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RESEARCH PAPER

Advanced Digital Technologies in Unionized Firms

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Abstract
This work examines how workplace employee organizations causally affect the adoption of advanced digital technologies in Italy. It does so by using information from the survey "Rilevazione Imprese e Lavoro" conducted by the National Institute for Public Policy Analysis on a nationally representative sample of Italian firms in the non-agricultural private sector in 2018. It shows that workplace employee organizations increase the probability of advanced digitalization by around 15 percentage points per year, and the number of different technologies adopted by 0.41. The empirical strategy follows an IV approach that eliminates simultaneity bias and builds upon a lagged internal instrument combined with a NUTS-3 measure of altruism—namely, per capita blood donations. Results survive when cybersecurity is excluded from the analysis and prove robust when the internal instrument is left alone, combined with an index of tolerance or with propensity score matching.

Keywords Advanced digital technologies · Unions · Instrumental variables

JEL Classification J51 · O14 · O31

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1 Introduction

The advent of Advanced Digital Technologies (hereafter ADTs), such as robots, internet of things, and big data analytics, are dramatically changing the world of work (Acemoglu and Restrepo 2019). While the implications on job polarization are relatively well understood (Autor and Salomons 2018), and the debate around the robots/labor complementarity or substitutability remains heated (e.g., De Canio 2016), economists are now also devoting attention to the drivers behind their adoption (Cheng et al. 2019). Among them, little has been said about the role of Employee Organizations (hereafter EOs). This is surprising considering that both labor economists and industrial relations scholars have long been studying the relationship between EOs and firm investments—for an overview, see Berton et al. (2021a)—as well as that between EOs and innovation—for an overview, see Menezes-Filho and Van Reenen (2003), and Doucouliagos and Laroche (2013). However, what these different streams of research suggest about the effect of EOs on ADT adoption is far from clear. As the literature reviewed in Sect. 2 makes clear, EOs may in fact either promote or hinder both regular and innovative investments. This depends upon their ability to voice their affiliates' needs and to create a positive dialogue with managers, on their power to capture rents by setting wages above the market-clearing level, on their opposition against labor-saving investments, and so forth. Hence, regardless of whether one considers ADT to be labor-neutral physical capital or labor-saving innovations, their relationship with EOs remains controversial.

The purpose of this paper is to investigate the empirical association between workplace employee organizations and ADT using data on Italian firms. We believe that Italy—whose institutional setting is described in Sect. 3—is an interesting case-study for at least three reasons. First, understanding the drivers of technology adoption in a country in which the firms' inability to invest and innovate curbed almost two decades of economic growth seems rather important (Schivardi and Schmitz 2020). Second, while union membership has declined in many other developed countries (Schnabel 2012; OECD 2017), some still advocate for labor market deregulation. Hence, shedding light on the long-debated question about what unions do also seems timely and important. Third, In Italy, as in many other European countries, industry- and firm-level organizations coexist. While the latter predominantly act as collective voice institutions, negotiating aspects of work organization and human resource management, the power to set wages is mostly concentrated in the hands of the former[1]—with a limited, albeit growing, company-level influence (Visser 2019). This implies that, in principle, the aforementioned faces of unionism might be assessed separately in the data; more specifically, any firm-level effect on economic performance could be largely attributed to the voice ability of company-level organizations.

[1] In Austria and France, around 95% of workers' wages are set by nation- or industry-wide unions without any role for firm-level organizations (OECD 2016, 2017). In Germany, industrial and sectoral unionism is much less important, and firm-level organizations much more diffused (Fitzenberger et al. 2013). However, the massive presence of work councils affects firm-level wages only marginally, suggesting that codetermination impacts on other aspects of on-the-job wellbeing (Jäger et al. 2022). In Finland, where shop-floor representation coexists alongside industry-wide unions and coverage is very high, firm-level organizations have no effect on local wages (Harju et al. 2021).

Our empirical strategy rests upon an overidentified instrumental variable approach in which a measure of blood donation per capita recorded at the province (NUTS3) level in 1995 (here taken as a measure of the area-specific level of altruism in the population) is paired with the lagged presence of EOs averaged at the sector (2-dgt NACE) and regional (NUTS1) levels. Results prove robust to the use of the internal instrument alone, also when combined with a PSM strategy or with a measure of tolerance retrieved from the World Value Survey carried out in 1995–1997. They suggest that the probability to adopt an ADT is 15 percentage points per year higher in unionized workplaces than it is in non-unionized establishments. This result is only partially driven by the adoption of security technologies, which are loosely related to production processes, as the effect survives when we drop them from our dependent variables, although is lower in magnitude when measured in absolute terms. The external validity of these results should not be overstated, given that they only apply to countries featuring a system of industrial relations comparable to Italy's (i.e., with negligible firm-level rent seeking, centralized bargaining, coexistence of industry- and firm-level organizations). Studies on more decentralized wage bargaining regimes may obtain opposite results and might still be compatible with the evidence examined in this work.

The remainder of this paper is organized as follows. Section 2 reviews the relevant streams of research. Section 3 describes the Italian system of industrial relations. Section 4 illustrates the data and provides baseline descriptive statistics. Section 5 describes the empirical strategy. Section 6 describes the identification strategy, rationalizing the choice of blood donation as an instrument for workplace EOs. Section 7 presents our main estimation results, while some robustness checks are presented in Sect. 8. Section 9 comments and concludes. This paper is complemented by two appendixes. Appendix 1 presents a simple conceptual framework that summarizes the multiple mechanisms outlined in the literature review section and that may affect the relationship between workplace EOs and ADT investments. In Appendix 2, we report our preferred IV model's full coefficient estimates.

2 Literature Review

The literature on the relationship between unionism and advanced digital technologies has been extremely scant to date. The relationship between unionism, investments, and innovation, conversely, is rich, having a long tradition in both labor economics and industrial relation studies. Moreover, scholars have studied whether employee organizations hamper or promote productivity, an issue that is logically related to the effect that they exert upon both investments and innovation. As investments in ADTs stand somewhere between investments in process innovation and in physical capital, the different streams of research that investigate how employee organizations may affect both provide insights that are valuable for theoretically framing the present paper's topic.

2.1 Unionism and Firm Investments

The major theoretical views on the relationship between unionism and firm investments are basically two. On the one hand, the monopoly view put forward in Grout (1984)—empirically confirmed by, e.g., Cardullo et al. (2015), but rejected by, e.g., Card et al. (2014)—postulates that EOs hold up investments by imposing a tax on sunk capital. Since EO-bargained wages exceed the market-clearing level of an amount that is proportional to the resources invested, firms anticipate the unions' rent-seeking behavior by choosing suboptimal investment levels.

Several channels may mitigate this underinvestment effect. First, when employee organizations and firms bargain over wages and employment levels, as in efficient bargaining models, the unions' preferences for employment may limit their rent-seeking behavior (Oswald and Turnbull 1985; Layard et al. 1991; Booth 1995). Second, firms may credibly commit to first-period wages that completely outweigh any second-period hold-up (Crawford 1988). Third, by financing their investments through debt, rather than equity, companies can reduce the final surplus that has to be shared with the supplier of an amount that is equal to the face value of debt, thereby leaving their share unchanged (Subramaniam 1996). Fourth, the distortionary effect of rent-sharing crucially depends upon the fraction of capital costs that firms can recoup before splitting rents with their employees. With rent-sharing, but no hold-up, negotiated wages contain an offset for the full cost of capital and this may even lead to optimal investments (Card et al. 2014).

