources of economic growth (Mokyr et al., 2015). However, the changes they bring about have a disruptive potential and entail important distributive effects across individuals, occupations, firms and regions. While there is still no consensus on the actual impact of technological innovations on aggregate employment dynamics and income distribution (see, on this, Calvino and Virgillito, 2018; Corrocher et al., 2023; Mondolo, 2022; Filippi et al., 2023), it is commonly believed that innovations are a source of concern for workers who worry about the security of their jobs.[1] However, workers may perceive the impact of technological innovations in different ways, depending on their individual characteristics as well as personal experiences that vary across firms. Thus, the level of job insecurity perceived by a worker may depend on whether her firm has adopted technological innovations, and what firm strategies have accompanied the innovations. This is important given that job security is one of the most important determinants of job quality (Esser and Olsen, 2011; Yates, 2022), job satisfaction (Cornelissen, 2009), meaningful work (Spencer, 2014) and job-related anxiety (McClure, 2018).

In this paper, we investigate, for the first time to the best of our knowledge, whether the relationship between technology adoption and workers' job insecurity is moderated by the strategies that accompany the introduction of innovations. In particular, we analyze whether Italian workers' perceived insecurity varies across firms with different strategies regarding training, layoff procedures, and the transformation of the tasks and activities of the surviving workers. Thus, we provide novel evidence on the importance of firm-level moderating factors affecting the relationship between technological innovation and workers' perceived job insecurity.

To test the importance of firm-specific experience of technological innovation, we take advantage of a unique dataset covering several characteristics of workers and firms,

[1] In addition to the concerns about technological displacement, workers may fear a more general loss of bargaining power: Traverso et al. (2022), for example, claim that firms resort to industrial robots to reduce employees' bargaining power and hold-up opportunities.

namely the eighth edition of the Participation, Labour, Unemployment Survey (PLUS), developed and conducted in 2018 by the National Institute for the Analysis of Public Policies (INAPP). This large and representative survey covers 45,000 individuals aged between 18 and 74.

To preview the main results, we show that the innovations that are deliberately introduced to make workers' tasks more precise and simpler are associated with lower levels of insecurity. We argue that this is related to the fact that new technologies tend to improve workers' ability to assess and correct their individual performance. Moreover, innovations that are introduced together with specific training programs and in the absence of automation-related dismissals are better viewed by workers, probably because these innovations are perceived as complementary to labour and productivity-enhancing. It is also possible that whenever the firm's innovation efforts are accompanied by certain strategies, workers perceive an overall message of the firm's good health and feel reassured, in line with the results shown by Caselli et al. (2021). In sum, the relationship between technological innovation and job insecurity in innovating firms is moderated by the firms' strategies related to training, firing procedures, and the transformation of the tasks and activities of the remaining workers.

Our analysis contributes to the rich literature on workers' perceived job insecurity. It should be noted that, despite the many studies on the impact of technology on employment and the importance of technological innovation as a determinant of workers' perceived job security, how people subjectively experience technological change has been much less explored and the available empirical evidence on this issue is inconclusive. While Coupe (2019) finds that the proportion of workers who fear losing their jobs to automation is relatively small, Dengler and Gundert (2021) conclude that German workers' insecurity is negatively affected by the degree of computerization of their occupations. Using the results of the 2012 Eurobarometer Public Attitudes towards Robots survey, Dekker et al. (2017) find that the fear of robots in the workplace is higher among workers in economic positions that are more likely to be negatively affected by robotics, while

employed workers tend to be less concerned than the unemployed. Brougham and Haar (2018) claim that workers' awareness of technological developments is positively correlated with replacement concerns. Caselli et al. (2021) find that workers employed in firms that introduce technological innovations tend to exhibit lower job insecurity, suggesting that the investment made by the firm tends to reassure workers about the conditions of the firm.

The explanations for these different empirical results in the literature can be manifold. For example, it is possible that different forms of innovation have heterogeneous effects: some advances may be complementary to the workers' main activities, while others may replace human workers. Moreover, different results may depend on the precise nature of the concerns examined (i.e., general concerns about the risks of technological unemployment vs. worries about workers' current jobs) and on the measure of technological progress considered (i.e., awareness of advances in different technological domains vs. direct experience of technological innovation at the workplace). Furthermore, workers' perceptions may be influenced by factors operating at the individual level: the academic literature on the antecedents of self-reported job insecurity shows that economic self-interest is an important micro-level determinant of insecurity, and that workers with weak positions and low employability skills tend to be more fearful, especially of innovations (Anderson and Pontusson, 2007; Chung and van Oorschot, 2011; Dekker et al., 2017; Erlinghagen, 2008; Esser and Olsen, 2011; Graham et al., 2023).

Within the literature on the relationship between workers' perceived job insecurity and technological innovations, few studies have focused on firm-specific conditions as an important environmental determinant of job insecurity. In fact, according to the model developed by Anderson and Pontusson (2007), workers estimate the probability of losing their job by taking into account both national institutions (such as those related to employment protection legislation) and the industrial relations in their own firms. Arntz et al. (2023) argue that workers' direct experience of technological innovations is an important source of the information that individuals use to form personal perceptions. It

follows that, in addition to general fears of technological unemployment due to widespread negative narratives (Jeffrey, 2021), the level of job insecurity perceived by a worker may depend on what firm strategies have accompanied the innovations.

