Digitalizzazione delle imprese e Industria 4.0.

Valutazioni dell'impatto

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VALUTAZIONE DELL'IMPATTO DELLE POLITICHE PUBBLICHE:
CONCETTI, METODI, APPLICAZIONI

Centro Rossi-Doria - Università Roma Tre

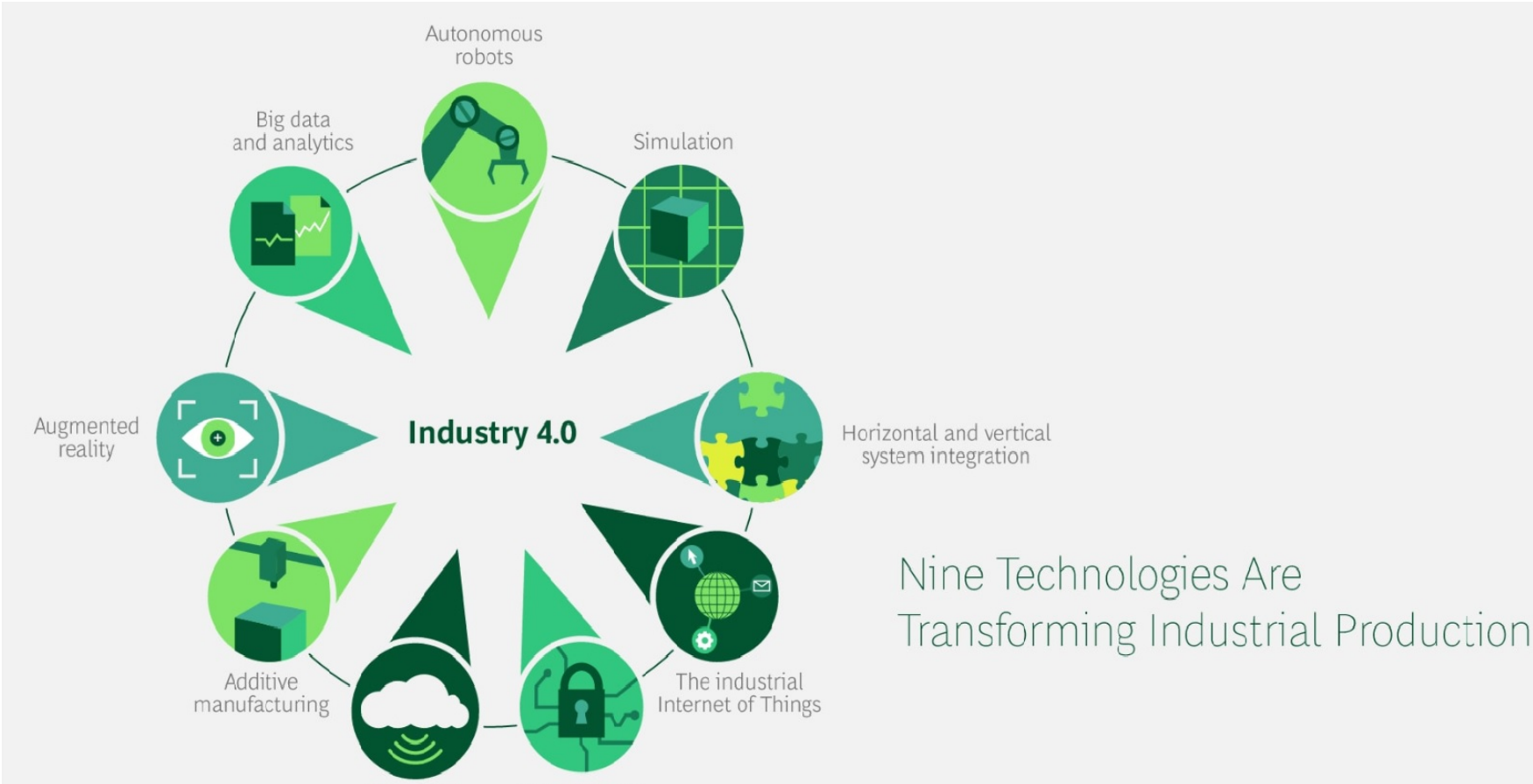
Outline

1. Digital, Automation, I4.0: a cluster of different technologies
2. Drivers of adoption and diffusion of digital and automation techs
3. Consequences of digital and automation techs on firm performances
4. Consequences of digital and automation techs on job flows
5. Digitalization and Work Organization: Qualitative Studies
6. The role of incentives
7. Final considerations

Digital, Automation, I4.0: a cluster of different techs

- Production and distribution processes are characterised by increased (i) digitization, (ii) automation, (iii) interconnection (Brynjolfsson and McAfee, 2014);
- New '**enabling technologies**' (Teece, 2018; Martinelli et al., 2019) display some of the characteristics of general purpose technologies (Bresnahan and Trajtenberg, 1995) but are not yet fully developed GPTs independently from the broader ICT paradigm to which they contribute;
- **Industry 4.0 (I4.0)**: set of policy interventions aimed at encouraging the adoption of new technologies with the potential to shift production paradigm towards 'smart factory' - see *Industrie 4.0, Industrie du Futur, Advanced Manufacturing Iniciative, Made in China 2025*;
- Not a common matrix, Industry 4.0 does not describe a coherent production model but rather a bundle of very different technical developments (Butollo et al., 2018)
- A 'cluster of different technologies':
  i) Internet of Things (IoT); ii) Big Data/Industrial Analytics; iii) Cloud Manufacturing; iv) Robotics; v) Artificial Intelligence (AI); vi) Additive Manufacturing (AM).

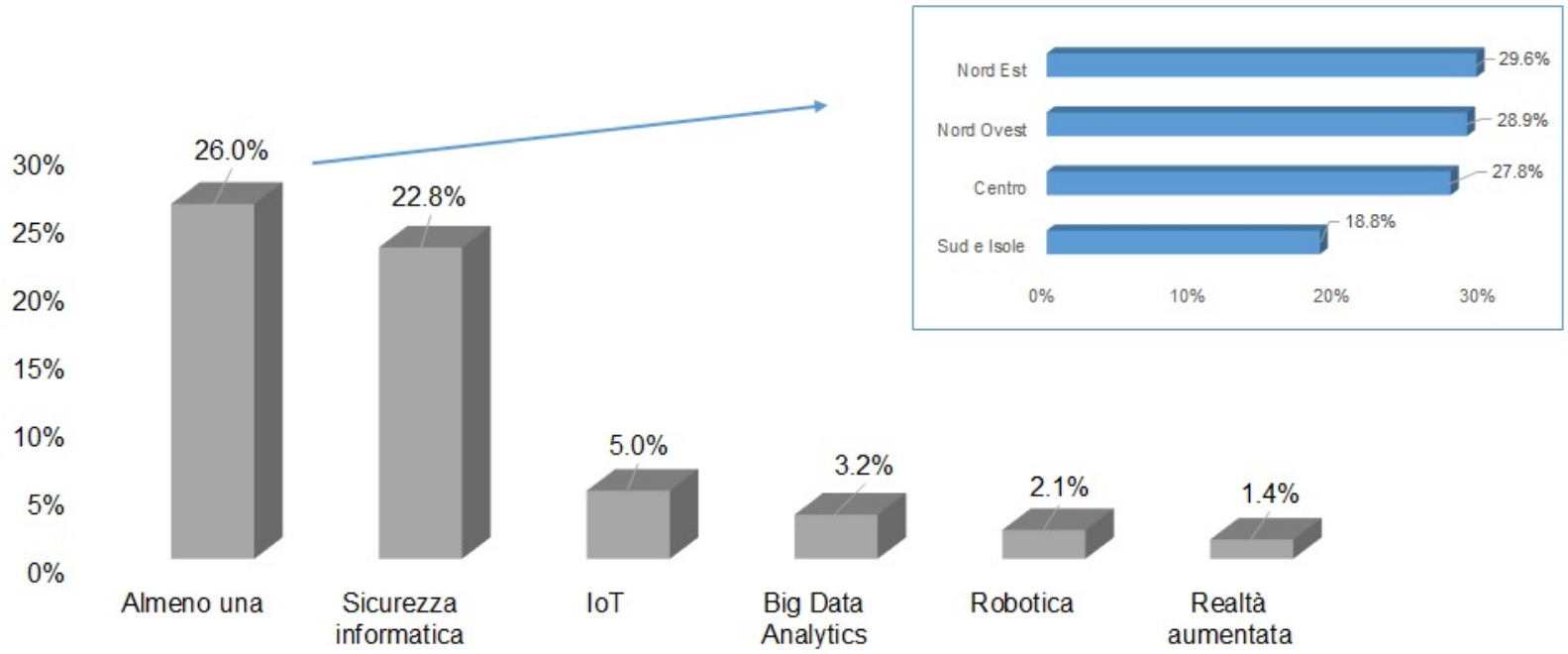
I4.0 ARTEFACTS



Measuring digital, automation, I4.0 techs...

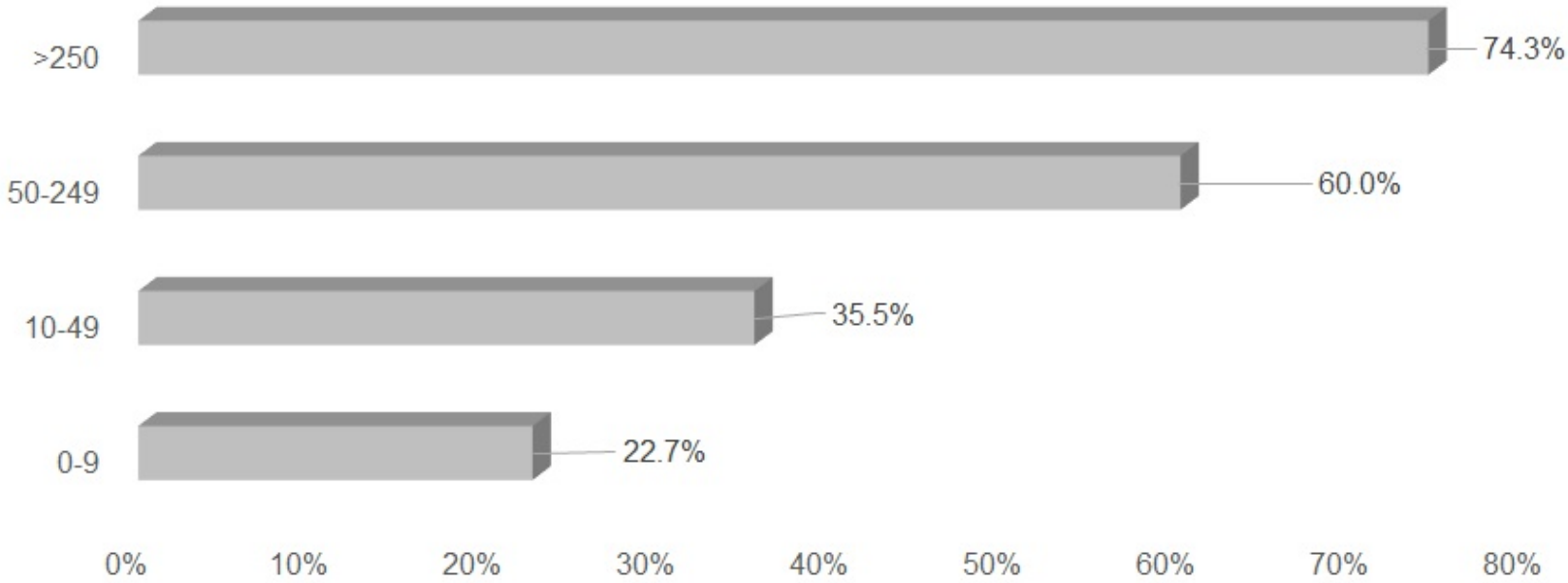
- Information on the 'production of new technologies' could be derived from the examination of patent records;
- Information on market diffusion is much rarer - ISTAT survey on ICTs (2018, 2019, 2020...) and Business Census ISTAT (2018, 2022); MET survey (waves 2017, 2019); Centro Studi Confindustria;
- Diffusion, rather than invention, is the real manifestation of Schumpeterian structural change in the economy;
- In different works we focus on I4.0 techs adoption choices made by the Italian firms;
- Tracing possible adoption patterns and drivers, focusing on the role of skills and different dimensions related to work organization
  –> avoiding a technological-deterministic perspective (Hirsch-Kreinsen, 2018): "importance to account for (a) the material and technical conditions, (b) the companies' motives, and (c) the companies' organizational and work models" (Krzywdzinski, 2020).
- To the purpose, unique information contained in the Italian firm-level survey '**Rilevazione Imprese e Lavoro (RIL)**' collected by the **National Institute of Public Policy Analysis**.

Share of Italian firms investing in I4.0 technologies



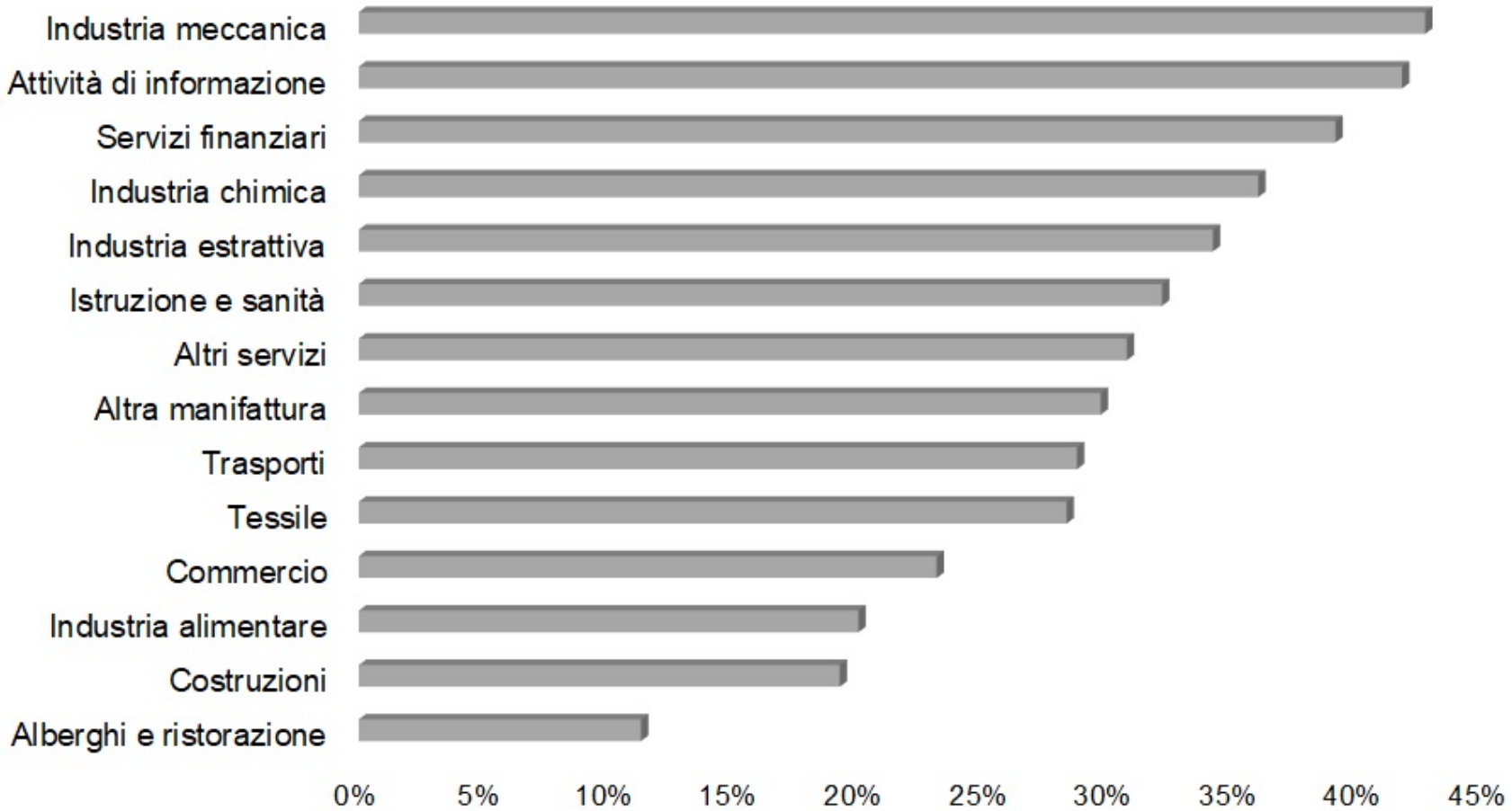
- V Rilevazione RIL-INAPP 2018 (Rilevazione su Imprese e Lavoro), firm-level survey of Italian businesses run by the National Institute for the Analysis of Public Policies (INAPP), which contains specific questions on the different digital technologies acquired by firms (30 000 firms)