The view that EOs are collective voice organizations, stemming from Freeman and Medoff (1984), highlights that EOs may conversely provide employers and employees with a two-way commitment device that promotes workplace trust and morale, with positive spillovers on both labor productivity (Barth et al. 2020) and on the accumulation of firm-specific human capital (Bellmann et al. 2018), and negative ones on worker absenteeism and quitting (Heavey et al. 2013).

As recalled by Hirsch (1997: 37), however, "[t]he monopoly and collective voice faces of unionism operate side-by-side, with the importance of each being very much determined by the legal and economic environment in which unions and firms operate." Moreover, these different "faces of unionism" are often embodied in organizations that operate at different levels (firm- vs industry-level), depending on each system of industrial relations' specific institutional set-up. Neglecting this organizational variety by focusing, for instance, on the role played by central unions without taking that of firm-level EOs into consideration would ultimately lead to wrongful assessments of EO's overall effect on economic performance.

2.2 Unionism and Innovation

The picture described in the previous subsection is further complicated by the fact that ADT, unlike traditional capital, may either complement or substitute labor, depending on the type of skills, workers, and tasks involved in the renovation. ADTs (and in particular robots) have been found to substitute low-mid-skill workers, as well as repetitive and routinary tasks, and to complement mid-high-skill workers as well as

cognitive and non-routinary tasks (Battisti et al. 2021). This is consistent with previous evidence on the skill-biased-technological-change (Acemoglu and Autor 2011) and routine-biased-technological-change hypotheses (Autor et al. 2003). Viewed in this way, ADTs are more similar to process innovations, the adoption of which, as another abundant stream of research in industrial relations has widely discussed (Menezes-Filho and Van Reenen 2003; Doucouliagos and Laroche 2013), is also ambiguously related to union presence.

On the one hand, Luddist-like arguments suggest that EOs oppose the introduction of labor-saving technologies unless they automate dangerous or physically demanding tasks (Genz et al. 2019).[2] On the other hand, EOs may favor the introduction of organizational innovations and encourage both workers and firms to invest in firm-specific human capital (Berton et al. 2023). Since technology, organization and human capital have all been found to complement in each other (Antonioli et al. 2011), unionized firms may have extra incentives to invest in ADT. Moreover, process innovation incentives have been shown to be non-monotonic, with respect to the degree of wage centralization, being lowest when centralization is intermediate, intermediate when wage-bargaining is completely decentralized, and highest when EOs negotiate a uniform wage for the entire industry (Haucap and Wey 2004). Indeed, when wage setting mostly occurs at the sectoral level, firms gaining efficiency through investments and innovation are not forced by company-level bargaining to pay higher wages than their less efficient competitors. Their investment decisions are therefore not hampered by any form of firm-level hold-up. On the contrary, when firms innovate in markets in which the wage setting procedure is completely centralized, then industry-wide unions react by raising the wage bill for *all workers* in the sector, somehow spreading the wage cost of innovation over the entire population of firms.[3] As a result, the wage-level hold-up is mitigated, and the wage-differential hold-up that specially penalizes new technology adopters in more decentralized settings, does not arise. It should thus come at no surprise that Haucap and Wey find that centralization provides the largest innovation incentives, compared to other unionization regimes, and that it can even outperform a competitive labor market when it comes to inducing innovation. Interestingly, the authors use this result to rationalize the empirical regularity reported in the reviews by Menezes-Filho and Van Reenen (2003) showing that the relationship between unions, investments, and innovation is negative; it is significant in decentralized North American systems, but remains insignificant or weakly positive in more centralized European countries.

The recent empirical evidence on the relationship between unionism and process innovation is quite scarce, as mentioned previously. Both Berton et al. (2021b) and

[2] The question of whether process innovation decreases or increases aggregate employment is quite old. The so-called "compensation theory" suggests that the direct effect of process innovations on job destruction may be offset by the increase in productive efficiency, profits, wages, and demand that, depending on the type of product and labor market competition, may altogether lead to an increase in overall employment. For further discussion, see Van Roy et al. (2018). The specific case of robots has been studied, for instance, by Chen et al. (2022) who show that one more robot per thousand workers reduced the employment-to-population ratio in Britain by 0.5 percentage points between 1993 and 2007.

[3] Incidentally, this also implies that union-bargained wages constitute a public good for workers in a given industry, given that they apply to both members and non-members equally, giving rise to the well-known free-rider problem in the workers' decision to join the union that was first studied by Booth (1985).

Bryson and Dale-Olsen (2021) find a positive relationship among fairly different countries, namely Italy, Norway, and Britain.

2.3 Unionism and Advanced Digital Technologies

The literature on ADT adoption is generally scarce; that on ADT adoption in Italy is, in particular, almost null, with the significant exception of Belloc et al. (2022)—see below for further discussion. Using macro data, Presidente (2023) provides evidence that countries with stronger institutional protection of workers' rights, centralized bargaining systems, and higher unionization rates use more robots per worker, and that this association is stronger in sunk cost-intensive industries where producers are more vulnerable to hold-up, thereby suggesting that robots are used by firms to thwart rent appropriation by workers. In the same vein, Traverso et al. (2021) also use aggregate data to estimate the relationship between labor regulation and robotization, reaching very different results. In their study, stronger employment protection is negatively associated with robot adoption, suggesting, in their view, that labor-friendly legislations make investment riskier by increasing adjustment costs (i.e., firing costs). The correlation, however, is mediated by the sectoral level of capital intensity, potentially suggesting that firms, in line with the message in Presidente (2023), rely on robots to replace employees and reduce their bargaining power and hold-up opportunities.

Dauth et al. (2021) provide extremely detailed evidence on how German local labor markets react to robot adoption, showing: (1) that labor displacement in manufacturing is more than compensated by job creation in services; (2) that robotization induces firms to update the task content of their incumbent workers' occupations and leads to improved levels of job satisfaction; (3) that young workers adapt their educational choices to robot exposure by substituting away from vocational training towards colleges and universities.

Genz et al. (2019), in turn, use data from Germany and show that the overall effect of works councils on firm-level ADT adoption is negative, but that it becomes positive in establishments with high shares of workers conducting physically demanding tasks, thereby suggesting that co-determination rights can play a crucial role in directing the process of technological change.

The study that we feel is closest to ours is Belloc et al. (2022) who document a positive association between workplace employee organizations and ADT adoption by using firm-level data from several European countries. The cross-country correlation they find seems robust to the inclusion of several controls that may mitigate the relationship between EOs and ADT, such as the level of industrial conflict and employment rigidity, as well as the complementarity between work organization and automation. By relying on the same data that we use in this paper, Belloc and colleagues then exploit the size-contingent cut-off in Italian labor law that makes the presence of EOs more likely in firms with more than 15 employees to develop an RDD approach, finding causal evidence of a positive effect of EOs on ADT adoption in Italy.