Some papers test the moderating effect of firm-level characteristics in more detail. Lingmont and Alexiou (2020) find that firms with an authoritarian culture risk increasing negative perceptions of technology in terms of job insecurity. In addition, Belloc et al. (2022) show that the allocation of authority within firms interacts with workers' exposure to automation risk, thereby providing evidence of an interaction between individual-specific and firm-specific moderating factors, and Gallie et al. (2017) conclude that insecurity varies across different organizational contexts. McGuinness et al. (2021) show that the introduction of technological improvements is often associated with increased firm investment in the training of highly skilled workers; perceptions of job insecurity seem thus to differ between innovative firms that develop specific training programs to help workers cope with the new technologies, and firms that do not invest in human capital at all (Kohlrausch and Rasner, 2014).

Our contribution to the above literature is twofold. First, the analysis focuses on workers who directly experience the introduction of technological innovations in their workplace: this allows us to provide novel evidence on job insecurity, complementing those studies that examine workers' concerns about an abstract risk of technological displacement.[2] The second contribution is that, thanks to the richness of the large and dedicated worker-level survey used to conduct our analysis, we are able to examine the role played by the work environment in which the respondents are employed and in which the innovations are adopted. Previous studies have focused on moderating factors mainly related to job and individual characteristics (e.g., age, gender, education, per-

[2]Workers' answers to questions about their general concerns about technological progress depend on a number of factors that cannot be easily disentangled: the perceived diffusion of the technology in their sector and area of activity; the likelihood that their firm adopts an innovation available at the technological frontier; the perception that such an innovation is either labour saving or labour augmenting; and the like. However, as shown by Campbell et al. (2007), workers' direct experience is important in shaping their perceptions. In this paper, therefore, we link workers' perceptions of job insecurity to the actual technological investments made by their firms.

sonality traits, technological awareness, task routine intensity, exposure to digitalization and robotization), whereas our analysis explores the firm-related factors. As suggested by Gallie et al. (2017), job insecurity varies across different organizational contexts and we are able to identify relevant sources of such heterogeneity. This allows us to show that, between the macro and the micro (individual) level determinants of job insecurity, there is also an intermediate level, the firm, which can have a direct impact on insecurity and a moderating role as regards the introduction of technological innovations in the workplace. This strengthens the case made by Belloc et al. (2022) for focusing more on the socio-institutional factors, even at the firm level, that shape the future of work.

The remaining of the paper proceeds as follows. Section 2 briefly describes the dataset, it presents the main variables employed in the empirical analysis and it offers a quick account of the estimation approach, namely the ordered logistic estimation method. The results are illustrated in Section 3, whereas a discussion of the main implications is elaborated in Section 4. Section 5 provides some closing remarks.

2 Data and methodology

2.1 Data sources and variables

This work explores a unique dataset spanning a number of characteristics of Italian workers, the firms in which they are employed and the occupations they hold. In particular, the eighth edition of the Participation, Labour, Unemployment Survey (PLUS), developed and administered in 2018 by the National Institute for the Analysis of Public Policies (INAPP), contains a 'Technology module' that covers various aspects associated with firms' technological innovations and workers' concerns for their jobs.[3] This large and representative survey, which covers 45,000 individuals aged between 18 and 74, allows us to identify those workers who are or have been employed in companies adopting technology

[3]Previous studies using the INAPP dataset are Bonacini et al. (2021); Clementi and Giammatteo (2014); Esposito and Scicchitano (2020); Filippetti et al. (2019); Meliciani and Radicchia (2011; 2016); Van Wolleghem et al. (2019).

innovations, whose answers to the questionnaire reflect their direct experience of technological innovations in the workplace. Given that our analysis restricts the INAPP-PLUS sample to the respondents who are employed, thereby neglecting both unemployed and inactive people, and to those firms for which data are available, we work with a large cross-section of 13,837 workers.

We use various questions in the 2018 wave of the survey to address our working hypothesis, i.e., the impact of firms' technological innovations on workers' job insecurity depends on firms' accompanying strategies. In particular, workers' perceptions about job insecurity are lower after the introduction of innovations in the workplace when the innovating firm adopts strategies that reassure workers about the health conditions of the firm, involve employees in appropriate training programs, and improve the control that workers exert on their activities thanks to the innovations.

As to what concerns the main variables of interest, that is, job insecurity, the 2018 wave of INAPP-PLUS includes the question 'How confident are you in your ability to keep your job over the next 12 months?'. Respondents can answer by choosing an integer from zero (very unsure) to six (very confident), and we invert the scale so that a larger value is associated with a higher level of job insecurity. In order to deal with the ordinal level of measurement of the dependent variable, we use the ordered logistic estimator to examine the correlation between job insecurity and technological innovations, as also done by Dengler and Gundert (2021) among others.[4]

INAPP-PLUS contains several questions that regard the technological innovations adopted by firms. At the more general level, workers are asked whether any major technological innovation has been introduced in the previous two years by the firm where the worker is currently employed. We create a dummy variable 'Introduction of technology', *IntroTech*, by codifying the 'yes/no' answers to this question.

To discuss the firm strategies associated with the adoption of technological innovations

[4]All our results are qualitatively similar if only three categories of job insecurity are considered, namely low insecurity (0, 1), middle insecurity (2, 3, 4) and high insecurity (5, 6). This robustness check is reassuring in relation to concerns that a small number of highly concerned individuals, those who report the highest levels of insecurity, drive the results.

that may impact on workers' perceptions, we consider various moderating factors.