Share of firms investing in I4.0 by size

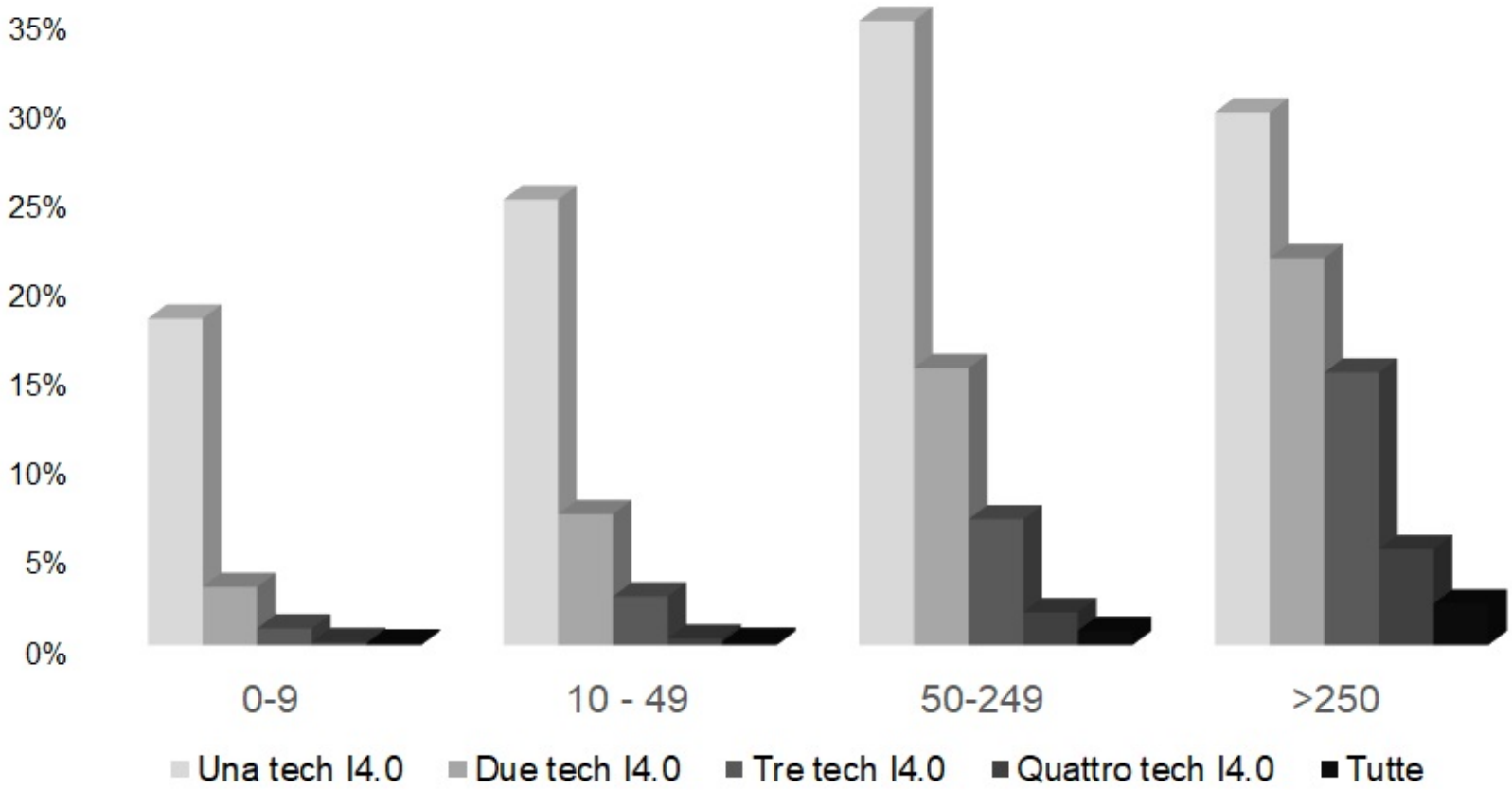


- Dichotomy between large companies, which are the most advanced buyers and lead users, and small and medium sized firms suggesting cost and "absorptive capacity" barriers to adoption;

Share of firms investing in I4.0 by macrosector



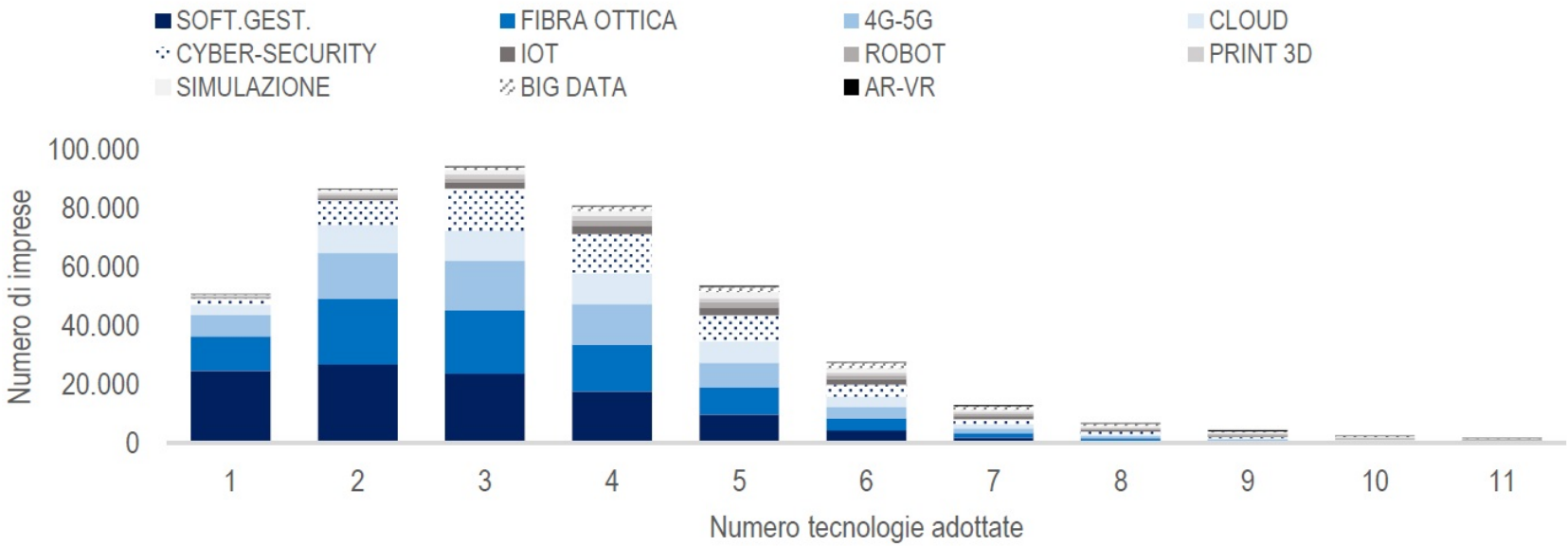
Complementarity of I4.0 investments



- 'Single-technology' approach more than 'multi-technology'

Complementarity of I4.0: Business Census ISTAT

FIGURA 1. ADOZIONE DI TECNOLOGIE DIGITALI DA PARTE DELLE IMPRESE CON ALMENO 10 ADDETTI PER NUMERO DI TECNOLOGIE ADOTTATE. Valori assoluti Anni 2016-2018

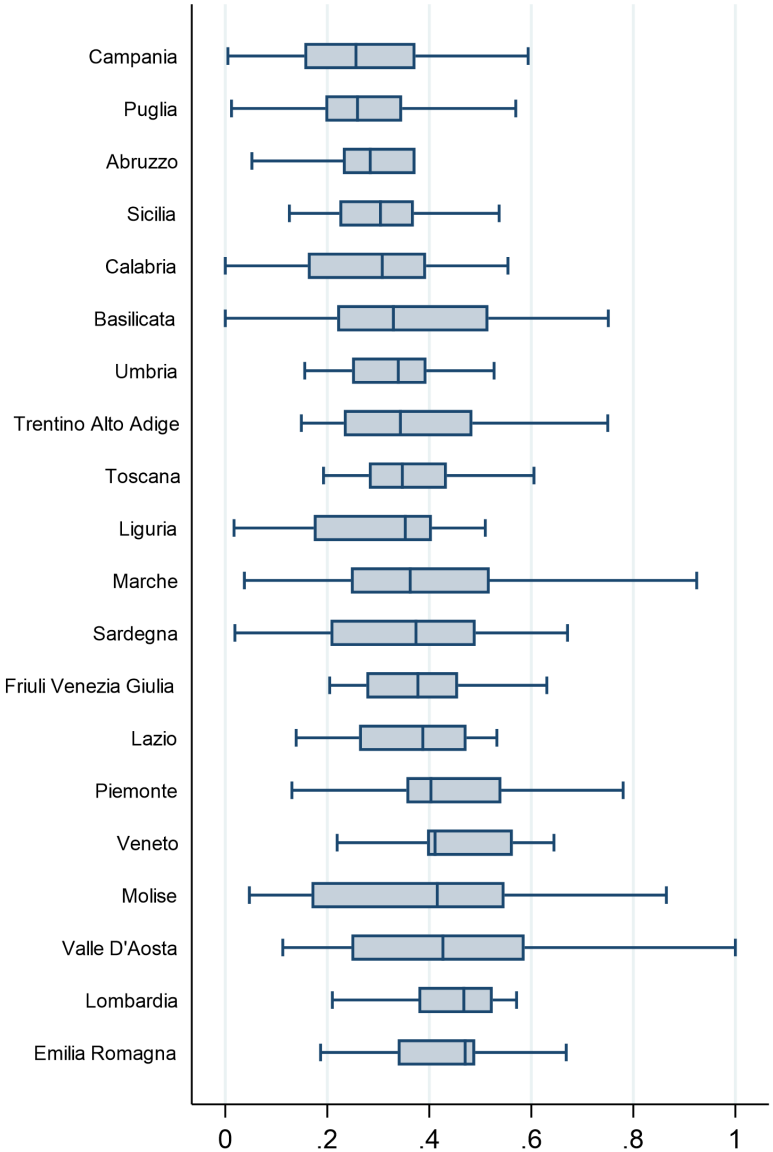


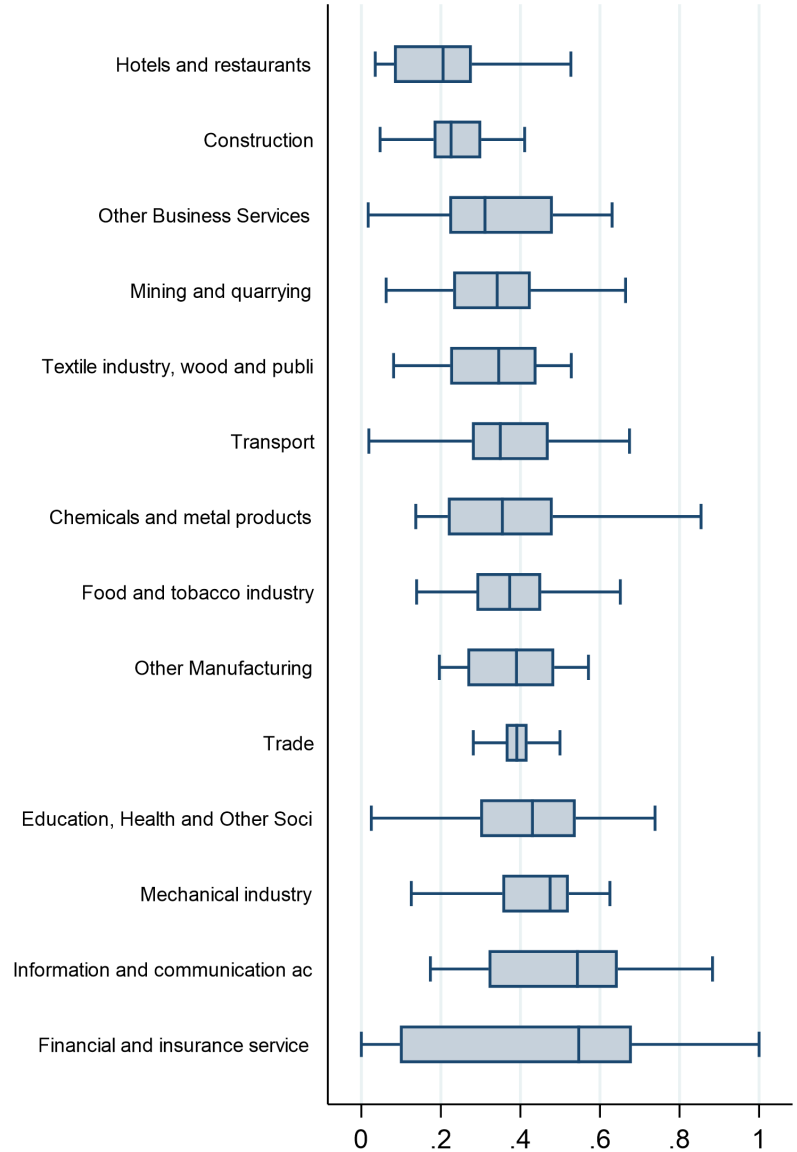
- Most enterprises use a limited number of technologies, giving priority to infrastructure investments (cloud solutions, mobile connectivity, management software and, necessarily, cyber-security) and possibly leaving the adoption of application technologies to a later stage.