Their results, although consistent in sign, are smaller than ours, ranging between 3 and 6%, depending on the specification. This quantitative gap may be due to the

different estimation techniques employed, and particularly to the fact that their RDD design compares firms that, apart from being differently exposed to workplace union presence, are also subject to different constraints when it comes to employment regulation. The existence of two other discontinuities at the cutoff of 15 employees in Italian labor law implies that firms above this threshold are not only more likely to face a locally organized workforce, but are also subject to more stringent regulation in terms of employment protection (Ardito et al. 2023). First, in the case of severe economic downturns or structural reorganization, firms with more than 15 employees are entitled to dismiss or to reduce the working hours of their workers, knowing that the latter can access publicly paid compensation that is provided by the so-called "Cassa Integrazione Guadagni Straordinaria" (CIGS). Second, unfairly dismissed workers can ask for compulsory reinstatement (or for a severance pay) on condition that they work in firms above the 15-employee threshold. As a result of these additional constraints, these organizations may find it harder to adjust their skill portfolio to the requirements of the new technology being implemented, thereby failing to keep up with the process of technological change. This may potentially explain why the coefficients estimated by Belloc are smaller than ours.

2.4 Unionism and Productivity

Our work also contributes to the abundant literature on the relationship between EOs and productivity. Irrespective of whether ADTs either complement or substitute labor, we can safely assume that they ultimately enhance productivity. Since the question as to whether employee organizations curb or foster firm investments is indissociably intertwined with their effect on productivity, obtaining results on either of these two variables indirectly sheds light on the other.Interestingly, Barth et al. (2020: 1898) mention the very same channels, which drive the relationship between employee organizations and firm investments/innovation, when rationalizing the relationship between employee organizations and productivity: "Union rent-seeking may impede capital investment, workers may shirk where unions provide insurance against dismissal, and union bargaining may be detrimental to manager–worker collaboration. On the other hand, unions may provide a 'voice' for workers, which improves information flows and increases tenure, raising the returns to firm investments in human capital, and local union bargaining may promote efficient provision of effort".

Unsurprisingly, evidence on the effect of unionism on productivity is mixed. Recent causal studies mostly focus on the US, finding a weakly negative effect (DiNardo and Lee 2004; Lee and Mas 2012; Frandsen 2012; Soujourner et al. 2015), which turns positive in the causal study on Norway conducted by Barth et al. (2020). These sharply different results are in line with the "Atlantic divide" stressed previously by the reviews of Menezes-Filho and Van Reenen (2003) and Doucouliagos and Laroche (2013), as well as with the model of Haucap and Wey (2004) which rationalizes why the hold-up problem is more severe in decentralized wage setting regimes. The evidence presented in this paper, which documents a positive effect of Italian workplace EOs on ADT adoption, is largely consistent with this view because it corroborates the idea that

wage centralization and workplace EOs voice may jointly encourage investments, innovation and, by extension, productivity.

3 3. The Italian System of Industrial Relations

The Italian system of industrial relations, like many others in Europe,[4] is characterized by a two-tiered structure in which different types of firm-level organizations (*Rappresentanza Sindacale Unitaria*, RSU, and *Rappresentanza Sindacale Aziendale*, RSA), coexist alongside industry-wide unions (*National Collective Labor Agreements*, NCLAs). While sectoral organizations strive to protect workers' purchasing power and on-the-job wellbeing (e.g., safety and working hours) that apply to entire industries, workplace organizations operate within the boundaries defined by sector-specific standards, adjust such standards to each company's peculiarities, and bargain over complementary issues (such as performance pay and training).[5]

Workplace organizations were introduced by Law no. 300/70 (the *Statuto dei Lavoratori*) and the actual decentralization of the Italian system of industrial relations is the result of two major institutional reforms. In 2007, Law no. 247 introduced significant tax-cuts for performance-related pays, thereby creating incentives for workers and firms to sign firm-level agreements and to profit from this favorable tax rate. A more radical transformation occurred in 2011, when the incumbent and prospective governors of the European Central Bank pressured the Italian government to weaken the country's employment protection legislation (Draghi and Trichet 2011). The government's response—albeit deemed insufficient thereafter, see Sacchi (2015)—was condensed in Law no. 148 (article 8), which introduced the possibility for workplace agreements to derogate *in peius* both the labor law and the national collective contracts.

The current layout states that workplace EOs can be set up at the workers' discretion in firms with more than 15 employees, implying that not all workforces of firms above 15 employees must be organized. Moreover, sectoral agreements can also introduce workplace EOs in firms with fewer than 15 employees, thereby creating substantial variability in the EO distribution.

Despite the lack of official information on the actual diffusion and content of workplace EOs, survey data suggests that coverage is around 60% for employees and between 15 and 25% for firms (Damiani and Ricci 2014), with greater incidence in manufacturing and larger firms. Over 60% of these agreements contain wage increases related to productivity gains, with the remaining 40% dealing with organizational workplace changes, performance-based human resource management practices, and employment flexibility. It is common practice that the results of these negotiations

[4] In systems where "certification elections" are not required for union recognition (as they are, for instance, in the US), workers can be simultaneously represented by more than one workplace organization. This type of "open-shop" arrangements are common in Continental Europe.

[5] RSU differ from RSA as in the former representatives are elected among all workers, while in the latter candidates are drawn from union lists only. Today, RSAs survive in small firms and in some specific sectors like banking. Beyond workplace representation, a territorial level also exists, but it is typically confined to specific industries, e.g., construction and agriculture, the latter being excluded in our empirical analysis.

involve the firm's entire workforce, without distinguishing between these organizations' members and non-members (Cella and Treu 2009).

4 Data

Our firm-level data source is the RIL (*Rilevazione Imprese e Lavoro),* a partially panel survey conducted by the National Institute for Public Policy Analysis on a nationally representative sample of firms in the Italian non-agricultural private sector.[6] Observables include information about management and corporate governance, firms' productive characteristics, and internal labor market and workforce composition in terms of gender, age, education, and contractual type.

Crucially, the RIL asks whether a workplace EO exists, reporting this information with a dummy that equals 1 if either of the two different types of workplace organizations mentioned in the previous section (RSU and RSA) was in place at the time of the survey and, in the 2018 wave only, whether the firm adopted an ADT in the current or within the previous two years (thus, over the window 2015–2017), to choose among (1) Internet of things; (2) robotics; (3) big data analytics; (4) augmented reality; and (5) cybersecurity. The survey also asks how many of these technologies were implemented over the three-years window 2015–2017.[7]

We are aware that these measures provide only a reasonable proxy of adoption, given that they considerably compress the variability in the diffusion of such technologies across firms. Continuous measures of expenditures in ADT would obviously be preferable. However, we are not aware of any data source that provides this type of information for a sample of Italian firms as rich and as representative as the RIL and, most importantly, that simultaneously reports information about workplace industrial relations. To date, we believe that the RIL provides the best available data source by which to implement the analysis that follows.