The first one regards whether the perception of job insecurity differs across workers according to whether their firms developed some technology-specific training programs after the introduction of technological innovations. INAPP-PLUS asks the following question: 'Following the introduction of new technologies, have training activities been conducted to educate workers on how new technologies work and how to use them?'. Accordingly, we create a dummy variable (*IntroTech - Specific training*) that takes value 1 if the firm introduced a new technology and also developed a training program associated with it; its complement (dummy *IntroTech - No training*) regards firms that introduced a new technology without developing a specific training program. These variables allow us to compare three groups of individuals: those employed in innovating companies with specific training programs, those in firms that innovate without proposing any specific training opportunities, and those working in non-innovating firms, thereby disentangling the moderating effect of firms' training strategies on the relationship between firms' innovations and job insecurity for the surviving workers.

The survey asks workers questions about the effects of the adopted innovations on the activities they carry out. As the impact of the innovations on the working activities cannot but reflect the firms' innovation goals, we use these questions to explore the heterogeneous responses of workers to differentiated forms of implementation of technological innovations across firms. In particular, we use two questions to build a set of dummy variables and explore additional moderating factors. To start, we consider whether the adopted innovation made the worker's tasks simpler (dummy *IntroTech - simpler*) or not (dummy *IntroTech - no simpler*). Then, we consider whether the innovations made more precise the assessment of the tasks carried out by the worker (dummy *IntroTech - more precise*) or not (dummy *IntroTech - no more precise*). Our working hypothesis is that workers react more positively to the introduction of innovations that facilitate their activities and the possibility of controlling with precision their effectiveness as these reduce workers' uncertainty and job insecurity.

A connected issue regards whether workers' activities have been made more intense and continuous, or less intense and more discontinuous by the innovation. Our working hypothesis is that workers facing more intense activities after the innovation may grow concerned of the increased likelihood of making mistakes. Accordingly, we build three dummy variables using the dedicated question in the survey: *IntroTech - more intense*, *IntroTech - less intense* and *IntroTech - same intensity*.

Workers are also asked whether the innovations adopted by the firm in which they are employed are associated with the introduction of robots and automated machines in the production process, and whether these latter are explicitly meant to substituting tasks previously performed by human workers. This direct question to the interviewees allows us to build a dummy variable that captures an important aspect of firms' strategies, namely whether they adopt labour-saving automation solutions or other types of product and process innovations. The dummy variable *IntroTech - automation* takes value one when labour-saving automation-related technological innovations are introduced, and zero otherwise. The dummy variable *IntroTech - no automation* identifies the workers employed in firms introducing innovations that are not related with labor-saving forms of automation. The hypothesis we test is whether this aspect of firms' strategies moderates the relationship between job insecurity and innovations, and we posit that workers are relatively more concerned of labour-saving automation-related technological innovations.

It could be argued that the introduction of technological innovations explicitly aimed at performing tasks previously performed by humans may not necessarily lead to a massive substitution of workers. Not only firms may substitute only few workers, but the alleged labour-saving effect of the innovations may be relevant only at the margin, so that production grows more than employment. The literature on the firm-level determinants of robotization shows that the latter is the case for those firms that expand the range and the quality of their products, hence their market shares, without firing/hiring employees. The survey contains a question that helps to address the issue: 'Are you aware of any cases in which the introduction of technological innovations (robots, automated ma-

chines) explicitly aimed at performing tasks that were previously performed by humans have resulted in the dismissal of workers?'. Using the answers to this question we can identify four categories of workers: those working in companies that did not introduce innovations (the baseline); those working in companies that introduced innovations not directly meant to substituting humans and carrying out certain tasks (dummy *IntroTech - no automation*); those working in firms that introduced forms of automation with the intent of substituting humans to carry out certain tasks, but that did not proceed with dismissals that the respondent is aware of (dummy *IntroTech automation - no dismissals*); those working in firms that introduced forms of labour-saving automation and that actually fired some workers (dummy *IntroTech automation with dismissals*). This allows us to investigate the impact of workers' experiences of the overall employment effects of technological innovations in their workplace, even when their own position is not affected, as suggested by Campbell et al. (2007), who show that job insecurity perceptions are affected by what happens to friends. If job insecurity varies in accordance with firms' records of dismissals even among survivors, then this offers some evidence that firms' strategies are important moderating factors of the relationship between innovation and job insecurity for the entire workforce.

Regarding the explanatory variables and controls that we include in the estimated specification, we borrow from the literature and encompass a number of variables so as to limit the possibility that the estimates are biased due to omitted confounding factors. The survey contains several questions that can be used to control for aspects related to individuals, occupations and firms. In short, we include individual covariates (i.e., gender, age, education, training, and the Big Five personality traits, that is, openness, conscientiousness, extraversion, agreableness, and neuroticism, as in Sverke et al., 2004, and Esposito and Scicchitano, 2023). This set of variables contains ordinary demographic features and non-cognitive personality traits that the literature has shown to be relevant for workers' perceptions (Bashkirova et al., 2023). Regarding the characteristics of professions and workers' status in the firm, we introduce a set of dummy variables for

the different aggregate professional groups in Italy (taken at the first digit of the ISCO taxonomy) and for some characteristics of the occupations: perceived routine intensity of the tasks performed by the worker (Cassandro et al., 2021; Vannutelli et al., 2022), the type of contract (part-time, fixed-term and open-ended contracts), and the payment of extra welfare benefits attributed to the worker. These variables help to distinguish worker-/job-related characteristics that might impact on job insecurity and on the individual exposure to technological innovations. To capture the presence of a skill mismatch, which is another dimension that may be relevant for both insecurity perceptions and risks of substitution, we build a dummy taking value one when the worker is overqualified, and another one when the worker is underqualified.

Among the characteristics of the firm, we control for the following variables that, if omitted, could bias the estimations: firm size, geographical position and sector of activity. We also consider the presence of trade unions in the firm as this variable can be related to the probability that the company introduces labour-saving automation, the adoption of complementary strategies (such as specific training), and the perceived job insecurity of the employees.