Share of firms investing in I4.0 by type of tech and macro-region (%)

Macroregion	At least one	IoT	Robotics	Big Data Analytics	Augmented reality	Cyber sec
North West	36,72	6,75	4,51	5,23	2,3	32,68
North East	37,7	7,28	4,7	5,48	1,89	32,95
Center Italy	35,9	7,96	4,19	6,67	3,37	29,77
Southern Italy	24,52	4,8	1,64	3,06	1	21,15
Total	33,62	6,62	3,74	5,03	2,09	29,15

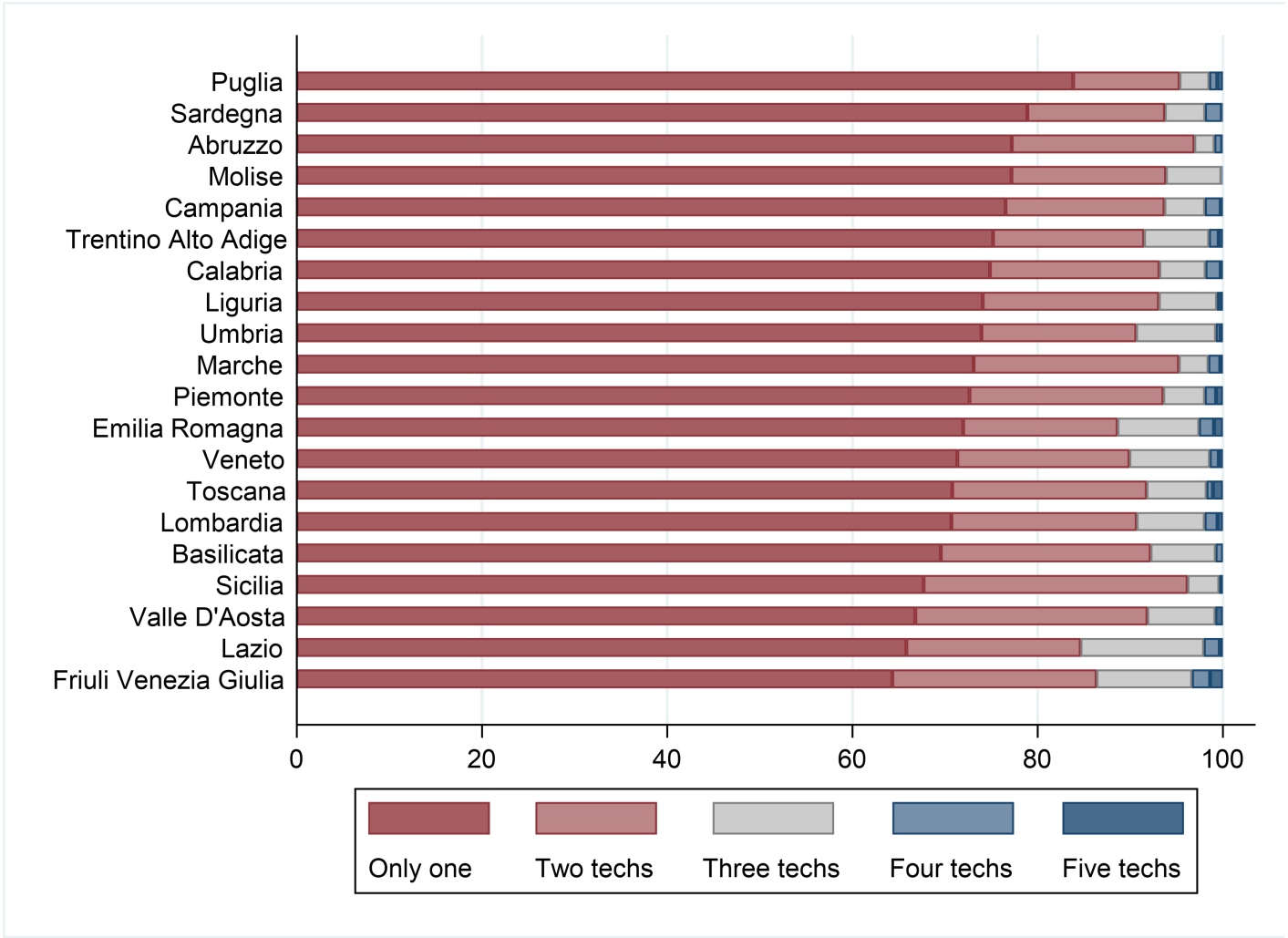
Share of firms investing in I4.0 by regions and sectors



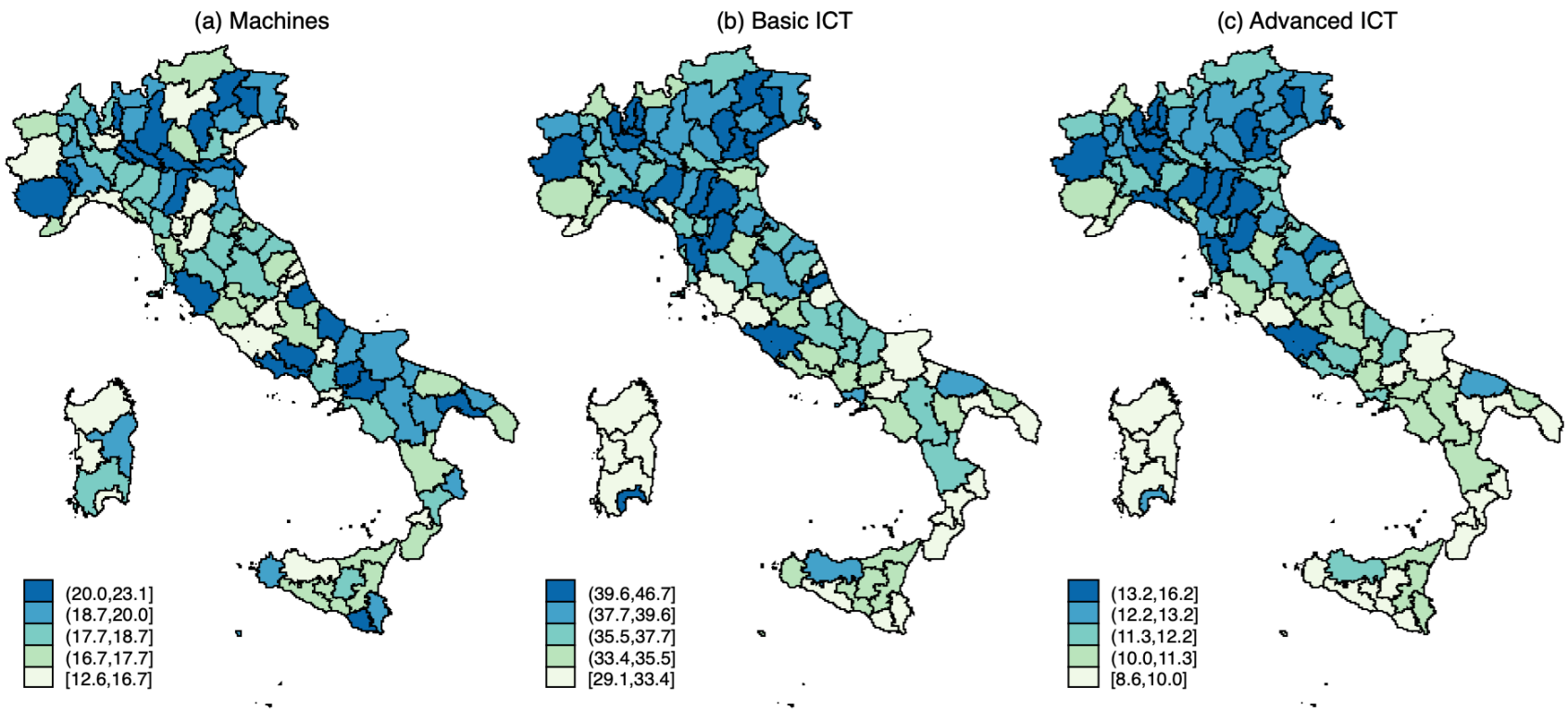


Fonte: Cirillo, V., Fanti, L., Mina, A., Ricci, A. (2021). Upgrading Italy's Industrial Capacity: Industry 4.0 across Regions and Sectors. SINAPPSI.

Quota di imprese che adottano I4.0 per numero di tecnologie

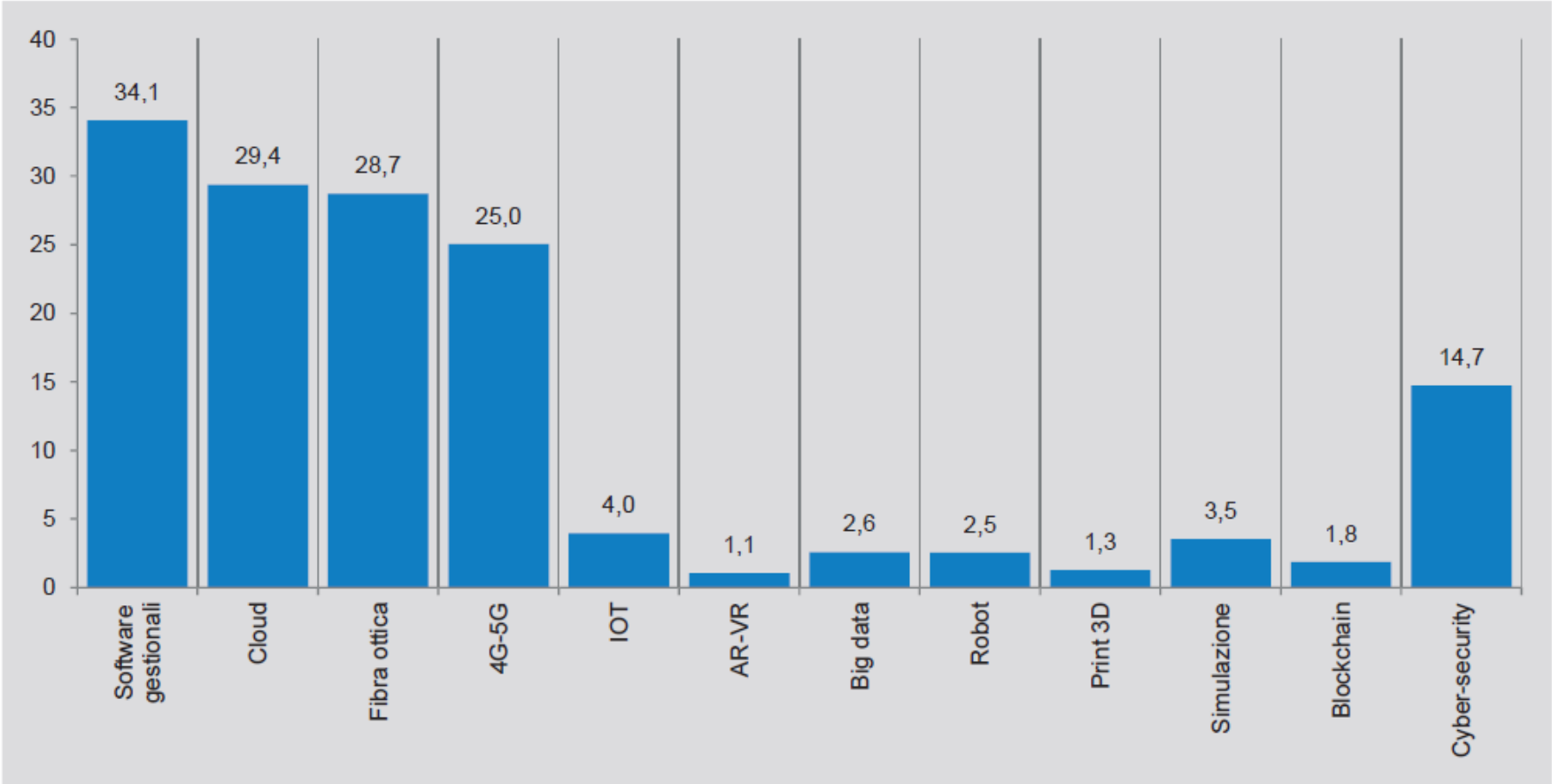


Share of employees by tools of work (RCFL-ICP)



Fonte: Cirillo, V., Prota, F., & Reljic, J. (2022). L'evoluzione recente del mercato del lavoro in Italia e in Puglia. Edizioni Radici Future.

The use of digital technologies in businesses in 2022

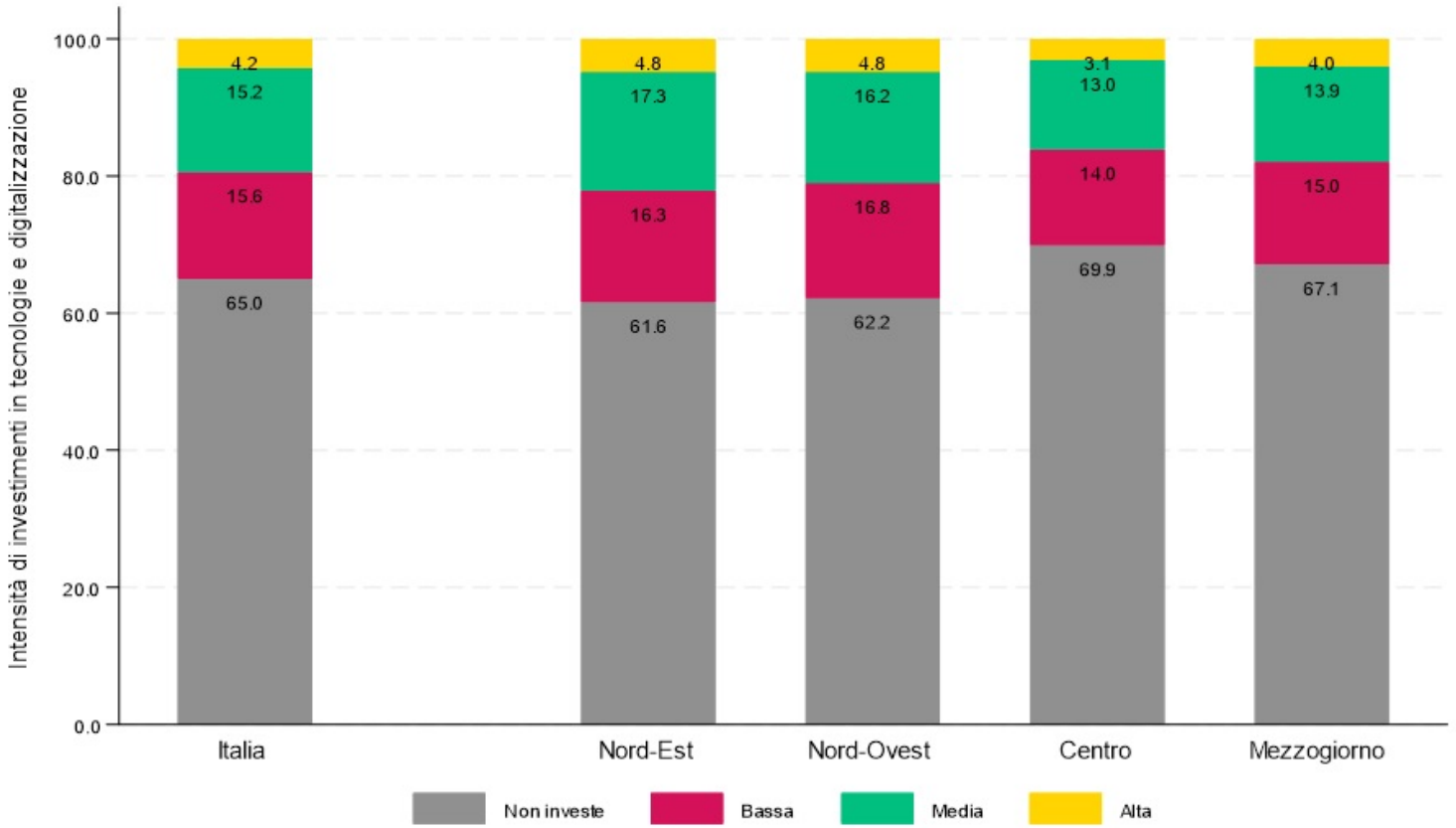


Fonte: Elaborazioni su dati Istat, Censimento permanente sulle imprese

- Results from the second multi-purpose census, covering the years 2021-2022, confirm a high degree of heterogeneity in the adoption of various technologies.