To allow for lagged regressors and prevent simultaneity bias, we focus on firms observed both in 2018 and 2015, while the dependent variables on ADT adoption are all tracked in 2018 only. Lagging explanatory variables seems important to ensure that the firms' choices and characteristics precede the decision to invest in ADT. Reassuringly, the majority of our covariates refer to decisions taken by surveyed firms in the two years preceding each interview. Descriptive statistics are reported in Table 1. Besides, we exclude from the analysis firms with less than ten employees: 6974 units survive in the sample. Indeed, it is well-known that small firms tend to fare worse when it comes to the adoption of new technologies, most of the time, because they lack the organizational resources required for their implementation.

On average, 46.5% (20.6%) of firms adopted at least one ADT in 2018, including (excluding) cybersecurity, with an average of 0.69 (0.29) per-firm innovations. The 2641 unionized firms did so more frequently: 56.1% (27.4%) in terms of share and 0.86

[6] See https://inapp.org/it/dati/ril for RIL data.

[7] The exact formulation of these survey questions are (our translation from Italian): "over the period 2015–2017, did the firm acquire any tangible or intangible asset or service (such as software, platforms, and apps) in one of the following technological domains? i) Internet of things; ii) robotics; iii) big data analytics; iv) augmented reality; and v) cybersecurity" [answer yes or no for each domain].

Table 1 Descriptive statistics, RIL components. Source: Computations on the longitudinal component (2015–2018) of RIL data. Notes: management characteristics are formalized as dichotomous variables, hence—e.g.—education refers to the highest attainment within management and gender to its head; workforce shares are computed with respect to total employment; explanatory variables are computed on 2015 wave (hence refer to 2014–2015), dependent variables (i.e. measures of advanced digital technologies) on 2018 wave (and refer to 2015–2017)

Variable	Mean	Standard deviation
Key variables		
At least one advanced digital technology (0/1)	0.465	0.499
At least one advanced digital technology—no cybersecurity (0/1)	0.206	0.405
Number of advanced digital technologies	0.691	0.920
Number of advanced digital technologies—no cybersecurity	0.291	0.651
Workplace union (0/1)	0.225	0.417
Management characteristics		
Tertiary education (0/1)	0.274	0.446
Upper-secondary education (0/1)	0.537	0.499
Lower-secondary or elementary education (0/1)	0.189	0.391
Female (0/1)	0.117	0.321
Family ownership (0/1)	0.840	0.366
External management (0/1)	0.049	0.215
Workforce composition		
Share with tertiary education	0.107	0.186
Share with upper-secondary education	0.466	0.284
Share with lower-secondary or elementary education	0.427	0.316
Share of executives	0.037	0.084
Share of white collars	0.369	0.295
Share of blue collars	0.593	0.316
Share of females	0.339	0.260
Share of workers with a fixed-term contract	0.109	0.183
Firm characteristics		
Involved in foreign trade (0/1)	0.376	0.484
Log of value added per employee	11.854	1.289
Age (years)	27.716	27.203
R&D (0/1)	0.127	0.333
No. of observations: 6974		

(0.39) in absolute terms, while figures for non-unionized firms (4,333) were 43.8% (18.7%) and 0.64 (0.26) respectively. The share of firms reporting a workplace body of employee representation below the critical threshold of 15 employees is around 7%, while above is around 50%.

5 Specification

We rely on an overidentified approach that combines two instrumental variables, given that the exogeneity assumption for the employee representation variable is questionable and is commonly discussed in the literature—for an overview, see Menezes-Filho and Van Reenen (2003), Doucouliagos and Laroche (2013), and the more recent discussion in Barth et al. (2020). The first instrument for the current presence of workplace EOs is their lagged (2010) mean incidence recorded at the industry (2-dgt NACE) and regional (NUTS1) level. The instrument has already been validated in the industrial relations literature, originally being used by Devicienti et al. (2018)—both alone and paired with another instrument—in a study using the same data as ours and that identified firms as "unionized" if they featured a workplace body of employee organization; namely, an RSU or RSA. While we pay particular attention to the distinction between firm- and industry-level organizations, Devicienti and colleagues are less careful in this respect, given that they use the expression "firm union status" to refer to the possible presence of workplace EOs. This should not confound the reader however, given that the empirical distinction we draw between unionized and non-unionized firms is exactly the same as that proposed by Devicienti and colleagues: in both studies, a firm is defined as "unionized" if the company faces an RSU or an RSA. Moreover, Devicienti and colleagues rely on the 2005 RIL wave to compute their instrument and then use it to appreciate how firm-level EOs causally affect the firms' propensity to hire workers in 2007 on a temporary basis. Instead, we compute our instrument using the 2010 wave and then analyze its effect on ADT investments in 2018. Hence, both the dependent variable and the time span considered are different.

The second instrument (whose choice is motivated in the following section) is the average number of blood bags every 10,000 inhabitants recorded at the province (NUTS3) level in 1995. We draw this measure from Nannicini et al. (2013) and merge it to RIL through NUTS3-level identifiers.[8] Descriptive statistics show that the unweighted average number of blood bags per 10,000 inhabitants is 2.9 at the national level, with regional values spanning from 6 in Emilia Romagna to 0.3 in Campania.

In the first stage of our 2SLS strategy we estimate the following specification linearly

$$U_{i2015} = \alpha \overline{U}_{r,s2010} + \beta Blood_{p,1995} + \delta X_{i2015} + \sigma \mathrm{s} + \lambda \mathrm{p} + \varepsilon_{i2015} \qquad (1)$$

where subscripts i = firm, r = NUTS1 region, p = provinces (NUTS3 regions) and s = two-digit NACE sector, while U_{i2015} is a dummy measuring whether an EO was present in firm i in 2015, $\overline{U}$ is the lagged average presence of EOs recorded at the industry (2-dgt NACE) and regional (NUTS1) levels, $Blood$ is the number of 16 oz blood bags donated for every 10,000 inhabitants in province p in 1995, s (p) are sector- (province-) fixed effects, and X_{i2015} is a vector of controls on management, firm, and workforce characteristics that are fully described in Table 1. The predicted values of

[8] The data are publicly available at the following link https://www.tommasonannicini.eu/it/works/measures-social-capital-italian-provinces-and-muni/ and were previously used in unrelated research, such as Guiso et al. (2004) for instance.

U_{i2015} ($\widehat{U}_{i2015}$) are then plugged into the second-stage equation

$$Digit_{i2018} = \mu \widehat{U}_{i2015} + \widetilde{\delta} X_{i2015} + \widetilde{\sigma} \mathrm{s} + \widetilde{\lambda} \mathrm{r} + \varepsilon_{i2018} \tag{2}$$

where $Digit_{i2018}$ is a dummy capturing firms that adopted at least one ADT or the number of such innovations, with and without cybersecurity; it is estimated linearly, with error terms clustered at the firm-level. Since both measures of adoption are based on survey questions that ask whether one or more ADTs have been implemented over the three years prior to the interview (namely 2015–2017), estimates of μ must be divided by three to get per-year impacts.

This approach is essentially cross-sectional, even though it uses lags. This choice mainly follows from data constraints, given that the adoption of ADTs is observed only in the last available wave (2018); moreover, we use the other two (2010 and 2014) in order to ensure that regressors are predetermined at the second stage and to compute the internal instrument at the first one.[9] There is eventually a third argument that may support a cross-sectional approach here: introducing workplace fixed effects would force the model to identify the effect of interest based upon within-firm variability over time. This option would greatly reduce the variability of our variable of interest, thereby amplifying any attenuation bias, because the presence of EOs mostly varies across firms, rather than within firms over time. We, hence, deem that a fixed-effects approach would not necessarily be a priori better because the RIL includes a great deal of observables.