Detailed descriptive statistics for all the variables described below are reported in Table 1.

Table 1: Descriptive statistics

	Mean	SD	Min	Max
Job Insecurity	1.182	1.576	0	6
IntroTech	0.290	0.454	0	1
IntroTech - no training	0.079	0.269	0	1
IntroTech - specific training	0.211	0.408	0	1
IntroTech - no simpler	0.087	0.282	0	1
IntroTech - simpler	0.203	0.402	0	1
IntroTech - no more precise	0.089	0.285	0	1
IntroTech - more precise	0.201	0.401	0	1
IntroTech - same intensity	0.146	0.354	0	1
IntroTech - more intense	0.100	0.300	0	1
IntroTech - less intense	0.044	0.204	0	1
IntroTech - automation	0.068	0.252	0	1

Before moving on to the empirical approach, a few clarifications are in order. First,

as only the respondents who were employed at the time of the survey were asked to answer the 'Technology Module', our estimates stem from the comparison of the answers provided by the survivors in adopting firms and the workers employed in non-adopting firms. Second, the cross-sectional nature of INAPP-PLUS does not allow us to address all possible endogeneity issues affecting the relationship between job insecurity and technological innovation and to tackle a possible survivor bias.[5] In addition, we cannot exclude that firms characterised by workers with higher/lower levels of insecurity are also more innovative, leading to problems of reverse causality, although the decision to innovate pre-dates the survey and is made by the top managers, not by the respondents. As we cannot rule out these problems, we include as many control variables as possible in the estimation and we refrain from drawing causal conclusions from the estimates. Rather, we interpret them in terms of correlations, although we endeavor to discuss what causal mechanisms could explain the results.

2.2 Empirical specification

The ordinal level of measurement of the dependent variable (seven levels i, ranging from 0 to 6, for job insecurity) calls for the use of the ordered logistic estimator. Hence, the functional form to estimate can be represented as follows:

$$Pr(JI_w = i) = Pr\left(\chi_{i-1} < \boldsymbol{TechInno}'_w\boldsymbol{\beta} + \boldsymbol{x}'_w\boldsymbol{\alpha} + \boldsymbol{z}'_w\boldsymbol{\delta} + \boldsymbol{k}'_w\boldsymbol{\gamma} + \epsilon_w \leq \chi_i\right) \tag{1}$$

where i stands for one of the levels of the dependent variable, and w refers to workers. The vector $TechInno_w$ refers to the adoption of different measures of technological innovations by the firm in which the worker is employed in combination with moderating firms' characteristics, $\boldsymbol{x}_w$ includes the controls for worker-specific characteristics, $\boldsymbol{z}_w$ accounts

[5] Although the relevance of this selection bias cannot be assessed, recent contributions suggest that it could be small as workers in adopting firms exhibit improved employment stability and higher wage growth (Genz et al., 2022), as well as better retraining opportunities (Battisti et al., 2023). A possible displacement of tasks connected with the new technologies, in fact, does not entail the displacement of the workers. Our focus on survivors is in line with several contributions exploring the evolution of the employment status after the adoption of innovations.

for occupation-specific features, and $\boldsymbol{k}_w$ groups the controls for firm-specific factors.

The main parameters of interest in this work are the coefficients in vector $\boldsymbol{\beta}$: they capture the impact of the adoption of technological innovations on workers' perceived job insecurity as moderated by some relevant firm characteristics. Each parameter of the model can be interpreted as follows: assuming all the other variables in the model constant, for one unit increase in the explanatory variable of interest one could expect a variation in the log-odds of being into a higher level of the dependent variable equal to the estimated parameter. The implications of the parameters on the predicted probability that the dependent variable is equal to a certain level of insecurity cannot be directly assessed because of the non-linearity of the functional form. Accordingly, we offer a graphical representation of the semi-elasticities, i.e., the percentage changes in the probability that the dependent variable has a given value when the firm adopts an innovative strategy, calculated by fixing the covariates at their mean level.

3 Results

The first estimation regards the average relationship between firms' technological innovations and workers' job insecurity. This value is reported in column (1) of Table 2, and it is in line with the reassuring effect of technological innovations found in Caselli et al. (2021). As discussed there, this relationship can be explained in terms of signalling (whereby workers perceive firms investing in innovations as healthier), but it is also possible that survivors project their positive personal experience on a more general level.

We posit that the relationship between firm innovations and workers' perceptions of job insecurity could be moderated by the characteristics of the environment in which the workers operate. In particular, we believe that firms' strategies associated with the introduction of technological innovations are particularly important.

To investigate this hypothesis, we start exploiting the richness of INAPP-PLUS and

Table 2: Technological innovations, job insecurity and firm-level moderating factors