The use of digital technologies in businesses in 2022

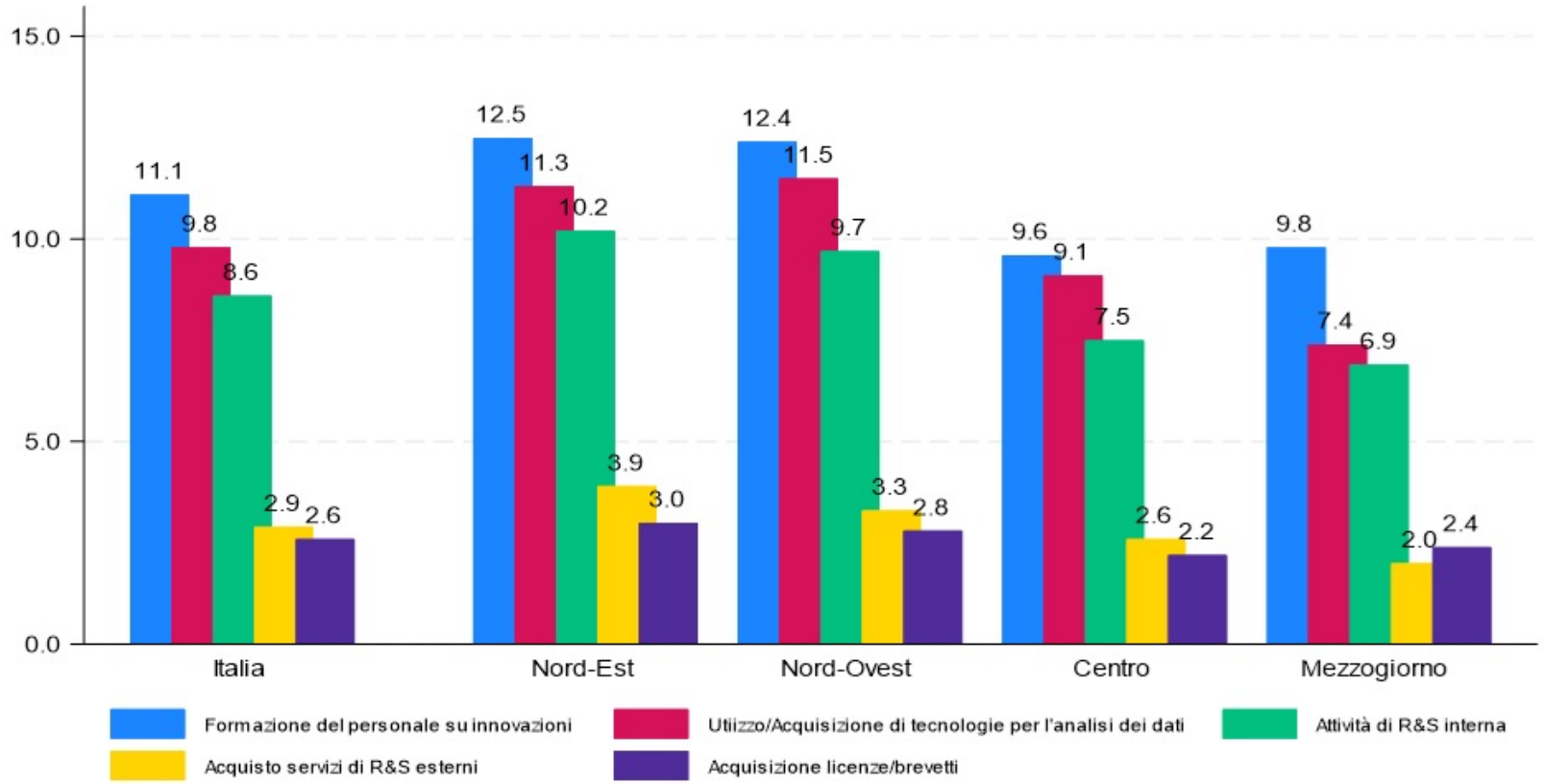
Figure: Intensità di investimento in tecnologie e digitalizzazione (2021-2022) per ripartizione territoriale



- Note: Il grafico mostra l'intensità di investimento in tecnologie e digitalizzazione da parte delle imprese con almeno 3 addetti nel biennio 2021-2022 per macro-ripartizione territoriale.
  Fonte: Cirillo, Divella, Gahn, Simone su Censimento Permanente delle Imprese 2022

The use of digital technologies in businesses in 2022

Figure: Attività svolte dalle imprese nell'ambito dei progetti di innovazione intrapresi nel biennio 2021-2022, ripartizione territoriale



- Note: percentuale di imprese con almeno 3 addetti, divise per ripartizione territoriale, che hanno svolto (internamente o attraverso un fornitore esterno) le attività nell'ambito dei progetti di innovazione intrapresi nel biennio 2021-2022
  Fonte: elaborazione degli autori su Censimento Permanente delle Imprese 2022-ISTAT

Businesses that use digital technologies, by digital technology area

- Interaction between three distinct groups of technologies:

  (i) "Infrastructural" enable access to Web services and the digital management of one or more business functions;

  (ii) "Application" (from IoT to Blockchain), allow businesses to achieve significant productivity gains through advanced automation and simulation processes; the adoption rate is lower compared to infrastructural technologies and is strongly influenced by sectoral and dimensional characteristics;

  (iii) "Cross-functional" (cybersecurity) perform essential functions to strengthen the digital infrastructure, specifically by reducing the risk of data loss caused by internal or external actions.

- Comparison of businesses' digital strategies around the pandemic crisis reveals complex dynamics:
  - Businesses leading in digital transition represent between 5 and 10 percent of the total – considering the universe of businesses with at least 3 employees;
  - The transition process is marked by necessary phases – such as infrastructure development and awareness of the need for cybersecurity investments – before measurable productivity advantages can be achieved;
  - Demand-side stimuli – particularly online demand – are encouraging even small businesses or those in less digitized sectors to invest in connectivity technologies and the adoption of digital production processes;

Drivers of adoption of digital and automation techs

- Cirillo, Fanti, Mina, Ricci (2023) The adoption of digital technologies: Investment, skills, work organisation. Structural Change and Economic Dynamics, Vol. 66, Sept. 2023, pp. 89-105

H1: *Firms with more skilled employees are more likely to invest in new digital technologies given the complementarity between workers' skills and technologies*.

H2: *The share of workers with 'on-the-job' training has a positive effect on the adoption of new digital technologies*.

H3: *The use of flexible staff arrangements has a negative effect on the adoption of new digital technologies*.

H4: *Second-level agreements have a positive effect on the adoption of new digital technologies*.

Drivers of adoption and diffusion of digital and automation techs

- Original database drawn from '**Rilevazione Longitudinale su Imprese e Lavoro' (RIL)** survey conducted by **INAPP** in 2015 and 2018 on a representative sample of Italian partnerships and limited liability firms.
- Each wave covers over 30000 firms in non-agricultural private sectors stratified by size, sector, geographical area and legal form.
- Panel component: sub-sample of firms (around 45%).

Data: the RIL-INAPP Survey

- The **V wave of RIL** includes a set of specific questions on the introduction of **I4.0 technologies** within the Italian firms.
  - "*In the period 2015-2017 did the firm invest in new technologies?*"
- Possibility of multiple answers: Internet of Things (IoT), Robotics, Big Data Analytics, Augmented Reality, Cybersecurity.
- Data collected after the '**National Enterprise Plan 4.0**': an incentive scheme implemented by the Italian government to lower firms' financial constraints and accelerate the diffusion of I4.0 technologies:
  - All firms were eligible and received the incentives if they invested.
- Final sample: panel of around 8000 firms (with at least 5 employees) for each year.

Econometric Strategy

- In order to analyse the role of skills, training and work organisation on digital techs adoption, we estimate the following equation:

$$Y_{i,t} = \alpha + \beta_1 E_{i,t-1} + \beta_2 T_{i,t-1} + \beta_3 FT_{i,t-1} + \beta_4 SB_{i,t-1} + \beta_5 X_{i,t-1} + u_{i,t} \quad (1)$$

with $t = [2015, 2018]$.

- $Y_{i,t}$ represents:
  - i) dichotomous variable ($I4.0$) indicating whether firm i invested in at least one I4.0 tech;
  - ii) a categorical variable ($NumberI4.0 \in \{0, 5\}$) depending on the number of I4.0 techs adopted.

Econometric Strategy

- Non linear regression models to estimate different specifications of eq. (1):
  - **Probit Model** to estimate average marginal effects of the probability of introducing at least one I4.0 tech;
  - **Zero Inflated Poisson Model** to estimate average marginal effects of the total number of I4.0 techs adopted.
- Both models may suffer from:
  - omitted variable bias $\Rightarrow$ wide set of controls minimising endogeneity;
  - reverse causality $\Rightarrow$ inclusion of controls as pre-determined controls (e.g. corporate governance or industrial relations).

Econometric Strategy

- We also implement a **two stage Heckman model** procedure conditioning the adoption choice on the likelihood that firms were investment-active, as follows:

$$Pr(I_{i,t-1}) = \alpha + \beta_1 E_{i,t-1} + \beta_2 T_{i,t-1} + \beta_3 FT_{i,t-1} + \beta_4 SB_{i,t-1} + \beta_5 X_{i,t-1} + \gamma Z_{i,t-1} + u_{i,t} \quad (2)$$

$$Y^*_{i,t} = \alpha + \beta_1 E_{i,t-1} + \beta_2 T_{i,t-1} + \beta_3 FT_{i,t-1} + \beta_4 SB_{i,t-1} + \beta_5 X_{i,t-1} + \lambda_i + \epsilon_{i,t} \quad (3)$$

- $Pr(I_{i,t-1})$ is the probability index (0 or 1) indicating whether firm i invested in 2015;
- As exclusion restriction we use a variable accounting for firms' bank loans demand (in 2015) due to cash or liquidity problems;
- $Y^*_{i,t}$ indicates $I4.0$ or $NumberI4.0$ and it is observed only if firm i invested in 2015. (i.e. $Pr(I_{i,t-1}) = 1$).

Main Results

Table: Marginal effects of the probability to invest in I4.0 and number of I4.0 technologies

	(1) At least one b/se	(2) Number of I4.0 b/se	(3) At least one b/se	(4) Number of I4.0 b/se
College workers	0.177028***	0.396379**	0.115041***	0.266226**
	(0.037)	(0.155)	(0.035)	(0.111)
Trained workers	0.043859***	0.087007***	0.060826***	0.003022
	(0.013)	(0.026)	(0.012)	(0.040)
Fixed-term workers	-0.063911*	0.020456	-0.004203	-0.022740
	(0.036)	(0.100)	(0.035)	(0.104)
Second lev. agreem.	0.036378**	0.117391***	0.037491***	0.066634
	(0.017)	(0.041)	(0.014)	(0.043)
Firm size	0.070322***	0.002281***	0.074574***	0.000298***
	(0.005)	(0.001)	(0.005)	(0.000)
Log (VA per worker)	0.009902**	0.034536***	0.012234***	0.028623**
	(0.005)	(0.009)	0.004	(0.013)
Old-age (>55)	-0.050792	-0.301616***	-0.063056**	-0.333603***
	(0.033)	(0.068)	(0.030)	(0.095)
Middle-age (35-55)	0.029385	-0.036414	-0.000807	-0.005286
	(0.029)	(0.057)	(0.028)	(0.088)
Family firm	-0.000216	-0.083669***	-0.022762*	-0.126162***
	(0.015)	(0.028)	(0.013)	(0.041)
High school	0.096306***	0.079446*	0.051784***	0.062981
	(0.021)	(0.047)	(0.019)	(0.063)
In a trade group	0.032560***	0.076495***	0.044883***	0.035137
	(0.012)	(0.025)	(0.011)	(0.036)

Main Results (I)

	(1) At least one b/se	(2) Number of I4.0 b/se	(3) At least one b/se	(4) Number of I4.0 b/se
Graduate manag.	0.029777*	0.108422***	0.012871	0.059479
	(0.018)	(0.039)	(0.016)	(0.048)
High-school manag.	0.009442	0.059701*	-0.004793	0.051265
	(0.015)	(0.035)	(0.014)	(0.041)
Female manag.	0.012188	-0.014869	0.023233	0.002512
	(0.017)	(0.033)	(0.015)	(0.045)
Product innovators	0.065874***	0.159434***	0.088955***	0.106009***
	(0.013)	(0.025)	(0.011)	(0.036)
Process innovators	0.081530***	0.186082***	0.123046***	0.060461*
	(0.013)	(0.025)	(0.012)	(0.036)
Firm age	0.000136	0.000540**	0.000233*	0.000924*
	(0.000)	(0.000)	(0.000)	(0.000)
FDI inv.	0.090194***	0.207316***	0.104813***	0.287045***
	(0.028)	(0.060)	(0.023)	(0.074)
Share of export	0.000168	0.000536	0.000246	0.001423*
	(0.000)	(0.000)	(0.000)	(0.001)
Sec. and reg. dum.	Yes	Yes	Yes	Yes
Observations	7746	7746	7675	7675
Non zero obs.		3719		
Censored obs			3413	3.413
Uncensored obs			4262	4262
Wald Chi2	996.03	714.49	1479.55	375.60
Prob > Chi2	0.0000	0.0000	0.0004	0.0000
Pseudo R^2	0.1051			
Sample sel. stat.:				
athrho			1,7084***	-0.4169
LR test (rho = 0):			0.4801	0.0535
chi2(1) =			12.66	60.66
Prob > Chi2	0.0000	0.0000	0.0004	0.0000

Main Results (II)

Table: Marginal effects of the probability to invest in I4.0 by firms' size and macrosector

	(1) At least one < 250 b/se	(2) At least one > 250 b/se	(3) At least one Manuf. b/se	(4) At least one Serv. b/se
College workers	0.156862***	0.254780**	0.271261***	0.157283***
	(0.030)	(0.120)	(0.082)	(0.046)
Trained workers	0.050749***	0.024989	0.037894*	0.038673*
	(0.012)	(0.050)	(0.020)	(0.021)
Fixed-term workers	-0.023647	-0.180278*	-0.013164	-0.036111
	(0.029)	(0.108)	(0.064)	(0.049)
Second lev. agreem.	0.029340*	-0.091568**	0.048062**	-0.008001
	(0.017)	(0.042)	(0.024)	(0.029)
Firm size (log)	0.080092***	0.112861***	0.087764***	0.061900***
	(0.005)	(0.022)	(0.009)	(0.008)
Log (VA per worker)	0.010587**	0.016044	0.009562	0.008513
	(0.004)	(0.011)	(0.007)	(0.007)
Old-age (>55)	-0.041770*	0.036595	0.011375	-0.078847
	(0.025)	(0.128)	(0.049)	(0.051)
Middle-age (35-55)	0.000515	-0.042711	0.043077	0.018206
	(0.021)	(0.118)	(0.045)	(0.043)
Family firm	0.005604	-0.012948	0.044743**	-0.053089**
	(0.015)	(0.034)	(0.022)	(0.022)
High school	0.107682***	0.042262	0.059836*	0.120764***
	(0.017)	(0.086)	(0.032)	(0.033)
In a trade group	0.039165***	0.058112	0.041175**	0.031277*
	(0.010)	(0.045)	(0.018)	(0.018)

Main Results (III)

	(1) At least one < 250 b/se	(2) At least one > 250 b/se	(3) At least one Manuf. b/se	(4) At least one Serv. b/se
Graduate manag.	0.039798**	-0.024698	0.034329	0.024055
	(0.016)	(0.075)	(0.025)	(0.030)
High-school manag.	0.014181	0.005985	0.031547	-0.007562
	(0.013)	(0.073)	(0.021)	(0.027)
Female manag.	0.006637	0.037783	-0.005873	0.030459
	(0.014)	(0.067)	(0.026)	(0.025)
Product innovators	0.068400***	-0.003449	0.038097**	0.100257***
	(0.011)	(0.044)	(0.019)	(0.020)
Process innovators	0.078312***	0.038322	0.101617***	0.034341
	(0.012)	(0.047)	(0.018)	(0.022)
Firm age	0.000139	0.000315	-0.000016	0.000364
	(0.000)	(0.000)	(0.000)	(0.000)
FDI inv.	0.059672**	0.066113	0.051836	0.103243*
	(0.030)	(0.044)	(0.036)	(0.053)
Share of export	0.000246	-0.001320*	-0.000137	0.000603
	(0.000)	(0.001)	(0.000)	(0.001)
Sec. and reg. dummies	Yes	Yes	Yes	Yes
Observations	9428	536	3533	2233
Wald Chi2	1212.91	105.02	519.69	345.66
Prob $>$ Chi2	0.0000	0.0000	0.0000	0.0000
Pseudo R^2	0.1086	0.1836	0.1219	0.0852

The diffusion of I4.0 techs and the main adoption drivers

- **Scattered adoption of I4.0 techs** among Italian firms;
- Vast majority of adopters opt for a **single-technology**, rather than an integrated (multiple technology) approach;
- Continuity with previous studies on ICTs, with **strong complementarities between skills and new digital technologies**;
- Both human capital measured by **education attainment levels** and **on-the-job training** are positively associated with the adoption of digital technologies;
- Weaker evidence points to the role of flexible work;
- **Decentralised bargaining** instead seems to favour new technologies adoption, albeit with strongly heterogeneous effects.

Digital technologies, firm performances and wages

- **Impact of I4.0 techs on productivity and wages**:

  Applying a policy evaluation framework, the following results:

  1. The adoption of I4.0 exerts a positive effect on both labour productivity and on average wages;
  2. The positive impact of I4.0 is driven by firms small in size and by those operating in manufacturing;
  3. Productivity gains higher than wage growth;
  4. The adoption of I4.0 techs contributes to reshape productivity distribution by widening the gap between low-productive and high-productive companies;

- Cirillo, V., Fanti, L., Mina, A., Ricci, A. (2023). New digital technologies and firm performance in the Italian economy. Industry and Innovation, 30(1), 159–188.