The following section explains our identification strategy, motivating the choice of blood donation as a complement to the already validated instrument proposed by Devicienti et al. (2018).

6 Identification

The idea of using blood donation to instrument the firm-level presence of employee organizations is, to the best of our knowledge, rather new and can be motivated as follows. As Booth (1985) seminally recognized, union membership suffers from a classic free-rider problem. Since EOs exist to secure benefits that are collective across workers employed in a given industry or firm—in Italy, for instance, coverage does not depend on membership, neither at the industry- nor at the firm-level—a major impediment to EO formation is that workers can enjoy these EO-provided goods without incurring the costs for their provision, such as membership fees and employers' stigma towards EO members. As a long-standing stream of research across economics, psychology, and evolutionary biology has extensively shown (both theoretically and experimentally), positive social feelings, such as altruism, can help overcome this free-rider problem. The model in Banerjee (2021), and the literature examined therein, show that altruism improves public goods provision, thereby suggesting that EOs should be more diffuse in places that are densely populated by individuals with other-regarding preferences. The idea of using blood donation to instrument EO's participation is

[9] The first RIL wave (run in 2007) is much smaller in size and has been excluded from the analysis.

straightforward, then, and follows from the fact that donating blood is considered to be an archetypal act of "pure altruism" (since it involves helping others at a personal cost with no extrinsic reward) and that altruism itself is mentioned as the most common self-reported motive for blood donation (Evans and Ferguson 2014; Ferguson 2015; Ferguson and Lawrence 2016).

Moreover, the specific piece of information that we use in this paper (number of 16 oz blood bags for every 10,000 inhabitants donated in each Italian province) dates back to 1995 which, in addition to reassuring against any simultaneity bias concern, is also consistent with the growing literature in the social sciences that emphasizes the notion of long-term persistence in cultural transmission (e.g., Voth 2021).[10] From this view, current socio-economic phenomena can be rationalized as the outcome of long-lasting processes of cultural socialization rooted back in the past. Shared beliefs and cultural values transmitted unchanged from generation to generation are key to building cohesive communities where individuals with other-regarding preferences cooperate to provide the public goods they collectively need, including systems of collective representation in defense of common claims and requests, as shown recently by, for instance, Guiso et al. (2006), Buggle and Durante (2021), Belloc et al. (2016) and Guiso et al. (2016).

As to the other "internal" instrument—past mean presence of EOs in a region-sector cell—relevance is granted by Italy's specific institutional setting, according to which EOs are created following a workers' initiative. In this framework, the prior presence of EOs can work as a sort of "incubator"—as Devicienti et al. (2018: 198) put it—for the subsequent growth of firm-level unionism at the regional-sectoral level, thereby generating positive externalities in terms of shareable expertise related to the formation of new employee organizations.

By combining lagged aggregated EO presence with blood donations, we preserve variability across sectors and space that are pivotal sources of heterogeneity for both ADT and EOs. In particular, as our two instruments together vary at the province/2-dgt NACE level, once our sample has been selected (see Sect. 5) their combination produces a potential of around 8000 cells.[11] The combination of both instruments varies virtually at the statistical unit level because we observe around 7000 firms per year.

The first-stage coefficients estimated from Eq. (1) are reported in Table 2. Reassuringly, both coefficients have the expected (positive) sign, thereby indicating that both the lagged average presence of EOs in a given sector-region cell and the number of donated blood bags at the NUTS-3 level in 1995 correlate positively and significantly with the current presence of workplace bodies of employee representation. More stringently, the value of the F-test of excluded instruments (205.72) is largely above the thresholds suggested in the literature (Baum et al. 2007; Steiger and Stock 1997), supporting the relevance of our instruments.

[10] For industrial relations papers relying on historical explanations of current outcomes, see Aghion et al. (2011), Blanden and Machin (2003) and Bryson and Davies (2019).

[11] The actual number of possible cells is not constant over time, due to growth in the number of provinces. Some cells remain empty if no firm with a specific combination of 2-dgt sector and province is present in the data.

Table 2 First stage estimation results. Source: computations on RIL and Nannicini et al. (2013) data

	Two-stage IV
$\widehat{\alpha}$	0.713*** (0.035)
$\widehat{\beta}$	0.189** (0.084)
F-statistic	205.72
# Obs	6523

Standard errors clustered by firm in parenthesis
***1% significant; **5% significant

Table 3 Second-stage estimation results: main overidentified estimates. Source: computations on RIL and Nannicini et al. (2013) data

	OLS	Two-stage IV
Panel a—Second or unique stage (for OLS): ADT (Y/N)		
$\widehat{\mu}$	0.051*** (0.014)	0.443*** (0.044)
Hansen J	–	0.556 (0.456)
Panel b—Second or unique stage (for OLS): number of ADTs		
$\widehat{\mu}$	0.121*** (0.027)	1.220*** (0.114)
Hansen J	–	0.014 (0.905)

Standard errors clustered by firm in parenthesis; the Hansen J test reports the p-value. For OLS we regress $Digit_{i2018}$ on U_{i2015} directly
***1% significant

7 Main Results

Table 3 shows the estimation's results: OLS appears in the first column for comparability, while 2-stage IV appears in the last one.[12] The values of the Hansen tests of overidentification (second lines of panels *a-b*, column 2) are reassuring, suggesting that our blood donation measure is at least as exogenous as the lagged average presence of workplace employees' representative bodies. This does not prove that blood donations are exogenous to firm investments and innovation per se and that the exclusion restriction, therefore, holds. However, the act of introducing a new technology to gain competitiveness seems to have little to do with any type of other-regarding preference. The literature on the relationship between altruism and innovation or altruism and investments is, unsurprisingly, rather scant. Both Alnajjar and Hashim (2010) and Mallén et al. (2019) suggest that altruism may play a mediating role between the company leaders' behavior and their employees' propensity to innovate. From this perspective, the direct effect between altruism and innovations is contingent in nature and is, therefore, ruled out by the time lag between our instrument (observed in 1995) and the firm's investments in ADT (tracked in 2018).

A comparable argument holds for the lagged mean union representation. Indeed, the incentives to invest in process innovation may be directly affected by employee organizations inasmuch as they increase the cost of labor. As discussed by Traverso et al.

[12] Full coefficient estimates of the IV models presented in Table 7 appear in Appendix 2.

(2021) and Presidente (2023), this may provide unionized firms with extra incentives to invest in ADT in order to reduce the employees' bargaining power and hold-up opportunities. This increase in labor cost may either occur at the workplace level—which is exactly the element of endogeneity that we want to eliminate—or at the national level, through collective bargaining. The regional level at which our instrument is computed, therefore, has little to do with it. Moreover, the frequency of bargaining rounds, to which process innovation might want to react, is higher than the time-lag that we introduce with our instrument. Cainelli and De Liso (2005) show that innovation strictly follows the degree of demand volatility in the goods markets and, hence, depends less (directly) on average union presence once this is lagged and taken at an aggregated level (sector and macroregional). We are, therefore, confident that both of our instruments are exogenous with respect to ADT investments.