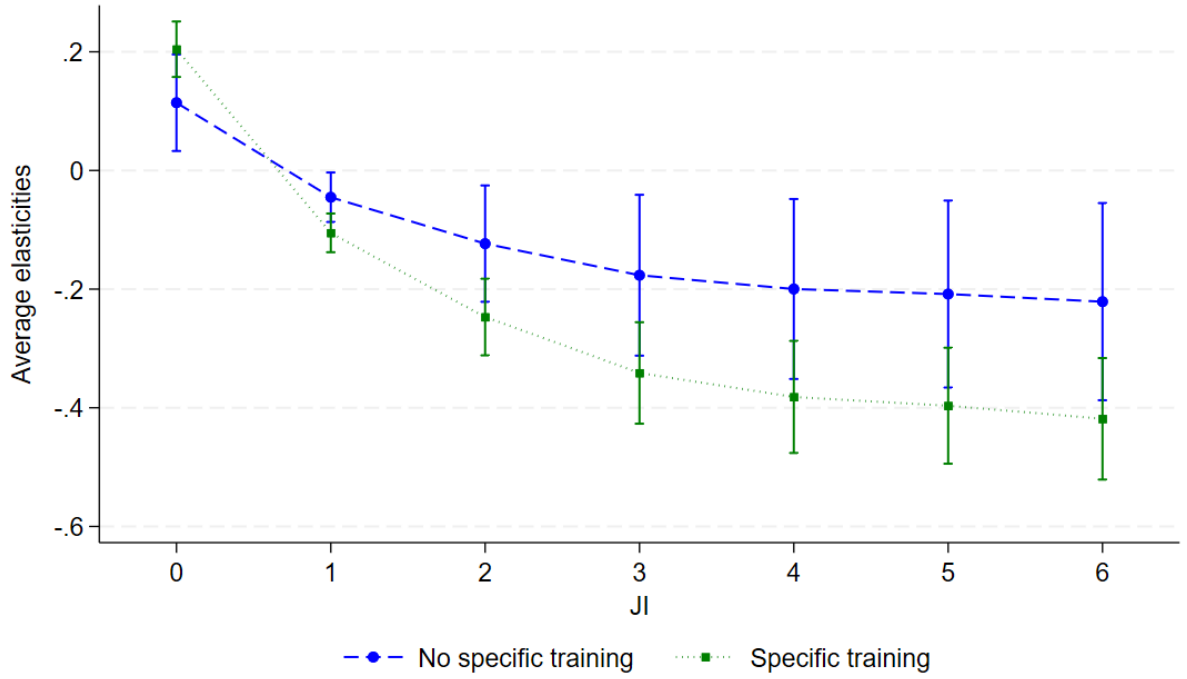
	(1)	(2)	(3)	(4)	(5)
IntroTech -	-0.373***				
	(0.049)				
IntroTech -		-0.230***			
no training		(0.088)			
IntroTech -		-0.434***			
specific training		(0.054)			
IntroTech -			-0.253**		
no simpler			(0.077)		
IntroTech -			-0.420***		
simpler			(0.055)		
IntroTech -				-0.174**	
no more precise				(0.082)	
IntroTech -				-0.453***	
more precise				(0.055)	
IntroTech -					-0.267**
more intense					(0.075)
IntroTech -					-0.352***
same intensity					(0.064)
IntroTech -					-0.584***
less intense					(0.100)
Worker ctrl	✓	✓	✓	✓	✓
Occupation ctrl	✓	✓	✓	✓	✓
Firm ctrl	✓	✓	✓	✓	✓
Observations	13,837	13,837	13,837	13,837	13,837

Notes: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

analysing whether the impact of technological innovations on job insecurity is moderated by whether the firm develops a technology-specific training program after the introduction of new technologies. The parameters of interest are those of the dummy variable (*IntroTech - Specific training*) and (*IntroTech - No training*), against a baseline group consisting of workers in firms that do not adopt technological innovations.

The estimations, whose results are reported in column (2) of Table 2, provide some comforting evidence. Workers employed in firms that developed specific training show a lower level of job insecurity. This lower concern of losing a job is in line with those studies that find that firm- and technology-specific knowledge strengthens the status of workers in the firm (Lingmont and Alexiou, 2020), even though it does not modify the abilities and skills that can be used in the market.

Figure 1: Average semi-elasticities of job insecurity wrt introduction of technology

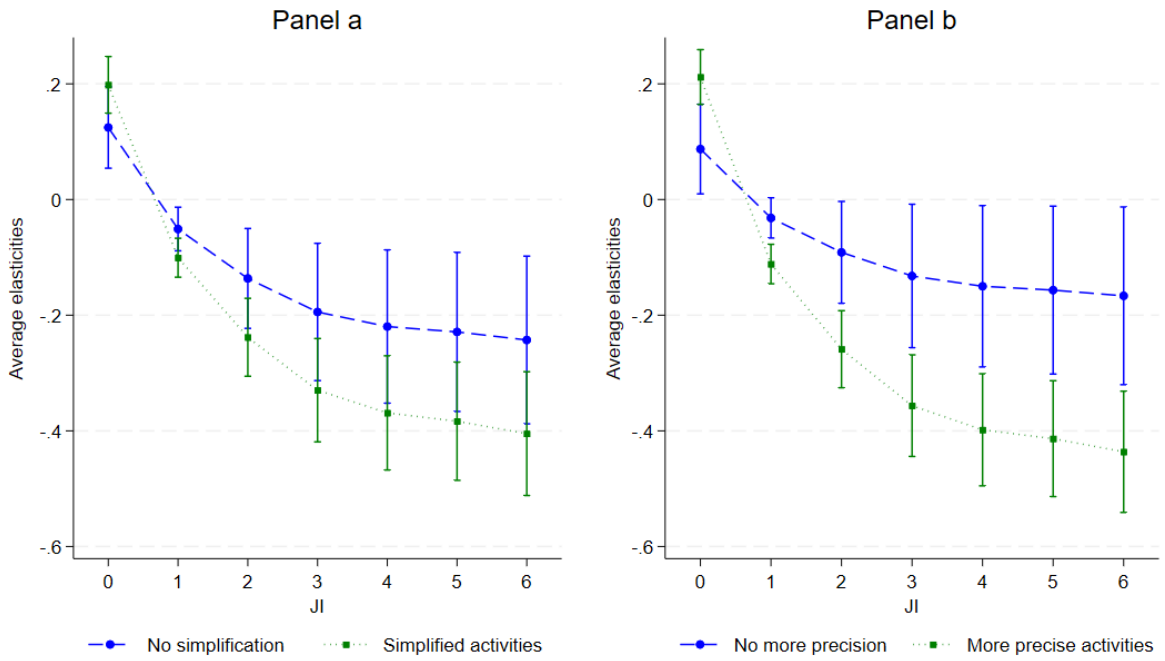


Notes: The figure shows the percentage change in the probability of being in each level of job insecurity due to the introduction of technology with and without specific training. The capped spikes represent 95% confidence intervals. All covariates are considered at their mean values.