Motivation (digital techs, productivity, sales)

1. Investments in digital technologies are expected to have positive effects on firm performance (Syverson, 2011; Brynjolfsson and McAfee, 2014; Munch et al., 2018);
   - Improving business processes toward customized productions (Bartel, et al.,2007);
   - Automating routine tasks and reducing costs of interactions with suppliers and customers (Akerman et al., 2013);
   - Upgrading internal knowledge-base through patents in digital techs (Grinza et al., 2019);
2. Empirical evidence at the industry and firm levels is scant (lack of appropriate microdata);
3. Not univocally reflect the revolutionary expectations placed on these technologies (Acemoglu et al., 2014; DeStefano et al., 2018; Cette et al., 2017; Gal et al., 2019)
4. Links between adoption of digital technologies and productivity are complex.

Motivation (digital techs, productivity and wages)

1. Discrepancy between digitalization and effective productivity gains, "modern productivity paradox" (Acemoglu et al., 2014; Brynjolfsson et al., 2017), lack of:
   - Complementarity with firms' complex set of capabilities (Dosi et al, 2000; Winter, 2003), including managerial / organizational practices, adaptive routines, absorptive capacity (Cohen and Levithal, 1990), or financial structure and organization.
2. At an aggregate level, slowdown of labour productivity growth and a decoupling between productivity and wage growth (OECD, 2015; 2018; IMF, 2017);
3. Dauth et al. (2017) find different effects depending on workers' skills and tasks: positive effect on high-skilled workers, negative for lower and medium-skilled workers' employed in machine-operating occupations.

Research questions (RQs)

- Do firms investing in I4.0 realize some productivity gains and improve their performance?
- If so, are these gains redistributed to workers through wage growth?
  - Does the introduction of I4.0 techs differently affect labour productivity, average sales and wages by firm size, sector of activity and firm age?
- How do digital investments affect firms having heterogeneous performances in terms of labour productivity, wages and revenues?
- Can digital techs facilitate the convergence of low-productive/low-paying firms towards high-productive paths?

Data

- Merge between 2 main sources of data:
  1. **Rilevazione Imprese e Lavoro (RIL)** conducted by INAPP in 2010, 2015 and 2018 on a representative sample of partnerships and limited liability firms:
     - Each wave of the survey covers over 25000 firms operating in non-agricultural private sector;
     - A subsample of the included firms (around 40%) is followed over time, making the RIL dataset partially panel over the period under study;
     - The V wave of the RIL-INAPP survey included a new set of questions collecting information on the introduction of new digital technologies;
  2. **ORBIS archive** provided by Bureau Van Dijk for the period 2010-2018:
     - The ORBIS data offers comprehensive information on the balance sheets of almost all the Italian companies operating in the private sector;
     - The merged dataset contains yearly values of financial variables such as revenues, added value, net profits, book value of physical capital, total wage bill and raw-material expenditures.

Data

- The V wave of the RIL-INAPP survey includes a new set of questions collecting information on the introduction of **new digital technologies**:
  - In the section 'Innovation, Internationalization, Extension of markets', a specific question was added on investments in new technologies over the period 2015-2017: "In the period 2015-2017 did the firm invest in new technologies?"
  - Although multiple answers are allowed, we adopt a **dichotomous measure of Industry 4.0**: a variable that is equal to 1 if a firm has invested in at least one specific I4.0 tech over the period 2015-2017, 0 otherwise.
- The final longitudinal RIL-ORBIS sample consists of approximately 3000 firm-year observations over 2010-2018 (after excluding firms with less than 5 employees and firms with missing information for the key variables).
- Outcome variables: **labour productivity** (value added per employee), **sales** (average sales per employee) and **wages** (total labour cost per employee).

Empirical strategy

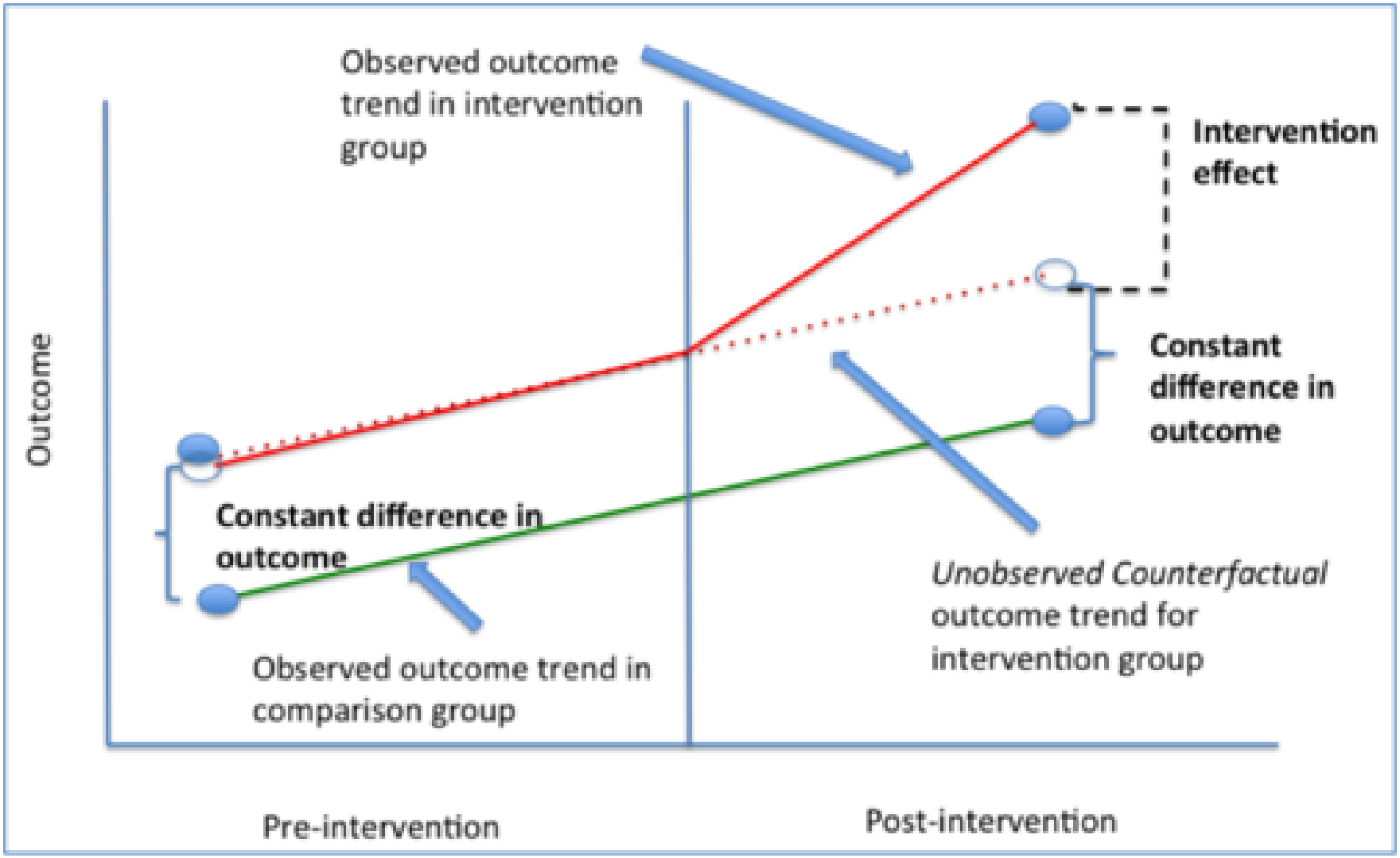
$$Y_{i,t} = \alpha + \beta_1 I4.0_i + \beta_2 t + \gamma M_{i,t} + \delta W_{i,t} + \lambda F_{i,t} + \epsilon_{i,t}$$

$$Y_{i,t} = \alpha + \beta_1 I4.0_i + \beta_2 t + \beta_3 I4.0_i \times t + \gamma M_{i,t} + \delta W_{i,t} + \lambda F_{i,t} + \mu_i + \epsilon_{i,t}$$

$$T = [2010, 2014/2015, 2018]$$

- $Y_{i,t}$ indicates alternatively log of labour productivity, average wages, average sales for each firm i at year t ;
- $I4.0_i$ is a dummy equal to 1 whether the firm has invested in at least one technology among Internet of things (IoT), Robotics, Big data analytic, Augmented reality and Cybersecurity introduced over 2015-2017, 0 otherwise;
- $M_{i,t}$ includes managerial and corporate governance characteristics;
- $W_{i,t}$ represents the workforce composition;
- $F_{i,t}$ is a rich set of firms' productive characteristics, geographical location and sectoral specialization;
- t is a time indicator;
- μ firm fixed-effects capturing time invariant unobserved heterogeneity;
- $\epsilon_{i,t}$ is the idiosyncratic error term (clustered standard error by firm);
- Pooled OLS and Fixed effects (FE);
- Heterogeneity by firm size, sector of activity and firm age.

Difference-in-Difference estimation, graphical explanation



Main Results

Table: Diff-in-diff labour productivity, wage and sales per employee

	Labour productivity		Average wage		Sales per employee	
	OLS	DIFF-FE	OLS	DIFF-FE	OLS	DIFF FE
Ind 4.0	0.058***		0.019*		0.041*	
	[0.019]		[0.012]		[0.027	
Ind 4.0*year 2018		0.051**		0.018*		0.048**
		[0.020]		[0.011]		[0.021]
Ind 4.0*year 2014		0.027		-0.009		0.014
		[0.019]		[0.011]		[0.018]
year 2018	-0.023	0.015	-0.009	0.052***	-0.02	-0.036*
	[0.016]	[0.017]	[0.010]	[0.010]	[0.023]	[0.020]
year 2014	-0.035***	-0.02	-0.015**	0.028***	-0.043***	-0.042***
	[0.011]	[0.015]	[0.007]	[0.009]	[0.014]	[0.015]
Management ch.	Yes	Yes	Yes	Yes	Yes	Yes
Workforce ch.	Yes	Yes	Yes	Yes	Yes	Yes
Firms ch.	Yes	Yes	Yes	Yes	Yes	Yes
Constant	9.853***	9.778***	10.048***	10.005***	10.528***	11.048***
	[0.088]	[0.189]	[0.064]	[0.130]	[0.131]	[0.243]
N of Obs	6971	6963	7251	7240	7244	7244
R2	0.378	0.105	0.455	0.183	0.421	0.104

Source: Longitudinal sample RIL-Orbis. Note: Managerial characteristics include level of education, age and gender of managers/entrepreneurs who run a firm, family ownership, occurrence of an external management; workforce characteristics controls for the composition by education, age, professional status, gender, contractual arrangements, citizenship; firms' characteristics include product innovation, process innovation, R&D, firms' age, foreign markets, foreign trade agreement, foreign direct investment, second level bargaining, membership to an employers' association. All regressions controls for 2-digit sectors of activity and nuts 2 regions fixed effects.

Results: Heterogeneity of effects by firm size (I)

Table: Diff-in-diff **labour productivity** by firm size

	Labour productivity			
	n of employees <50		n of employees >49	
	OLS	DIFF-FE	OLS	DIFF-FE
Ind 4.0	0.070***		0.038	
	[0.023		[0.033	
Ind 4.0*year 2018		0.066***		0.029
		[0.024		[0.035
Ind 4.0*year 2014		0.033		0.067
		[0.021		[0.047
year 2018	-0.016	0.015	-0.023	0.032
	[0.019	[0.02	[0.032	[0.031
year 2014	-0.031**	-0.006	-0.039*	-0.063
	[0.014	[0.016	[0.023	[0.045
other controls	Yes	Yes	Yes	Yes
constant	10.069***	10.110***	9.467***	9.722***
	[0.097	[0.184	[0.157	[0.328
Obs	4873	4873	2090	2090
R2	0.32	0.07	0.49	0.138

Source: longitudinal sample RIL-Orbis. Note: controls include managerial ancd coprporate governance characteristics, workforce composition, firms' productive characteristics, sectors of activity, nuts 2 regions, industrial relations

Results: Heterogeneity of effects by firm size (II)

Table: Diff-in-diff **wage** by firm size

	Average wage			
	n of employees <50		n of employees >49	
	OLS	DIFF-FE	OLS	DIFF-FE
Ind 4.0	0.031**		-0.01	
	[0.014]		[0.020]	
Ind 4.0*year 2018		0.023*		-0.004
		[0.014]		[0.018
Ind 4.0*year 2014		-0.011		0.014
		[0.013		[0.019
year 2018	-0.019	0.044***	0.027	0.075***
	[0.012	[0.012	[0.021	[0.018
year 2014	-0.01	0.034***	-0.012	0.005
	[0.009	[0.01	[0.012	[0.017
other controls	Yes	Yes	Yes	Yes
constant	10.118***	10.006***	10.047***	10.163***
	[0.071	[0.134	[0.125	[0.175
Obs	5105	5105	2135	2135
R2	0.378	0.126	0.613	0.276

Source: longitudinal sample RIL-Orbis. Note: controls include managerial and corporate governance characteristics, workforce composition, firms' productive characteristics, sectors of activity, nuts 2 regions, industrial relations

Results: Heterogeneity of effects by firm size (III)

Table: Diff-in-diff **sales** by firm size

	n of employees <50		n of employees >49	
	OLS	DIFF-FE	OLS	DIFF-FE
Ind 4.0	0.069**		0.001	
	[0.032]		[0.054]	
Ind 4.0*year 2018		0.067***		0.006
		[0.025]		[0.035]
Ind 4.0*year 2014		0.021		0.002
		[0.020]		[0.034]
2018	-0.018	-0.039*	0	-0.012
	[0.026]	[0.020]	[0.051	[0.037]
2014	-0.046***	-0.043***	-0.019	-0.022
	[0.017]	[0.016]	[0.027]	[0.028]
management ch	Yes	Yes	Yes	Yes
workforce ch	Yes	Yes	Yes	Yes
firms ch	Yes	Yes	Yes	Yes
constant	10.826***	11.277***	10.059***	9.995***
	[0.141]	[0.231]	[0.258]	[0.443]
Obs	5106	5106	2138	2138
R2	0.376	0.053	0.522	0.129

Source: longitudinal sample RIL-Orbis. Note: Managerial characteristics include level of education, age and gender of managers/entrepreneurs who run a firm, family ownership, occurrence of an external management; workforce characteristics controls for the composition by education, age, professional status, gender, contractual arrangements, citizenship; firms' characteristics include product innovation, process innovation, R&D, firms' age, foreign markets, foreign trade agreement, foreign direct investment, second level bargaining, membership to an employers' association. All regressions controls for 2-digit sectors of activity and nuts 2 regions fixed effects.