The second-stage impact estimates (second columns of panels *a*-*b*) prove that OLS suffers from a sizeable downward bias. They suggest that the presence of workplace EOs enhances the probability to adopt ADTs by around 15 p.p. per year (panel *a*), a magnitude that is in line with what Bryson and Dale-Olsen (2021) found in Norway for process innovation generally. When measured in absolute terms (panel *b*), our per-year impact estimate amounts to 0.41 for new advanced technologies adopted.

This positive effect is consistent with previous studies that document that Italian EOs create a favorable environment for firms to commit to investments and innovation. Indeed, Card et al. (2014) find that bargaining does not lower the returns on investments, in spite of the strong evidence of a rent-sharing behavior by workplace unions. The authors argue that rents are split only after the deduction of the full cost of capital and, therefore, that rent-seeking does not hinder the companies' investment decisions. Relatedly, Berton et al. (2023) and Berton et al. (2021b) respectively show that workplace unions in Italy encourage firm-sponsored training and stabilize employment by reducing both hirings and quitting, thereby potentially increasing the rate of firm-specific human capital accumulation that may constitute a facilitator in the process of organizational updating related to the adoption of ADT. These pieces of evidence are also confirmed by Belloc et al. (2022), who also found a positive effect on training and a positive, albeit insignificant, effect on employment stabilization among EOs. Devicienti et al. (2018) further dig into this tripartite relationship among workplace EOs, training, and employment volatility. They found that the presence of workplace EOs increases the use of temporary work at low levels of market volatility, but reduces it for high levels; however, when temporary contracts envisage some training content, then the interplay between market volatility and EOs does not have any effect. The authors argue that this effect may occur because, while non-training contracts can be used to protect the insiders with open-ended contracts, training contracts are themselves understood as a long-term investment, that constrain EOs from opportunistic behaviors that might (once again) be detrimental for firms' investments.

8 Robustness

While ADTs affect the organization of production (with a priori ambiguous effects on capital/labor substitution), cybersecurity should have no such organizational implications. This is why, as a first robustness check, consistently with Belloc et al. (2022), we re-estimate our model dropping cybersecurity. Results are reported in Table 4. Impact estimates on the probability of adopting an ADT are not affected (panel *a*), while per-year impact estimates fall to 0.27on the number of ADTs adopted (panel *b*).

The fact that including cybersecurity (or not) makes a difference in terms of the number of ADTs adopted, but not in terms of the probability to adopt one, is consistent with the recent evidence by Cirillo et al. (2023) who show that Italian firms tend to adopt these new digital tools in clusters, rather than in isolation, often implementing more than one technology at a time. What is truly important is that the effect remains positive, which might be counterintuitive, given that some of these technologies may have labor-saving effects. Traverso et al. (2021) and Presidente (2023) suggest that unionized firms may want to curb their employees' bargaining power by substituting them with new automated technologies, such as robots. This interpretation, while generally inconsistent with Card et al.'s (2014)—who find no evidence of hold-up on investments in the Veneto region—is also inconsistent with Belloc et al.'s (2022), who find no significant effect of Italian EOs on robot adoption, however. The different results obtained by these groups of authors may be due to the fact that while Traverso and colleagues and Presidente develop a cross-country/cross-industry analysis focusing on the role of national and sectoral unions—that normally retain the majority of wage bargaining power—our analysis, like those of Card and colleagues and Belloc and colleagues, remains at the firm-level, focusing on organizations that have little hold-up potential.

We then tested the robustness of our results in three more directions. First, we re-estimate our model using average EO presence alone, in the spirit of Devicienti et al. (2018), because blood donations is a less common instrument within the industrial relations and innovation literatures. Second, we reinforced this exactly-identified IV approach by combining it with a propensity score matching between unionized

Table 4 Second-stage estimation results: excluding cybersecurity. Source: computations on RIL and Nannicini et al. (2013) data

	OLS	Two-stage IV
Panel a—Second or unique stage (for OLS): ADT (Y/N) excluding cybersecurity		
$\widehat{\mu}$	0.048*** (0.012)	0.445*** (0.049)
Hansen J	–	0.837 (0.360)
Panel b—Second or unique stage (for OLS): number of ADTs excluding cybersecurity		
$\widehat{\mu}$	0.075*** (0.020)	0.815*** (0.094)
Hansen J	–	0.742 (0.389)

Standard errors clustered by firm in parenthesis; the Hansen J test reports the p-value. For OLS we regress $Digit_{i2018}$ on U_{i2015} directly

***1% significant

Table 5 Second-stage estimation results: exactly identified estimates, PSM, and alternative overidentified estimates. Source: computations on RIL and Nannicini et al. (2013) data

	Two-stage IV, internal instrument only	Two-stage IV, internal instrument with PSM	Two-stage IV, internal instrument paired with Tolerance indicator
Panel a—First stage			
$\widehat{\alpha}$	0.706*** (0.033)	0.510*** (0.106)	0.709*** (0.034)
$\widehat{\beta}$	–	–	1.771*** (0.630)
F-stat	451.43	22.97	212.77
# Obs	6969	5219	6304
Panel b—Second stage: ADT (Y/N)			
$\widehat{\mu}$	0.461*** (0.043)	0.793*** (0.206)	0.446*** (0.043)
Hansen	–	–	1.666 (0.197)
Panel c—Second stage: ADT (Y/N) excluding cybersecurity			
$\widehat{\mu}$	0.474*** (0.047)	0.792*** (0.226)	0.441*** (0.049)
Hansen	–	–	0.379 (0.538)
Panel d—Second stage: number of ADTs			
$\widehat{\mu}$	1.280*** (0.111)	1746*** (0.487)	1.206*** (0.111)
Hansen	–	–	0.265 (0.607)
Panel e—Second stage: number of ADTs excluding cybersecurity			
$\widehat{\mu}$	0.860*** (0.093)	1.175*** (0.352)	0.797*** (0.093)
Hansen	–	–	0.218 (0.641)

Standard errors clustered by firm in parenthesis but for the Hansen J statistic of overidentification, which reports the p-value. PSM diagnostics in Table 6
***1% significant

Table 6 PSM diagnostics. Source: computations on the longitudinal component (2015–2018) of RIL data

Sample	Ps-R2	LR chi2	P > chi2	Mean bias	Median bias	B	R	% Var
Unmatched	0.123	1100.01	0.000	20.9	19.6	86.2	1.58	88
Matched	0.007	48.10	0.000	5.7	2.9	18.4	0.22	38

and non-unionized firms, in order to reduce heterogeneity *ex ante* (for a discussion, see Ichimura and Taber 2001). Third, we returned to an overidentified IV approach and combined our internal instrument with the measure of tolerance provided by the World Value Survey carried out in 1995–1997.[13] This variable is given by the share of individuals in each province that quoted "tolerance and respect for other people" as important in their responses to the survey. While being tolerant and respectful is something that seems "less strong" than being altruistic, it nonetheless falls in the same

[13] Following Tabellini (2010, p. 684), we consider the question "Here is a list of qualities that children can be encouraged to learn at home. Which, if any, do you consider to be especially important? Please choose up to five". The data, much like blood donations, was retrieved from Nannicini et al. (2013).

category of "moral sentiments" that, as already recalled by Adam Smith, allows individuals to "understand the passions of others." Hence, it may have a similar mitigating effect (albeit perhaps less significant) on the free-rider problem that may hamper EO formation. This is why we believe that it potentially constitutes a valid alternative to our preferred measure of altruism which the main estimates presented in the previous section are built upon.