A graphical representation of the differential impact of specific training on the semi-elasticity of job insecurity with respect to technological innovations is provided Figure 1. The moderating role of training is significant and particularly relevant in the case of the highest values of insecurity, as the semi-elasticities are almost twice as large (in absolute terms) when specific training is provided for.

The second aspect to consider is the impact of the innovations on workers' activities. To examine this aspect, we exploit the dummy variables *IntroTech - simpler* and *IntroTech - no simpler*, and subsequently *IntroTech - more precise* and *IntroTech - no more precise*. We recall that, in these two cases, the baseline group consists of workers employed in firms that do not adopt technological innovations, and the estimated coefficients capture the differential impact with respect to the baseline group. The estimations are reported in columns (3) and (4) of Table 2, and they confirm our prior: workers exhibit lower

Figure 2: Average semi-elasticities of job insecurity wrt introduction of technology



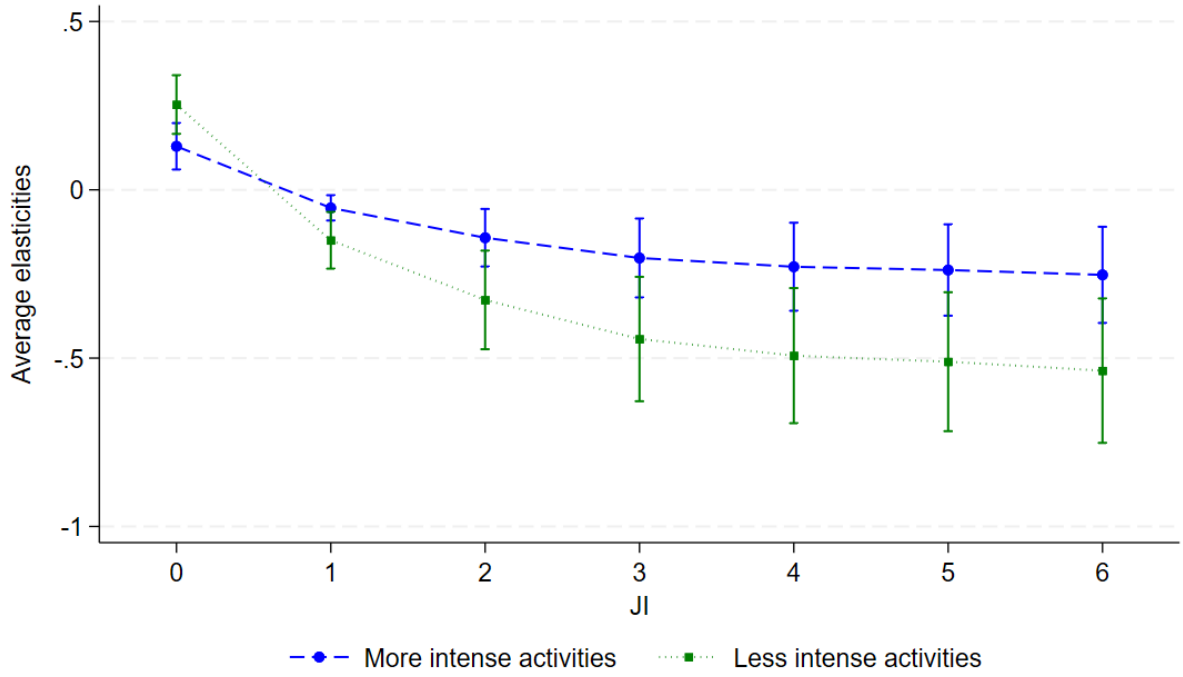
Notes: The figure shows the percentage change in the probability of being in each level of job insecurity due to the introduction of technology with and without simplifications of the activities (Panel a) and with and without greater precision (Panel b). The capped spikes represent 95% confidence intervals. All covariates are considered at their mean values.

insecurity levels when the innovations modify their activities by making them either simpler or more precise.

The graphical representation of the differential impact of the simplification effects on the semi-elasticity of job insecurity with respect to technological innovation is reported in Panel (a) of Figure 2. The moderating role is clear for all higher values of insecurity. The moderating effect of innovations that make working activities more precise is even more evident because, as can be seen in Panel (b) of Figure 2, the 95% confidence intervals of the semi-elasticities are entirely separated.