Results: Heterogeneity of effects by macrosector (I)

Table: Diff-in-diff **labour productivity** by macrosector

	Labour productivity			
	Manufacturing and Constructions		Services	
	OLS	DIFF-FE	OLS	DIFF-FE
Ind 4.0	0.062***		0.054	
	[0.022		[0.033	
Ind 4.0*year 2018		0.047*		0.037
		[0.025		[0.032
Ind 4.0*year 2014		0.039		0.002
		[0.024		[0.029
year 2018	-0.002	0.044**	-0.056**	-0.024
	[0.019	[0.021	[0.029	[0.029
year 2014	-0.01	0.001	-0.081***	-0.045**
	[0.014	[0.018	[0.02	[0.022
other controls	Yes	Yes	Yes	Yes
constant	9.962***	10.048***	9.647***	8.855***
	[0.099	[0.268	[0.126	[0.277
Obs	4470	4470	2493	2493
R2	0.328	-0.601	0.442	0.243

Source: longitudinal sample RIL[Orbis. Note: controls include managerial ancd coprporate governance characteristics, workforce composition, firms' productive characteristics, sectors of activity, nuts 2 regions, industrial relations

Results: Heterogeneity of effects by macrosector (II)

Table: Diff-in-diff **wage** by macrosector

	Average wages			
	Manufacturing and Constructions		Services	
	OLS	DIFF-FE	OLS	DIFF-FE
Ind 4.0	0.026**		0.01	
	[0.013		[0.023	
Ind 4.0*year 2018		0.02		0.009
		[0.013		[0.022
Ind 4.0*year 2014		-0.006		-0.011
		[0.013		[0.02
year 2018	0.004	0.069***	-0.03	0.025
	[0.012	[0.012	[0.019	[0.019
year 2014	0.007	0.048***	-0.047***	-0.006
	[0.009	[0.011	[0.013	[0.016
other controls	Yes	Yes	Yes	Yes
constant	10.178***	10.206***	9.905***	9.641***
	[0.067	[0.139	[0.094	[0.176
Obs	4592	4592	2648	2648
R2	0.397	0.149	0.505	0.277

Source: longitudinal sample RIL[Orbis. Note: controls include managerial ancd co-prporate governance characteristics, workforce composition, firms' productive characteristics, sectors of activity, nuts 2 regions, industrial relations

Results: Heterogeneity of effects by macrosector (III)

Table: Diff-in-diff **sales** by macrosector

	Manufacturing and construction		Services	
	OLS	DIFF-FE	OLS	DIFF-FE
Ind 4.0	0.059*		0.007	
	[0.031]		[0.050]	
Ind 4.0*year 2018		0.056**		0.036
		[0.028]		[0.031]
Ind 4.0*year 2014		0.013		0.022
		[0.024]		[0.027]
2018.anno	-0.015	-0.018	-0.02	-0.056*
	[0.029]	[0.025]	[0.039]	[0.030]
2014.anno	-0.017	-0.014	-0.084***	-0.081***
	[0.017]	[0.019]	[0.024]	[0.022]
management ch	Yes	Yes	Yes	Yes
workforce ch	Yes	Yes	Yes	Yes
firms ch	Yes	Yes	Yes	Yes
constant	10.598***	11.307***	10.323***	10.695***
	[0.146]	[0.311]	[0.319]	[0.288]
Obs	4590	4590	2654	2654
R2	0.335	0.057	0.498	0.255

Source: longitudinal sample RIL-Orbis. Note: Managerial characteristics include level of education, age and gender of managers/entrepreneurs who run a firm, family ownership, occurrence of an external management; workforce characteristics controls for the composition by education, age, professional status, gender, contractual arrangements, citizenship; firms' characteristics include product innovation, process innovation, R&D, firms' age, foreign markets, foreign trade agreement, foreign direct investment, second level bargaining, membership to an employers' association. All regressions controls for 2-digit sectors of activity and nuts 2 regions fixed effects.

Heterogeneity of effects along distributions (IV)

Table: Diff-in-diff quantile fixed effect estimates. **Labour Productivity**

Diff-in-diff quantile fixed effect estimates. Labour Productivity.

	q10	q50	q90
Ind 4.0	-0.009	0.003	-0.014
	[0.019	[0.013	[0.023
Ind 4.0*year 2018	0.047*	0.038**	0.061*
	[0.026	[0.018	[0.032
Ind 4.0*year 2014	0.038	0.015	0.038
	[0.026	[0.018	[0.031
Year 2018	0.026	0.021	0.016
	[0.019	[0.013	[0.023
Year 2014	0.010	-0.005	-0.046**
	[0.018	[0.013	[0.022
Management characteristics	Yes	Yes	Yes
Workforce characteristics	Yes	Yes	Yes
Firm characteristics	Yes	Yes	Yes
Constant	9.616***	9.904***	10.255***
	[0.058	[0.04	[0.07
Obs	6963	6963	6963

Note: Managerial characteristics include level of education, age and gender of managers/entrepreneurs who run a firm, family ownership, occurrence of an external management; workforce characteristics controls for the composition by education, age, professional status, gender, contractual arrangements, citizenship; firms' characteristics include product innovation, process innovation, R&D, firms' age, foreign markets, foreign trade agreement, foreign direct investment, second level bargaining, membership to an employers' association. All regressions controls for 2-digit sectors of activity and nuts 2 regions fixed effects. Clustered standard errors in parentheses: * statistical significance at 10%, ** at 5%, *** at 1%. Source: our elaborations on RIL-Orbis merged sample

Heterogeneity of effects along distributions (V)

Table: Diff-in-diff quantile fixed effect estimates. **Average Wage**

Diff-in-diff quantile fixed effect estimates. Average wage.

	q10	q50	q90
Ind 4.0	0.002	-0.010	-0.014
	[0.012	[0.006	[0.013
Ind 4.0*year 2018	0.007	0.028***	0.054***
	[0.017	[0.008	[0.018
Ind 4.0*year 2014	0.004	0.003	-0.001
	[0.017	[0.008	[0.017
Year 2018	0.079***	0.049***	0.031**
	[0.012	[0.006	[0.013
Year 2014	0.035***	0.024***	0.018
	[0.012	[0.006	[0.012
Management characteristics	Yes	Yes	Yes
Workforce characteristics	Yes	Yes	Yes
Firm characteristics	Yes	Yes	Yes
Constant	9.830***	9.973***	10.109***
	[0.037	[0.018	[0.039
Obs	7240	7240	7240

Note: Managerial characteristics include level of education, age and gender of managers/entrepreneurs who run a firm, family ownership, occurrence of an external management; workforce characteristics controls for the composition by education, age, professional status, gender, contractual arrangements, citizenship; firms' characteristics include product innovation, process innovation, R&D, firms' age, foreign markets, foreign trade agreement, foreign direct investment, second level bargaining, membership to an employers' association. All regressions controls for 2-digit sectors of activity and nuts 2 regions fixed effects. Clustered standard errors in parentheses: * statistical significance at 10%, ** at 5%, *** at 1%. Source: our elaborations on RIL-Orbis merged sample.

Summarizing

- The adoption of digital technologies exerts a positive effect on labour productivity, average sales and wages;
- The positive impact of I4.0 appears to be driven by **small and medium-size firms**: different time span of realization of productivity gains, in large companies the adoption of new technologies may require long adjustments of existing production processes;
- Sales increase more in medium-small and small companies with respect to the largest ones: I4.0 investments encompass a large set of technologies such as 3D printing or cybersecurity offering cost advantages without necessarily relying on economies of scale (Weller et al., 2015), hence enabling also SMEs to exploit such technologies for competitive purposes;
- Strong complementarities are required between digital technologies and organizational capabilities, managerial skills; R&D and intangible investments, human capital and ICT-related skills: all these factors might require long time span to be fully in place enabling more **mature firms** to properly capture productivity gains form digital technologies.

Summarizing

- The economic size of the effect on productivity is approximately twice as large as the effect on average wages.

  –> This may be an indication of **poor redistribution** of gains from digital technology adoption, in line with the dominant pattern of wage-productivity decoupling detected in several countries over the last decade (OECD, 2018)

- The adoption of I4.0 techs contribute to reshape productivity distribution by widening the gap between low-productive and high-productive companies;

  (i) productivity gains detected at the top of the distribution are transferred to wages in high-paying firms defining a virtuous process going from digital transformation of companies to productivity and wages;

  (ii) the redistributive effect of I4.0 techs does not occur among mid and low-productive/paying companies where a sizeable decoupling of wages from productivity arises.

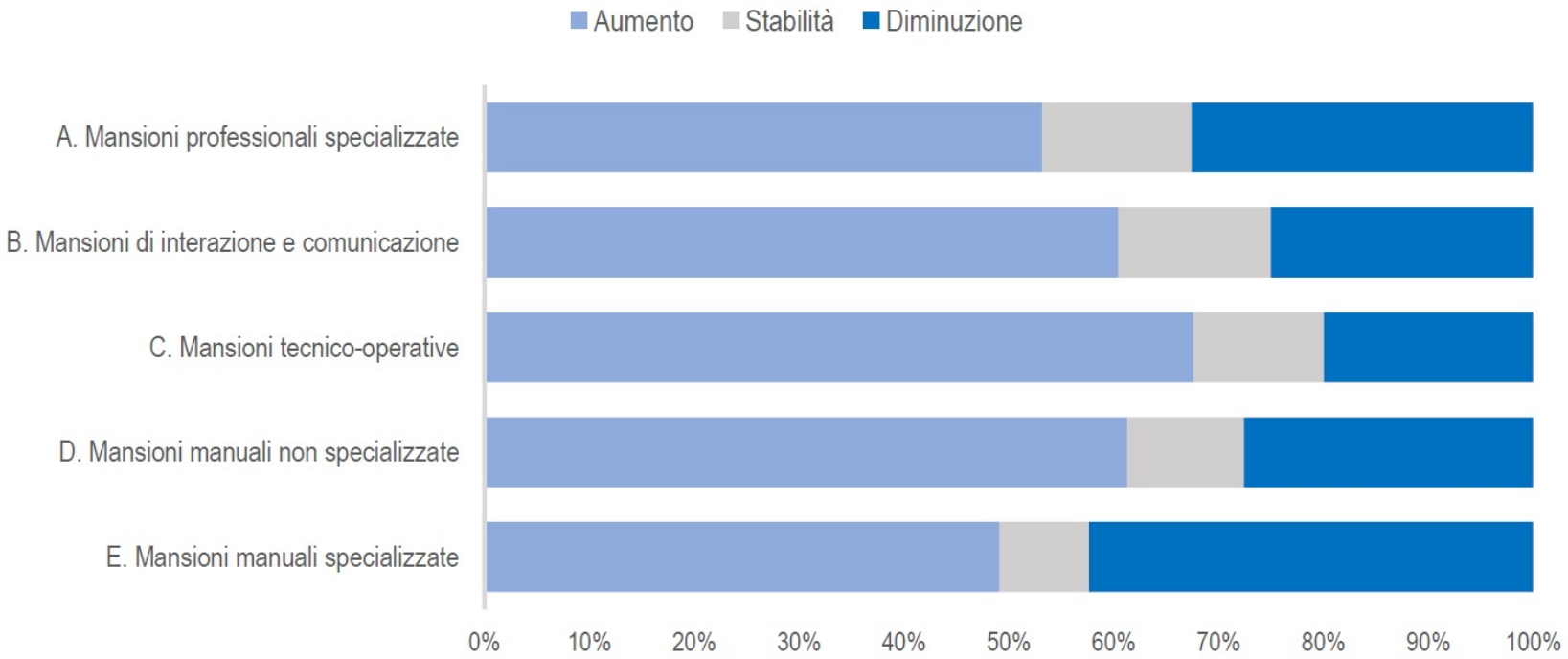
  Unlike other economies (Schwellnus et al., 2018), in Italy the decoupling of wages from labor productivity seems to be related to laggard firms, whereas in (few) frontier-firms wages and productivity go almost hand in hand, according to our evidence, and are both positively associated to digitalization occurring at the workplace level.

Further development

- **Impacts of I4.0 investments on hiring rate, separation rate and training**
- Cirillo V., Mina A., Ricci A. (2022), Digital Technologies, Labor market flows and Training: Evidence from Italian employer-employees data, Roma, Inapp, WP 79

I4.0 and employment

FIGURA 10. IMPRESE CON ALMENO 10 ADDETTI IN BASE ALLA VARIAZIONE DELLA QUOTA DI OCCUPATI PREVISTA NEL TRIENNIO 2019-2021 IN CINQUE MANSIONI LAVORATIVE. Valori percentuali



- Companies that have invested in digital technologies in 2016-2018 or plan to invest in 2019-2021: expectations on employment change

Data

Merge between 3 main sources of data:

1. **Comunicazioni Obbligatorie (COB-SISCO)**, an administrative archive provided by the Italian Ministry of Labor and Social Policies recording from 2009 each job relationship that started or ended (for firing, dismissal, retirement, or transformation of the contractual arrangement within the same firm) for all individuals working in Italy as an employee or through apprenticeship, temporary agency work arrangements, and parasubordinate collaborations;
2. **Archivio Statistico delle Imprese Attive (ASIA-Imprese)**, the archives of Italian firms provided by National Institute of Statistic (Istituto Nazionale di Statistica - ISTAT) containing information on Italian firms
3. **Rilevazione Imprese e Lavoro (RIL)** conducted by INAPP in 2010, 2015 and 2018 on a representative sample ofpartnerships and limited liability firms;

Job flows

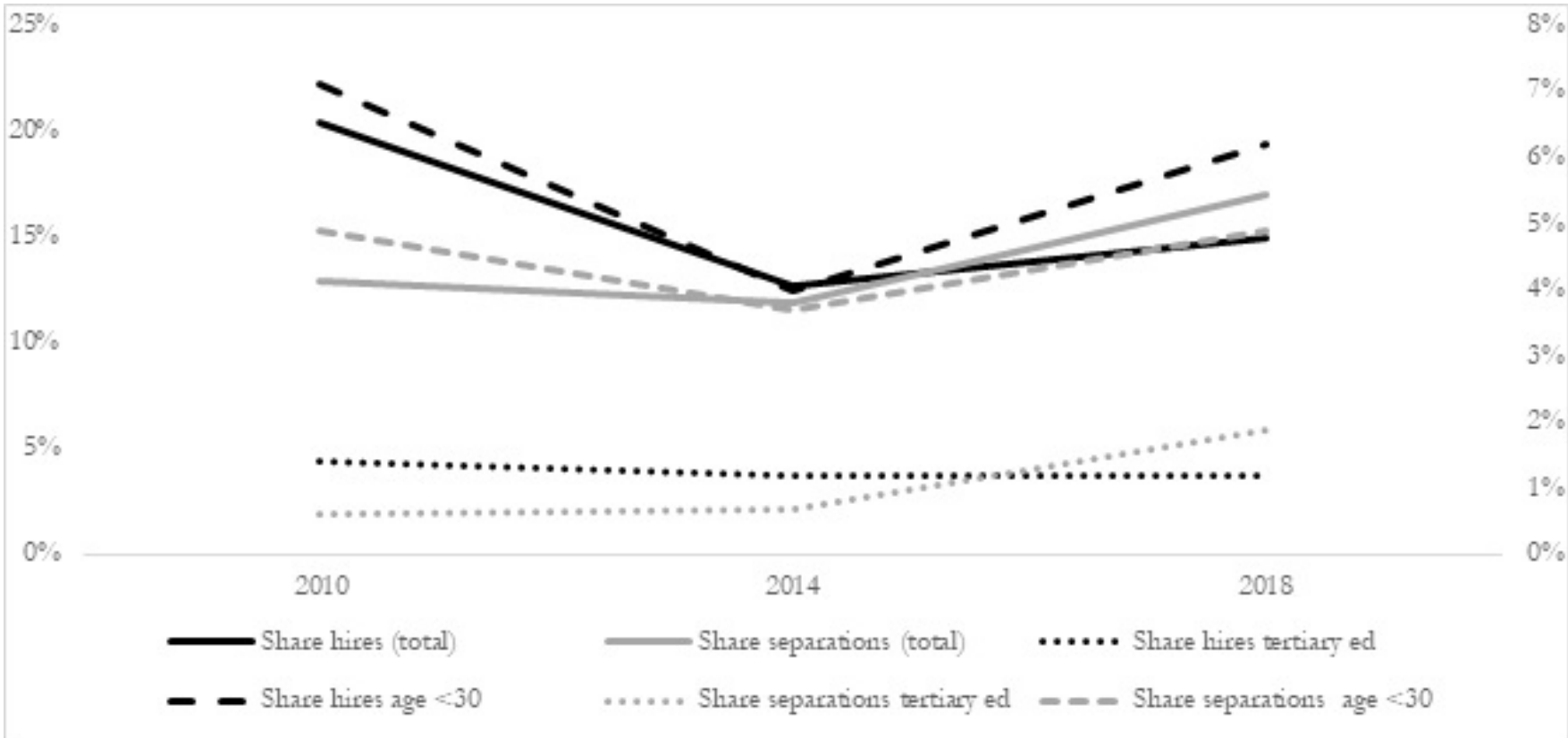
–> Linking the three different sources of information through firms' fiscal codes allows us to create a unique **longitudinal employer-employee linked database**:

–> information at the individual level stemming from COB-SISCO has been collapsed at the **firm level for each year**, high-quality information on the total number of hirings and separations for each firm by age group, educational titles and type of contract stemming from administrative archives.