Results appear in Table 5. We have reproduced the main results reported in Table 3 almost exactly with the internal instrument alone (column 1). When this approach is augmented by the use of a propensity-score matching (column 2), all of the impacts grow further: in terms of the probability to adopt an ADT technology, the point estimates move from 15 to 26 percentage points per year, both including and excluding cybersecurity. In terms of the number of ADTs adopted, estimates grow from 0.41 (0.27) more technologies per year to 0.58 (0.39) with(out) cybersecurity. However, PSM diagnostics (see Table 6) show that the residual mean bias and Rubin's B-test are fine, whereas the Sianesi-LR and Rubin's R-test are not; estimates should, hence, be taken somewhat cautiously.[14] IV estimates combining the mean EOs presence with the tolerance index (column 3) in particular return us either to the same magnitudes detected in our main estimates (Table 3) or with the internal instrument alone (Table 5, column 1). Moreover, the first-stage coefficient is consistent with our expectations as well as with the first-stage results obtained for our measure of altruism, given that it shows a positive correlation between the current presence of EOs and the lagged index of tolerance employed. This is reassuring because it suggests that tolerance, much like altruism, may contribute to creating a socio-cultural milieu that discourages opportunistic behaviors. Both the F-test of excluded instruments and Hansen J statistic of overidentification support the use of this alternative pair of instruments.

9 Concluding Remarks

This paper shows that workplace EOs have both a positive and sizeable effect on the adoption of advanced digital technologies in Italy. Using an overidentified instrumental-variable approach that combines an internal instrument (lagged mean presence of EOs in a region/sector cell) with blood donations as a measure of altruism, we find that workplace EOs increase the probability to adopt an advanced digital technology by 15 percentage points per year; this finding is in line with what Bryson and Dale-Olsen (2021) found in Norway and with what both Belloc et al. (2022) and Berton et al (2021b) found in Italy with respect to the adoption of innovations. In terms of the absolute number of technologies adopted, our estimates point to an impact of 0.41 (0.27) when we include (exclude) cybersecurity in the dependent variable.

While we have claimed that this positive effect is consistent with previous evidence on the effects on workplace Italian EOs on firm performance, we have also observed that it is not totally in line with some, like Presidente (2023) and Traverso et al. (2021), who claim that unionized firms may want to substitute their workers with automated digital capital to reduce their hold-up opportunities. As a possible explanation, we

[14] Full coefficient estimates from the models in Table 5 are available, upon request, from the authors.

have reviewed the Italian system of two-tier collective bargaining: since the most sensitive issues, such as wages and safety, are negotiated at the sectoral level, room is left for workplace representatives to engage in a productive social dialogue with managers (Berton et al. 2023; Kriechel et al. 2014), thereby constructively expressing the workers' voices in a way that leads to bilateral gains for employers and employees. This suggests once more that "[t]he monopoly and collective voice faces of unionism operate side-by-side, with the importance of each being very much determined by the legal and economic environment in which unions and firms operate" (Hirsch 1997: 37). While the first-hand implication is that policies aimed at reducing union power should be implemented cautiously, it also suggests that unionism should neither be fully decentralized nor fully centralized, given that each layer of industrial relations systems may exert its own peculiar effects on economic performance. Testing these hypotheses directly goes beyond the power of our data, however, and may even require trespassing the boundaries of quantitative analysis.

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Data availability All the data sources we have used for our analysis are publicly available. More specifically, RIL is avaiable upon request to the National Institute for Public Policy Analysis INAPP (see https://www.inapp.gov.it/rilevazioni/microdati). Data on blood donations and on tolerance are instead available here: https://www.tommasonannicini.eu/it/works/measuressocial-capital-italian-provinces-and-muni/.

Declarations

Conflict of interest None.

Appendix 1. Conceptual Framework

In this Appendix, we lay out a simple conceptual framework that puts together the many mechanisms highlighted in the Introduction which relate the firm-level willingness to invest in ADT to workplace EOs. The purpose is not to develop an original, fully formalized theoretical model, but rather to provide a clear tool with which to summarize the multiple reasons highlighted by the streams of research on industrial relations and investments on the one hand, and on industrial relations and process innovation on the other, for which locally organized firms may have different incentives to invest in ADT.

Setup

We consider a framework where a right-to-manage firm (i..e., that chooses its employment level, consistently with the Italian reality) possibly facing a local body of employee representation sells its product in an imperfectly competitive market and decides whether to discretely invest in ADT anticipating that this may lead to a wage increase (depending on the degree of wage centralization and on the presence of workplace EOS), but also, to a competitive advantage when it eventually competes with rival companies in the product market.[15] Non-digital capital is assumed to be fixed in the short run and normalized to zero to avoid abuse of notation.

Firm Choice

The decision to invest in ADT is indexed by I; to non-invest by N. The firm's revenue in each of the two states $S = \{I, N\}$ is denoted by R_S, the firm's employment by L_S, the firm's wage by W_S, and the state-specific payoff function is therefore given by:

$$V_S = R_S - W_S L_S - C_S \tag{3}$$

where C_S measure fixed non-labor costs, which we normalize to zero when $S = N$ (i.e., $C_N = 0$), while we assume that $C_I > 0$. This normalization implies that the increase in fixed costs $C_I - C_N \equiv \Delta C(U) > 0$ that follows the ADT investment can be viewed as measuring the adoption cost that must be sunk implement the new technology. When the firm choose $S = I$, its revenues, employment and wages may all change, and may do so to a different extent depending on the presence of workplace EOs. Hereafter, the change in total revenue will be denoted by $R_I - R_N \equiv \Delta R(U)$, the change in labor cost by $W_I - W_N \equiv \Delta W(U)$, and the change in employment by $L_I - L_N \equiv \Delta L$.[16] The term in the bracket, $U \in \{0, 1\}$, is a dummy variable that equals 1 if the firm faces a local body of employee representation and 0 otherwise. In line with the literature reviewed in Sect. 2, this variable indicates that the revenue, wage, and non-labor cost variations may all be affected by the presence of a workplace body of employee representation, as analyzed in the following sub-sections.

Given the above discussion, a firm finds it rational to invest in ADT iff $V_I - V_N \equiv \Delta V(U) \geq 0$, or, using Eq. (3), iff

$$\Delta R(U) - (\Delta W(U) L_I - W_N \Delta L) - \Delta C(U) \geq 0 \tag{4}$$

which implies that incentives to invest in ADT are larger in unionized firms iff $\Delta V(1) - \Delta V(0) \geq 0$, or, rearranging, iff

$$(\Delta R(1) - \Delta R(0)) \geq (\Delta W(1) - \Delta W(0)) L_I + (\Delta C(1) - \Delta C(0)) \tag{5}$$

[15] The focus on discrete investment decisions is made for simplicity only. How the framework applies to the case of continuous investment will be briefly discussed throughout the model's presentation.