INAPP-PLUS asks the workers stating that their firm introduced innovations whether such innovations made their work more intense (*IntroTech - more intense*) or less intense (*IntroTech - less intense*), or neither of the two (*IntroTech - same intensity*). We explore this against the baseline category that consists of workers employed in firms that do not

Figure 3: Average semi-elasticities of job insecurity wrt introduction of technology



Notes: The figure shows the percentage change in the probability of being in each level of job insecurity due to the introduction of technology and with lower and higher work intensity. The capped spikes represent 95% confidence intervals. All covariates are considered at their mean values.

adopt technological innovations. The estimates are reported in column (5) of Table 2, and the semi-elasticities moderated by the innovation-induced changes that make the activities more or less intense and continuous are plotted in Figure 3. The estimates support our prior that workers are much less reassured when their activities are made more intense by innovations, as probably this is connected with higher risks of making mistakes. This interpretation is supported by unreported estimates (available upon request) showing that the reassuring effect of training is stronger when the activities become more intense.[6]

The unifying message from these findings is that the workers employed in firms undertaking innovations that make working activities less uncertain and that implement technology-specific training programs are relatively less insecure about their job. This is consistent with Dekker et al. (2017)'s conclusions that employees with previous positive

[6]Unreported results also show that the effect is stronger for workers with a permanent contract.

experience with robots show lower concerns than others.[7]

It could be argued that workers may not look at all kinds of innovations in the same way if they have reasons to believe that the firm that introduced them with explicit labour-saving goals. To address this concern, we distinguish the innovations that are directed to saving labour (i.e., automation) from other innovations. We introduce the dummy variables *IntroTech - automation* and *IntroTech - no automation*. The estimates are reported in column (1) Table 3. Notably, as expected, the reassuring effect of the innovations is highly reduced when these are introduced with the deliberate intent of substituting humans in certain tasks. However, also in this case workers exhibit some reassurance, albeit to a lower extent. The semi-elasticities in Panel (a) of Figure 4 provide further evidence about it.

Table 3: Labour-saving innovations, job insecurity and firm-level moderating factors

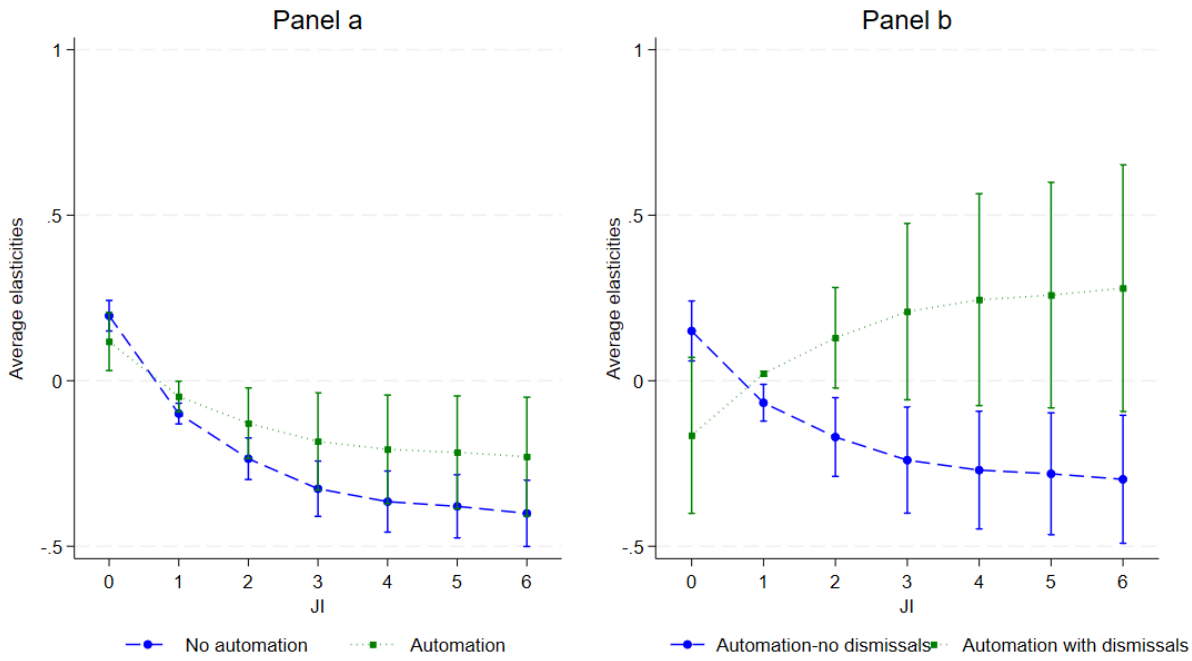
	(1)	(2)
IntroTech- no automation	-0.416*** (0.053)	
IntroTech- automation	-0.239*** (0.095)	
IntroTech no automation		-0.415*** (0.053)
Automation - without dismissals		-0.310*** (0.102)
Automation - with dismissals		0.295 (0.202)
Worker ctrl	✓	✓
Occupation ctrl	✓	✓
Firm ctrl	✓	✓
Observations	13,837	13,837

Notes: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

What happens to overall employment at the firm level can influence how surviving workers assess the impact of innovations and the probability of losing their jobs. Column (2) of Table 3 reports the estimated coefficients for the moderating role of technology-related dismissals, where the baseline group consists of workers in firms that do not adopt

[7]Unreported results show no significant differences in terms of job insecurity being associated with changes in how innovations change communication with colleagues. Only specific changes in the activities carried out by the worker are associated with variations in her perceptions of job insecurity after the introduction of an innovation.

Figure 4: Average semi-elasticities of job insecurity wrt introduction of technology



Notes: The figure shows the percentage change in the probability of being in each level of job insecurity due to the introduction of automation (panel a), and with or without dismissals (panel b). The capped spikes represent 95% confidence intervals. All covariates are considered at their mean values.

technological innovations. Workers employed in firms that introduced labour-saving automation solutions and that dismissed some workers carrying out tasks now performed by new machines show a relatively higher level of job insecurity. Workers employed in firms that introduced other kinds of innovations or that adopted automation-related solutions without dismissing workers, instead, exhibit lower levels of job insecurity.[8] The semi-elasticities associated with these estimates, reported in Panel (b) of Figure 4, confirm that when automation is not associated with firm-level dismissals, workers' job insecurity is still negatively correlated with the introduction of innovations. These findings corroborate both the idea of investigating data from workers who had a direct experience of innovations introduced in their firms and the focus on the moderating role of firm strategies that accompany the adoption of the innovations.