–> having a clear picture not only of aggregate changes in employment, but also of the gross flows providing a much richer picture of the dynamics underlying net job creation figures (Criscuolo et al., 2014)

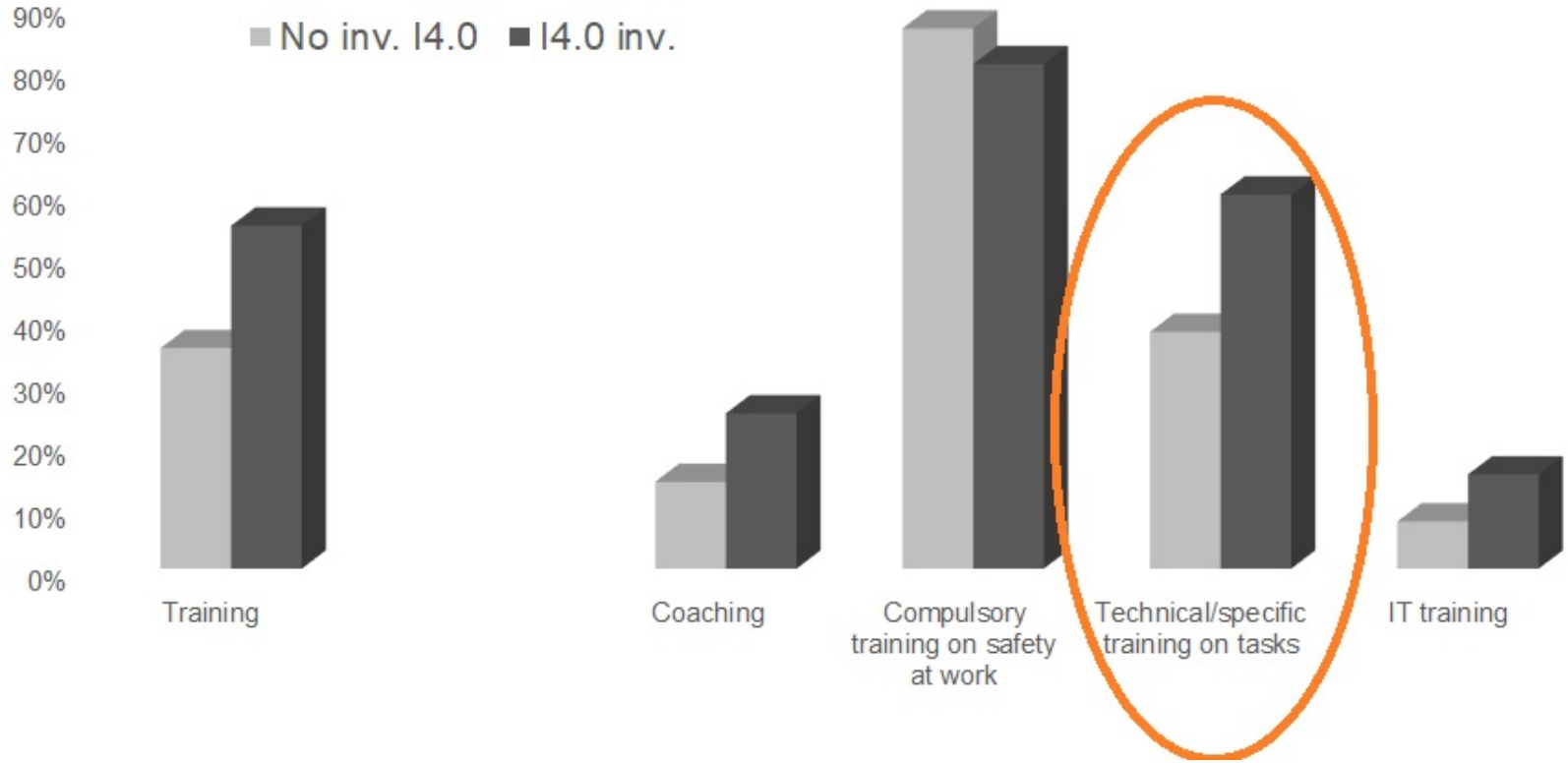
–> for example lower employment may be due to lower creation or higher destruction of jobs, which is crucial information when designing policies to tackle (eventual) employment effects of digital technologies.

Hiring and separation rates over time by educational title and age



Source: our calculations on longitudinal component of RIL-COB-ASIA merged sample. Note: sampling weights applied.
*share of employees hired/separated over total firm employment and by specific educational and age groups

Share of firms investing in training, share of trained workers and average costs for training over time



Source: our calculations on longitudinal component of RIL-COB-ASIA merged sample. Note: sampling weights applied. Share of firms investing in training and share of trained workers on the left axis; training costs on the right axis.

Empirical strategy

$$Y_{i,t} = \alpha + \beta_1 I4.0_i + \beta_2 t + \gamma M_{i,t} + \delta W_{i,t} + \lambda F_{i,t} + \epsilon_{i,t}$$

$$Y_{i,t} = \alpha + \beta_1 I4.0_i + \beta_2 t + \beta_3 I4.0_i \times t + \gamma M_{i,t} + \delta W_{i,t} + \lambda F_{i,t} + \mu_i + \epsilon_{i,t}$$

$$T = [2010, 2014, 2018]$$

- $Y_{i,t}$ indicates alternatively share of new hired, the share of separated over firm total employment and workplace training proxied by adoption of training, share of trained employees, the (log of) training costs per employees;
- $I4.0_i$ is a dummy equal to 1 whether the firm has invested in at least one technology among Internet of things (IoT), Robotics, Big data analytic, Augmented reality and Cybersecurity introduced over 2015-2017, 0 otherwise;
- $M_{i,t}$ includes managerial and corporate governance characteristics;
- $W_{i,t}$ represents the workforce composition;
- $F_{i,t}$ is a rich set of firms' productive characteristics, geographical location and sectoral specialization;
- t is a time indicator;
- μ firm fixed-effects capturing time invariant unobserved heterogeneity;
- $\epsilon_{i,t}$ is the idiosyncratic error term (clustered standard error by firm);
- Pooled OLS and Fixed effects (FE).

Robustness checks: Diff-in-diff Propensity score matching

- As robustness check for controlling self-selection of companies into treatment, we test effect of Industry 4.0 technologies on job flows by adopting a two-step procedure:

1. **First step**: estimating propensity score matching (PSM) enabling to control for sample selection into the decision of I4.0 investment [2015-2017] by adjusting for "observable" variables (nearest neighbor matching with replacement);

2. **Second step**: using this "restricted" control group to estimate the counterfactual effects of the I4.0 investment on our three outcomes through a Diff-in-Diff approach.

Main estimates - Hiring rate

Table: Pooled OLS estimates. **Hiring rate**

	Workers over total employment	Share of graduated workers	Share workers aged<30
Digital Tech	0.0101*	0.0024*	0.0049*
	[0.005]	[0.002]	[0.003
year 2018	-0.0255***	-0,0022	-0,0033
	[0.007]	[0.001]	[0.003]
year 2014	-0.0392***	-0,0022	-0.0107***
	[0.005	[0.002	[0.003
vacancy	0.0254***	0,0028	0.0095***
	[0.005	[0.002	[0.003
lwage pc	-0.0168***	-0,0031	-0,0046
	[0.005	[0.002	[0.003
managment characteristics	Yes	Yes	Yes
workforce chacacteristics	Yes	Yes	Yes
firms characteristics	Yes	Yes	Yes
constant	0.3435***	0.0377**	0.1429***
	[0.057]	[0.019]	[0.031]
Obs	11251	11251	11251
R2	0,222	0,127	0,188

Source: our calculations on RIL-COB-ASIA merged sample. Other controls include: managerial characteristics (education, age and gender), family ownership and the presence of external managers; workforce composition (education, professions, age, female, contractual arrangements); firms productive characteristics such as nace sectors, nuts 2 regions, international markets, second level bargaining, multinationals, vacancy. Clustered robust standar errors (at firm level) in parantheses. Statistical significance: *** at 1%, ** at 5% and * at 10%

Table: Diff-in-diff fixed effects estimates. **Hiring rate**

	Workers over total employment	Share of graduated workers	Share workers aged<30
Digital Tech* year 2018	0.0179***	0.0041*	0.0084**
	[0.006]	[0.002]	[0.004]
Digital Tech*year 2014	0,0125	0,0016	0.0076*
	[0.008]	[0.003]	[0.004]
year 2018	-0.0268***	-0,0024	-0.0080**
	[0.007	[0.002	[0.004
year 2014	-0.0459***	-0,003	-0.0164***
	[0.006	[0.002	[0.003
vacancy	0.0280***	0,0006	0.0139***
	[0.006	[0.002	[0.003
lwage pc	-0.0213***	-0.0035**	-0.0070***
	[0.005	[0.001	[0.003
Managment characteristics	Yes	Yes	Yes
Workforce chacacteristics	Yes	Yes	Yes
Firms' characteristics	Yes	Yes	Yes
Costant	0.3777***	0.0491***	0.1344***
	[0.058]	[0.016]	[0.030]
Obs	10703	10703	10703
R2	0,394	0,259	0,331

Source: our calculations on RIL-COB-ASIA merged sample. Other controls include: managerial characteristics (education, age and gender), family ownership and the presence of external managers; workforce composition (education, professions, age, female, contractual arrangements); firms productive characteristics such as nace sectors, nuts 2 regions, international markets, second level bargaining, multinationals, vacancy. Clustered robust standar errors (at firm level) in parantheses. Statistical significance: *** at 1%, ** at 5% and * at 10%

Main estimates - Separation rate

Table: Pooled OLS estimates. **Separation rate**

	Workers over total employment	Share of graduated workers	Share workers aged<30
Digital Tech	-0.0154**	0,0007	-0,0009
	[0.007]	[0.002]	[0.004]
year 2018	0.0320***	0.0035*	0,0017
	[0.006]	[0.002]	[0.003]
year 2014	-0.0073*	0,0008	-0.0072***
	[0.004]	[0.001]	[0.002]
vacancy	0.0222***	0,0017	0.0081***
	[0.005]	[0.002]	[0.003]
lwage pc	0.0161***	-0,0004	0,0024
	[0.005]	[0.002]	[0.003]
managment characteristics	Yes	Yes	Yes
workforce chacacteristics	Yes	Yes	Yes
firms characteristics	Yes	Yes	Yes
constant	-0,0344	0,0078	0.0477*
	[0.061]	[0.020]	[0.028]
Obs	11251	11251	11251
R2	0,164	0,093	0,149

Source: our calculations on RIL-COB-ASIA merged sample. Other controls include: managerial characteristics (education, age and gender), family ownership and the presence of external managers; workforce composition (education, professions, age, female, contractual arrangements); firms productive characteristics such as nace sectors, nuts 2 regions, international markets, second level bargaining, multinationals, vacancy. Clustered robust standard errors (at firm level) in parantheses. Statistical significance: *** at 1%, ** at 5% and * at 10%

Table: Diff-in-diff fixed effects estimates. **Separation rate**

	Workers over total employment	Share of graduated workers	Share workers aged<30
Digital Tech* year 2018	-0.0152**	0,002	-0,0005
	[0.007	[0.003	[0.005
Digital Tech*year 2014	-0,0104	-0,0021	-0,0026
	[0.008	[0.003	[0.004
year 2018	0.0299***	0.0046**	0,0004
	[0.006	[0.002	[0.005
year 2014	-0,0042	0,0021	-0.0072**
	[0.006	[0.002	[0.003
vacancy	0.0215***	0,0006	0.0087**
	[0.005	[0.002	[0.004
lwage pc	0.0192***	0,0023	0,0031
	[0.005	[0.002	[0.002
managment characteristics	Yes	Yes	Yes
workforce chacacteristics	Yes	Yes	Yes
firms characteristics	Yes	Yes	Yes
constant	-0,0397	-0,0029	0,036
	[0.058	[0.017	[0.028
Obs	10703	10703	10703
R2	0,347	0,251	0,313

Source: our calculations on RIL-COB-ASIA merged sample. Other controls include: managerial characteristics (education, age and gender), family ownership and the presence of external managers; workforce composition (education, professions, age, female, contractual arrangements); firms productive characteristics such as nace sectors, nuts 2 regions, international markets, second level bargaining, multinationals, vacancy. Clustered robust standar errors (at firm level) in parantheses. Statistical significance: *** at 1%, ** at 5% and * at 10%

Main estimates - Workplace training

Table: Pooled OLS estimates. **Workplace training**

	training investment	share of trained	training costs per employee
Digital Tech	0.0744***	0.0489***	0.4762***
	[0.015]	[0.013]	[0.085]
year 2018	0.1332***	0.1610***	0.5919***
	[0.012]	[0.010]	[0.065]
year 2014	0.1070***	0.1161***	0.5837***
	[0.010]	[0.008]	[0.053]
vacancy	0.1075***	0.0627***	0.6817***
	[0.013	[0.011	[0.075
lwage pc	0.0184***	0.0218***	0.1648***
	[0.007]	[0.006]	[0.042]
managment characteristics	Yes	Yes	Yes
workforce chacacteristics	Yes	Yes	Yes
firms characteristics	Yes	Yes	Yes
constant	0.2459***	0,0395	0,1397
	[0.073]	[0.064]	[0.434]
Obs	11251	11251	10214
R2	0,203	0,148	0,193

Source: our calculations on RIL-COB-ASIA merged sample. Other controls include: managerial characteristics (education, age and gender), family ownership and the presence of external managers; workforce composition (education, professions, age, female, contractual arrangements); firms productive characteristics such as nace sectors, nuts 2 regions, international markets, second level bargaining, multinationals, vacancy. Clustered robust standar errors (at firm level) in parantheses. Statistical significance: *** at 1%, ** at 5% and * at 10%

Table: Diff-in-diff fixed effects estimates. **Workplace training**

	Training investment	share of trained	Training costs per employee
Digital Tech* year 2018	0.0517***	0.0333**	0.2918***
	[0.019	[0.016	[0.109
Digital Tech*year 2014	0.0371*	0,0255	0,0999
	[0.02	[0.017	[0.11
year 2018	0.1574***	0.1749***	0.7508***
	[0.014	[0.012	[0.076
year 2014	0.0951***	0.1059***	0.5381***
	[0.014	[0.011	[0.072
vacancy	0.0468***	0.0281**	0.3223***
	[0.016	[0.014	[0.093
lwage pc	0,0117	0.0169*	0.1101*
	[0.009	[0.009	[0.06
managment characteristics	Yes	Yes	Yes
workforce chacacteristics	Yes	Yes	Yes
firms characteristics	Yes	Yes	Yes
constant	0.3927***	0,1151	0,9167
	[0.1	[0.095	[0.644
Obs	10699	10699	9361
R2	0,396	0,359	0,408

Source: our calculations on RIL-COB-ASIA merged sample. Other controls include: managerial characteristics (education, age and gender), family ownership and the presence of external managers; workforce composition (education, professions, age, female, contractual arrangements); firms productive characteristics such as nace sectors, nuts 2 regions, international markets, second level bargaining, multinationals, vacancy. Clustered robust standar errors (at firm level) in parantheses. Statistical significance: *** at 1%, ** at 5% and * at 10%

Propensity score matching

Table: Diff-in-diff Fixed effects estimates with propensity score matching. **Hiring rate**

	Workers over total employment	Share of graduated workers	Share workers aged<30
I4.0* year 2018	0.018**	0.004*	0.008*
	[0.008]	[0.002]	[0.005]
I4.0*year 2014	0,013	0,002	0,008
	[0.008]	[0.003]	[0.005]
year 2018	-0.027***	-0,002	-0.008*
	[0.007]	[0.002]	[0.005]
year 2014	-0.046***	-0.003*	-0.016***
	[0.006]	[0.002]	[0.004]
Management characteristics	Yes	Yes	Yes
Workforce characteristics	Yes	Yes	Yes
Firms' characteristics	Yes	Yes	Yes
constant	0.379***	0.049***	0.134***
	[0.048	[0.015	[0.026
Obs	10707	10707	10707
R2	0,394	0,259	0,331