[16] These changes can be loosely looked at as marginal effects in case of continuous rather than discrete ADT investments.

The following sub-sections analyzes more closely condition (5), commenting how the presence of a workplace body of employee representation may affect the revenue, wage and non-labor cost variations that ultimately define whether locally organized firms have greater incentives to invest in ADT.

Revenue Differential: the Role of Firm-Specific Human Capital

When they compete in the product market, ADT-investors monetize the efficiency gain they paid for when they decided to implement the new technology. The increase in total revenues that results, besides depending on exogenous features of the economic environment,[17] may depend on the ability of workplace bodies of employee representation to ease the accumulation of firm-specific human capital, that in turn, may facilitate the process of technological updating.[18] Workplace EOs may increase human capital investments either directly—by negotiating with firms over firm-sponsored training—or indirectly—by reducing voluntary quits, since stable employment relationships provide workers and firms with incentives to commit to long-term specific investments. That workplace voice may reduce voluntary quits is consistent with Freeman's and Medoff's (1984) application of Hirschman's (1970) exit-or-voice model to the theory of industrial relations, and with the evidence presented, for instance, by Berton et al (2021b). That it may increase training investments, in turn, is in line with the recent evidence that Berton et al. (2023) show for Italy in particular. Hence, it seems reasonable to assume that $\Delta R(1) - \Delta R(0) \geq 0$.

Employment Effect and Labor-ADT Substitution

The increase in total revenues commented above should a priori imply an upward adjustment in the firm's workforce, since companies investing in ADT must hire new personnel to cope with the increase in market share—for a discussion of how and when this "compensation" mechanism may work, see Dosi et al. (2021). This positive employment effect, however, may be offset if the specific ADT implemented is labor-saving (like robots, that directly substitute low-skill workers especially in routine and repetitive tasks). This implies that the employment variation measured by ΔL can be either positive or negative, depending on the strategic relationship between the technology implemented and human labor, and on market compensation mechanisms that may counterbalance the reduction in labor requirements per unit of output. Since employment is assumed to be a firm's choice, this mechanism should not be affected

[17] Such as: (i) the level of competition prior to the investment (the fiercer the competition, the larger the revenue increase), (ii) the share of ADT adopters among rival firms (the larger the share, the lower the investment's strategic benefits), and (iii) market structure (e.g., demand elasticity, market size, price vs quantity competition, degree of product differentiation, and so on).

[18] The skill-biased and routine-biased technological change hypotheses recalled in the Introduction are both based on the idea that human capital and new technologies complement each other, while many others have amply discussed the complementarity between human capital and innovation.

by the presence of workplace EOs, as can be seen from the assumption that ΔL does not depend on U.[19]

Implementation Cost and Hold-Up

Implementing the ADT requires investing a fixed amount of resources, measured by the increase in non-labor cost $\Delta C(U) > 0$. It seems reasonable to assume that this implementation cost is larger in locally organized firms when the specific ADT adopted has labor-saving effects. The (Luddist-like) intuition is that workplace EOs, albeit formally entitled to bargain over employment, may oppose the introduction of labor-saving techniques by harshening industrial conflict (for instance, through strike organization). To model this, we assume that $\Delta C(1) - \Delta C(0) > 0$ if $\Delta L < 0$, and $\Delta C(1) - \Delta C(0) \leq 0$ if $\Delta L \geq 0$. The second part of this assumption models the idea that workplace employee representatives may indirectly reduce the cost of investing in ADT when these technologies lead to an increase in employment. The intuition is that EOs may improve the workers' perception of the process of technological change by facilitating the flow of information between employers and employees, thus decreasing their opposition towards new technology adoption.

Rent-Sharing

A part of the extra revenue that ADT-investors seize in the product market may be appropriated by employee organizations through wage bargaining. This rent-sharing mechanism is crucial in determining to which extent the surge in total revenues actually translates in higher profits and thus, to which extent it ultimately discourage ADT investment. Whether workplace EOs have a role in this mechanism crucially depends on the institutional organization of each country's industrial relations system. When wage bargaining power is entirely in the hand of sectoral unions, in fact, the heterogenous presence of firm-level employee organizations within industries does not affect this hold-up channel, providing locally organized firms with the same incentives to invest in ADT than their non-organized competitors, as stressed in the main text. The only situation in which workplace EOs do affect this hold-up mechanism is that in which at least a part of wage bargaining is decentralized at the firm-level, in which case non-organized ADT adopters have a comparative advantage over their organized competitors who must share a part of the extra revenues with their workforce. In our framework, this implies that $\Delta W(1) - \Delta W(0) > 0$.

Appendix 2. Full Coefficient Estimates

See Table 7.

[19] Even under the alternative assumption of efficient bargaining, where unions have a say on labor demand, the bottom-end message of our reasoning here—i.e., that the effect of EOs on the adoption of ADTs is a priori undecided, being hence an empirical issue—would not be affect, as we would simply introduce one more degree of freedom within the model.

Table 7 Full coefficient estimates, baseline IV model. Source: computations on RIL and Nannicini et al. (2013) data

	First stage	Second stage			
		ADT Y/N	ADT Y/N, no cybersecurity	#ADTs	#ADTs, no cybersecurity
Main					
Lagged av. EO	0.713***	–	–	–	–
Blood donation	0.189**	–	–	–	–
Workplace EO	–	0.443***	0.445***	1.220***	0.815***
Management characteristics					
Tertiary education	0.162***	− 0.041	− 0.056**	− 0.123**	− 0.087**
Upper sec. education	0.085***	− 0.019	− 0.030*	− 0.048	− 0.037
Female	0.021	0.016	0.005	− 0.001	− 0.009
Family	− 0.129***	0.050**	0.050**	0.010**	0.059
External manag	0.137***	− 0.036	− 0.044*	− 0.131*	− 0.085*
Workforce composition					
Tertiary education	− .136***	0.163***	0.186***	0.474***	0.332***
Upper sec. education	− 0.48**	0.094***	0.047**	0.181***	0.089**
Executive	0.054	− 0.038	− 0.183**	− 0.199	− 0.239*
White collar	− 0.090***	0.123***	0.025	0.130*	− 0.005
Female	− 0.141***	0.024	0.089**	0.155*	0.158**
Fixed-term contract	− 0.240***	0.086**	0.129***	0.269***	0.202***
Firm characteristics					
Foreign trade	0.026**	0.051***	0.050***	0.109***	0.064***
Log of value added	− 0.015***	0.011**	0.025***	0.047***	0.040***
Age	0.001**	0.000	− 0.000	− 0.000	− 0.000
No. of employees	0.000***	0.000*	0.000***	0.000**	0.000**
R&D	0.026**	0.102***	0.119***	0.275***	0.201***
Macro fixed effects					
2dgt NACE sectors	Yes	Yes	Yes	Yes	Yes
NUTS3 provinces	Yes	Yes	Yes	Yes	Yes

Standard errors clustered by firm. ***1% significant; **5% significant; *10% significant

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