[8]Although the estimated parameter for *Automation - dismiss* is not significantly different from zero, the differences between this coefficient and those associated with *IntroTech - no automation* and *IntrodTech automation - no dismiss* are statistically significant.

4 Discussion and implications

In contemporary capitalist societies, the risk of losing a job is a major source of uncertainty and this impacts on a number of socio-economic dimensions. Job insecurity affects mental health, the quality of life and social relations, expectations and actions, among other issues. Moreover, the risk of losing a job, together with the associated income stream, tends to reduce the propensity of individuals to consume and invest.

What should concern firms is that workers' job insecurity may also affect the activities they carry out and, indirectly, the functioning of the entire organization. Workers who are worried about their situation tend to dedicate less attention to their job tasks, let their performance worsen (Reisel et al., 2007; Chirumbolo et al., 2017; Jose and Mampilly, 2014; Cuyper et al., 2008), and generate withdrawal attitudes. All these, in turn, reduce workers' commitment to the job and the organization.

Notably, the relationship among workers' health, well-being, job satisfaction and commitment depends both on the characteristics of the individual and on firm-specific moderating factors (Graham et al., 2023; Probst et al., 2023; Sverke and Hellgren, 2002). Our findings show that firm strategies are important, and suggest that firms should not be preoccupied by the effects of investing in technological innovations *per se*: what matters is how innovations are introduced, what accompanying strategies are deployed, and how communication works. Firms that do not deliberately intend to dismiss workers can adopt various actions to soothe workers' worries. For instance, the impact of innovations on workers' insecurity is lower in the presence of specific training, when the innovation improves the quality of occupations, and when the firm is not simultaneously carrying out employment reduction plans. Moreover, as workers try to see through the motivations behind technology adoption, innovative firms are more likely to preserve workers' motivation and commitment if they develop a constructive dialogue with their employees. This dialogue could reduce the risks that workers make mistakes in drawing conclusions about the possible impact of innovations on the company and their jobs. In sum, our findings

suggest that innovative firms should be particularly careful in shaping an environment that reassures workers about their jobs and reduces insecurity.[9]

As to the policy domain, our findings suggest that firms could be called to play an active role in tackling the social risks associated with technological progress. Rather than developing policies aimed exclusively at addressing the most rapidly evolving industries and at protecting the most sensitive occupations and the most vulnerable individuals, the authorities could try to design technology-related incentives that induce firms to adopt those strategies and practices that enhance workers' confidence in the positive effects of adopting technological innovations in the workplace.

5 Closing remarks

Workers' perceptions of job insecurity are influenced by a large number of factors. In the attempt to explain the wide variation of levels of insecurity across countries (or across welfare systems), the literature so far has mainly focused on ascertaining the contribution of macro-level factors (such as national institutions, public policies, labour market conditions). Other contributions have explored the role of factors at the individual level, thereby assessing characteristics of the workers (such as employability skills, age, education) and of their occupations (e.g., routine intensity, exposure to automation). Yet, limited attention has been attributed to the moderating role that firms play in determining workers' perceived job insecurity.

By taking advantage of a recent and representative survey distributed to Italian workers, we study how the adoption of technological innovations by Italian firms during the period 2016-2018 correlates with workers' perceived levels of job insecurity, and what firm-level strategies moderate such relationship. We exploit the richness of the INAPP Plus dataset that allows us to explore workers' perceived insecurity and firms' innovation activities.

[9]Preventing the increase in job insecurity could be seen as a preventive effort, to which companies can add attempts to mitigate the impact of job insecurity on unpleasant outcomes, as suggested by Jiang and Probst (2019).

Our estimations suggest that the adoption of technological innovations tends to be associated with lower levels of job insecurity, probably because workers who remain active after the introduction of an innovation perceive the latter as a signal of the firm's health. This reassuring effect, however, is differentiated across companies, and it is stronger when workers are aware that the firm also invested in technology-related training programs and did not dismissed workers because of the adoption of forms of automation. Moreover, workers are reassured when the innovations help make their tasks simpler, less intense and easier to assess. This also shows that it is important to consider the role played by the workers' experiences of innovation in their workplace, rather than looking only at people's abstract concerns of technological unemployment.

These results add to the scant literature showing that firms' training schemes, internal culture and workers' participation have an impact on job insecurity and on the fear of technological progress. Our findings complement those obtained in previous studies focusing on the moderating impact of jobs' features and workers' characteristics. Indeed, our results show that workers sharing similar characteristics and occupations may still perceive job insecurity differently in accordance with the other actions undertaken by their innovative firms.

This implies that between the two levels usually studied to assess the determinants of job insecurity, i.e., the national level and the individual level, there is an additional level to consider, that is, the firm. This bears on the debate about the connection between emerging social risks due to technological progress and changes in social policies (Busemeyer et al., 2022). First, the moderating role played by firms suggests that social policies should not focus exclusively on sensitive industries and/or occupations, nor on workers' characteristics, as variation across workers' insecurity may depend on firm-specific conditions. Second, this suggests that firms could play, and be asked to play, a twofold role in economic and social progress: being the engine of economic growth through the development and the adoption of technological innovations, and contributing to reduce social risks via the adoption of practices that boost workers' confidence. This could also

reduce the likelihood of polarization between those who fear job losses due to technological change and ask compensatory and protective policies, and those who are reassured by technological innovations who support further investment in human capital, as suggested by Busemeyer et al. (2022).

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