Source: our calculations on RIL-COB-ASIA merged sample. Other controls include: managerial characteristics (education, age and gender), family ownership and the presence of external managers; workforce composition (education, professions, age, female, contractual arrangements); firms productive characteristics such as nace sectors, nuts 2 regions, international markets, second level bargaining, multinationals, vacancy. Clustered robust standard errors (at firm level) in parentheses. Statistical significance: *** at 1%, ** at 5% and * at 10%

Table: Diff-in-diff Fixed effects estimates with propensity score matching. **Separation rate**

	Workers over total employment	Share of graduated workers	Share workers aged<30
I4.0* year 2018	-0.016*	0,002	-0,001
	[0.008	[0.002	[0.005
I4.0*year 2014	-0,011	-0,002	-0,003
	[0.008	[0.002	[0.004
year 2018	0.030***	0.005***	0,000
	[0.007	[0.002	[0.004
year 2014	-0,004	0,002	-0.007**
	[0.006	[0.002	[0.004
Management characteristics	Yes	Yes	Yes
Workforce characteristics	Yes	Yes	Yes
Firms' characteristics	Yes	Yes	Yes
other controls	Yes	Yes	Yes
constant	-0,04	-0,003	0,036
	[0.049	[0.015	[0.024
Obs	10707	10707	10707
R2	0,347	0,251	0,313

Source: our calculations on RIL-COB-ASIA merged sample. Other controls include: managerial characteristics (education, age and gender), family ownership and the presence of external managers; workforce composition (education, professions, age, female, contractual arrangements); firms productive characteristics such as nace sectors, nuts 2 regions, international markets, second level bargaining, multinationals, vacancy. Clustered robust standard errors (at firm level) in parentheses. Statistical significance: *** at 1%, ** at 5% and * at 10%

Table: Diff-in-diff Fixed effects estimates with propensity score matching. **Workplace training**

	training investment	share of trained	training costs per employee
I4.0* year 2018	0.052***	0.033**	0.289***
	[0.019]	[0.016]	[0.109]
I4.0*year 2014	0.037*	0,026	0,096
	[0.020]	[0.017]	[0.110]
year 2018	0.157***	0.175***	0.752***
	[0.014]	[0.012]	[0.076]
year 2014	0.095***	0.106***	0.540***
	[0.014]	[0.011]	[0.073]
Managment characteristics	Yes	Yes	Yes
Workforce chacacteristics	Yes	Yes	Yes
Firms' characteristics	Yes	Yes	Yes
constant	0.393***	0,115	0,915
	[0.100]	[0.095]	[0.644]
Obs	10699	10699	9359
R2	0,396	0,359	0,408

Source: our calculations on RIL-COB-ASIA merged sample. Other controls include: managerial characteristics (education, age and gender), family ownership and the presence of external managers; workforce composition (education, professions, age, female, contractual arrangements); firms productive characteristics such as nace sectors, nuts 2 regions, international markets, second level bargaining, multinationals, vacancy. Clustered robust standar errors (at firm level) in parantheses. Statistical significance: *** at 1%, ** at 5% and * at 10%

Exploring tech heterogeneities...

- Compared to general results, we detect that:

  –> cybersecurity, IoT and robotics are associated with higher hiring rate for graduates,
  –> whereas no significant effects emerge for separations, except for cybersecurity which is negatively associated to firm level separation rate;

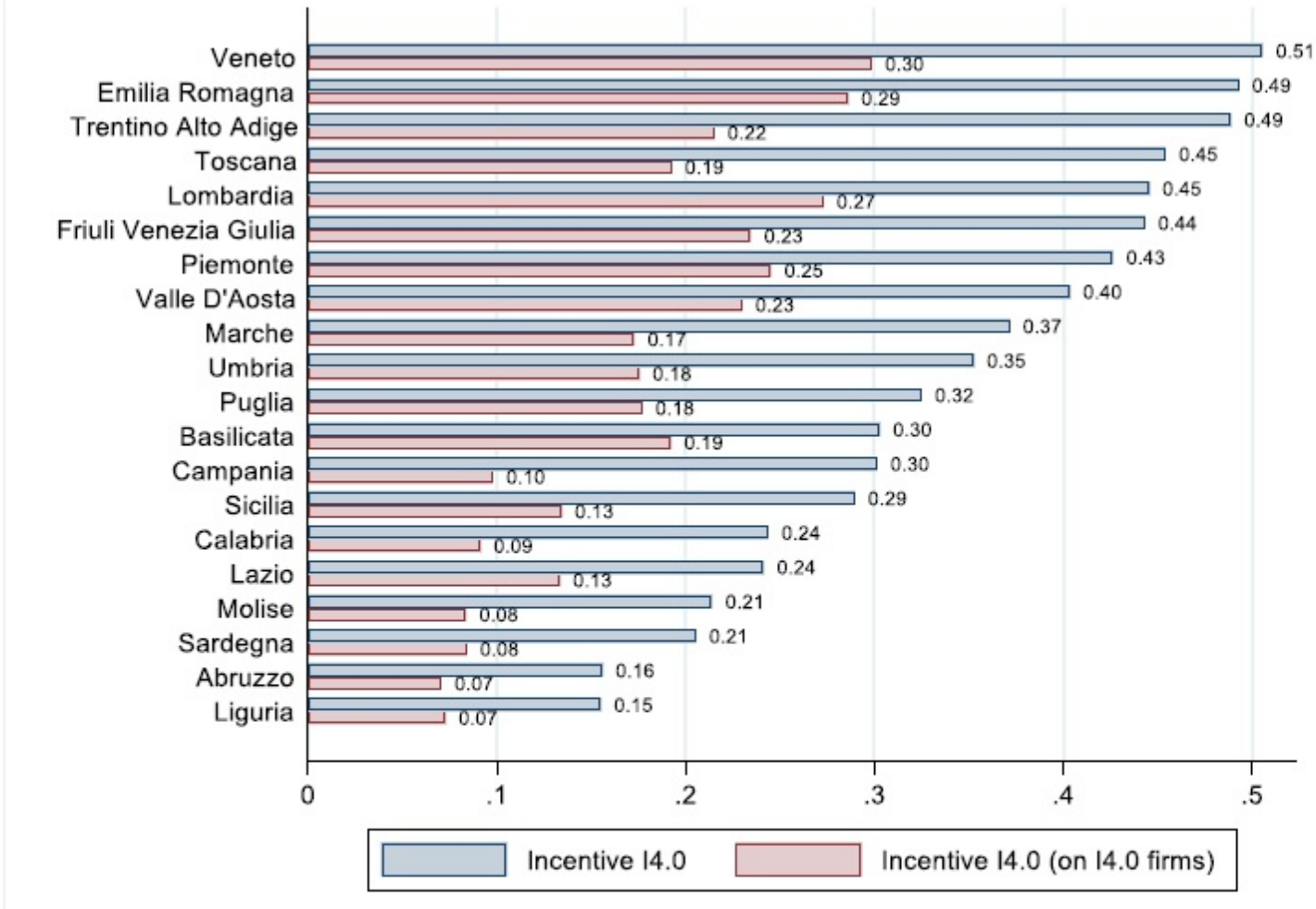
- **Our evidence discards, so far, a labour-displacing effects of I4.0 technologies on jobs, conversely, they appear to be associated to job creation at least for young and graduated workers**;
- Further research is needed to explore which kind of workers are more likely to be affected by the digital transformation
- This is in line with the vision in Zysman and Kenney (2018) –> processess can never be totally 'automated' and remains a domain of human creativity and initiative (Fareri and Solinas, 2021).

Industry 4.0 and Work Organization

- The relationship between I4.0 investments and work organization: a qualitative research approach
  1. The Fondazione Sabattini FIOM-CGIL research project ('Il lavoro operaio digitalizzato' il Mulino);
  2. Case studies of Automation in Services funded by JRC-European Commission Seville, realized in collaboration with SSSA and UNIMORE

- Cirillo, Rinaldini, Staccioli, Virgillito (2023) Trade unions responses to Industry 4.0 in the Italian Motor Valley: Old and new dualistic tendencies. PSL Quarterly Review;
- Cirillo, V., Rinaldini, M., Staccioli, J., Virgillito, M. E. (2021). Technology vs. workers: the case of Italy's Industry 4.0 factories. Structural Change and Economic Dynamics, 56, 166-183.

Imprese che beneficiano delle agevolazioni I4.0 (2017)



*Since the question is exclusively addressed to firms that have declared to realize general investments in 2017, we compute the incidence of I4.0 incentives (incentives related to the Plan I4.0) on two subpopulations: (i) firms realizing general investments; (ii) firms introducing at least one I4.0 techs – IoT, Cybersecurity, Augmented Reality, Big Data Analytics, Robotics.

Source: Authors' elaborations on RIL 2018 data

- I4.0 (Piano Calenda) policy incentive scheme, 'neutral' measure not redressing pre-existing gaps in the distribution of technological capabilities among Italian regions

I sussidi I4.0 hanno modificato le scelte di investimento delle imprese?

Table 2. Distribution of firms by investment choices in absence of I4.0 incentive and regions (%)

Regions	made the investment anyway, for the same amount	made the investment anyway, for a smaller amount	not have made the investment
Lombardia	64.03	23.98	11.99
Veneto	59.88	30.43	9.69
Umbria	59.28	32.99	7.72
Piemonte	57.66	31.99	10.35
Abruzzo	56.21	39.62	4.17
Emilia-Romagna	55.42	33.23	11.35
Toscana	55.19	25.87	18.94
Friuli-Venezia Giulia	54.46	33.49	12.05
Campania	52.33	37.7	9.97
Lazio	52.07	36.04	11.89
Trentino-Alto Adige	51.58	29.95	18.47
Puglia	51.17	26.24	22.59
Marche	50.21	41.62	8.17
Sardegna	48.64	36.85	14.51
Valle D'Aosta*	48.38	37.64	13.98
Liguria	48.21	40.86	10.93
Molise*	46.73	37.14	16.13
Calabria*	41.15	37.22	21.63
Basilicata*	37.24	50.35	12.4
Sicilia	35.11	42.52	22.37
Total	**57.4**	**30.31**	**12.3**

*Low reliability due to low number of observations.
Source: Authors' elaborations on RIL 2018 data

PNRR, transizione digitale e Mezzogiorno

- Transizione 4.0: principali iniziative trasversali del Piano Nazionale di Ripresa e Resilienza, linea di investimento M1C2-1.1, 13,38 miliardi di euro (a cui si aggiungono 5,08 miliardi del Fondo complementare)

- Sostenere investimenti privati in diversi ambiti:

  → beni materiali 4.0; beni immateriali 4.0; investimenti standard in beni immateriali; attività di ricerca, sviluppo e innovazione per favorire la transizione verde, digitale e del design; e attività di formazione legate alle tecnologie per il trattamento dei big data, l'analisi dei dati, l'interfaccia uomo-macchina, l'internet delle cose e la sicurezza informatica;

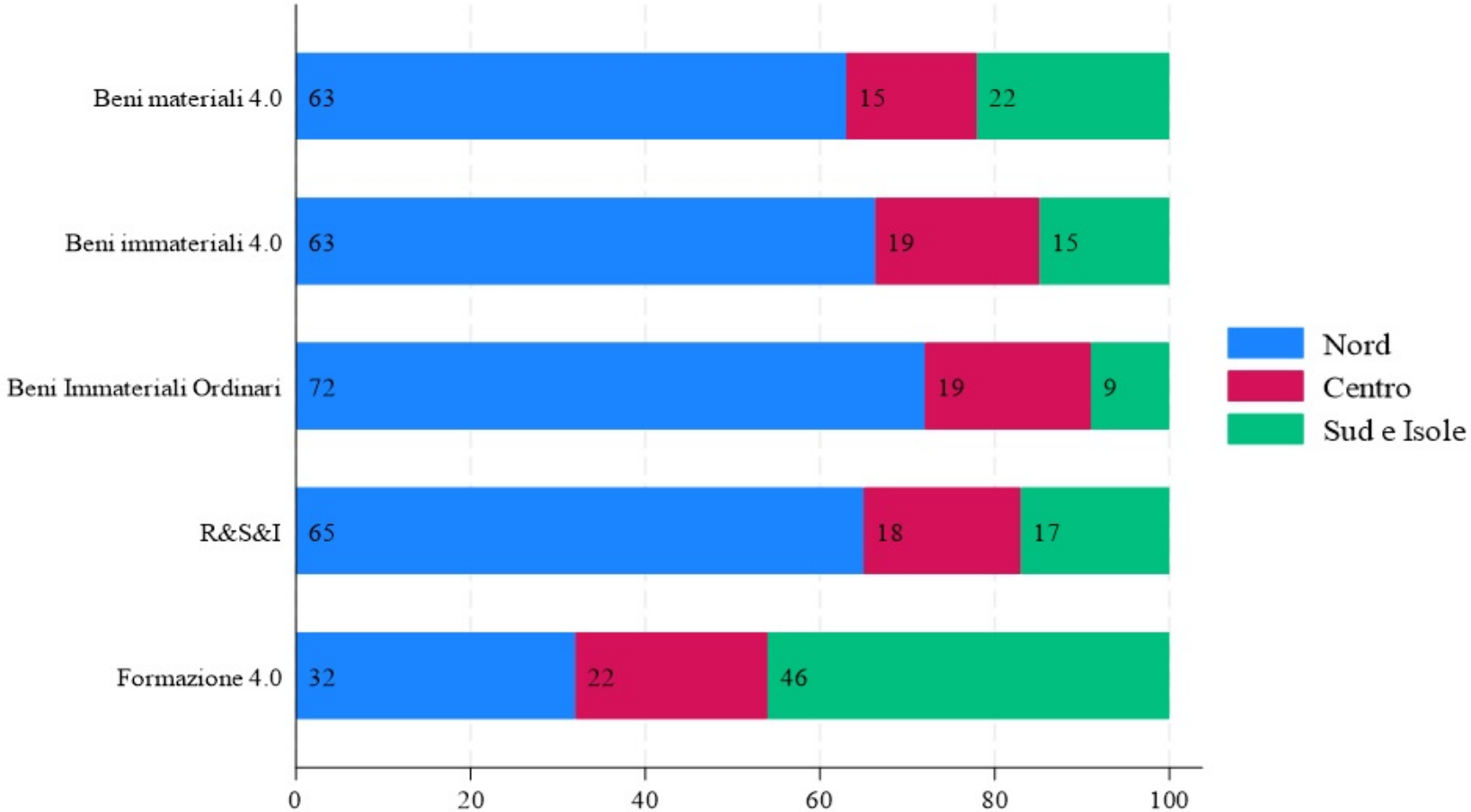
- Investimenti finanzianti attraverso crediti di imposta a favore delle imprese di tutti i settori che ne fanno richiesta

  → **approccio orizzontale di politica industriale, non vi è una selezione da parte del policy maker dei settori considerati di interesse strategico**

  → approccio diretto "tecnologicamente neutrale", le imprese utilizzano sovvenzioni ma selezionano la propria tecnologia preferita

  → misure territorialmente non neutre, amplificano asimmetrie territoriali della struttura produttiva italiana (Viesti, 2024)

Distribuzione territoriale degli incentivi 'I4.0' (PNRR)



Fonte: dati Corte dei Conti, Rapporto 2023 sul coordinamento della finanza pubblica, in Svimez (2024)

- Rapporto annuale Svimez (2024): più alta concentrazione dei crediti maturati nel Centro-Nord soprattutto con riferimento ai beni materiali 4.0, crediti che rappresentano la componente di maggior rilievo in termini finanziari di Transizione 4.0
- L'unica eccezione è rappresentata dai crediti di imposta per formazione 4.0 che, con una quota del 46%, sono stati maggiormente utilizzati dalle imprese meridionali rispetto alle altre ripartizioni del Paese.

Conclusioni

- I4.0 policy support scheme introduced in Italy was successful in lowering the financial barriers to adoption faced by firms, but it was **not sufficient to eliminate the divides in productive capacities** found across geographical areas;
- Sectoral and geographic agglomerations of adopters are associated with **strong innovation activities** (not only infrastructure);
- Importance of complementary targeted as opposed to 'neutral' innovation policies.

Grazie

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