Upgrading Italy's Industrial Capacity: Industry 4.0 across Regions and Sectors

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How are Industry 4.0 investments distributed across Italian regions and sectors? Which are the main drivers of diffusion? To address these questions, in this study we exploit rich firm survey data on the adoption of the new digital technologies and examine their adoption patterns. On the one hand, we produce novel insights into the drivers of structural change in the Italian economy, and on the other, we provide evidence on the technological upgrading of Italy's production capacity that is relevant for policy. The results of econometric tests on region-sector pairs indicate that corporate governance characteristics, innovation patterns and type of industrial relations are significant predictors of the uneven regional and sectoral distribution of Industry 4.0 investments.

Come sono distribuiti gli investimenti di Industria 4.0 nelle regioni e nei settori italiani? Quali sono i principali driver di diffusione? Al fine di rispondere a tali domande, in questo lavoro utilizziamo i dati di una ricca survey somministrata alle imprese italiane sull'adozione delle nuove tecnologie digitali ed esaminiamo i loro modelli di adozione. Lo studio esplora quali siano le principali caratteristiche del tessuto produttivo italiano che si associano al cambiamento tecnologico nell'economia italiana, fornendo evidenza empirica utile al policymaker. I risultati delle analisi econometriche condotte a livello settore-regione indicano che le caratteristiche della governance aziendale, i modelli di innovazione e il tipo di relazioni industriali sono predittori significativi della disomogenea distribuzione regionale e settoriale degli investimenti in Industria 4.0.

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Introduction

After displaying a marked slowdown in output and productivity growth since the mid-1990s, Italy was one of the countries worst hit by the 2008 crisis. In the recovery process, it was lagging behind comparable Eurozone economies even before the damage caused by the pandemic. Net of well-known macroeconomic factors, specific challenges have contributed to this economic outlook, including a fragmented productive system characterised by a very high share of small firms, a pronounced focus on traditional sectors relative to high-tech sectors, and a weak – and weakening – propensity to invest. The implications for the innovation capacity of the economy are deep and far-reaching. First of all, expenditures on research and development activities, and corresponding patent yields, are low by international standards; secondly, risk-aversion and the absence of specialist investors are associated with steep financial constraints and credit rationing for young firms with growth potential; and finally, underinvestment in human capital limits not only the development of innovation, but also the absorption of new scientific and technological knowledge (Bugamelli *et al.* 2012; Dosi *et al.* 2019; Bugamelli *et al.* 2020).

When we consider sources of productivity growth from which other economies derived long-term benefits, Italy was slow in adapting to the ICT revolution. Indeed, despite some indications of progress over the last few years, Italian firms have generally been less digitalised than their EU competitors according to both national (Istat 2017, 2018; MISE 2018) and international sources (European Commission 2018). Against this backdrop, and in the context of increased international competition, the new wave of enabling technologies that go under the Industry 4.0 paradigm is generating new competitive challenges as well as new opportunities for growth (Martinelli *et al.* 2021)[1]. Industry 4.0 results from the convergence of a number of correlated technologies, including advanced automation with high AI content and strong reliance on big data, internet of things, 3D printing and the cloud, which should constitute the backbone of the 'smart' factory of the future (Kagermann *et al.* 2013).

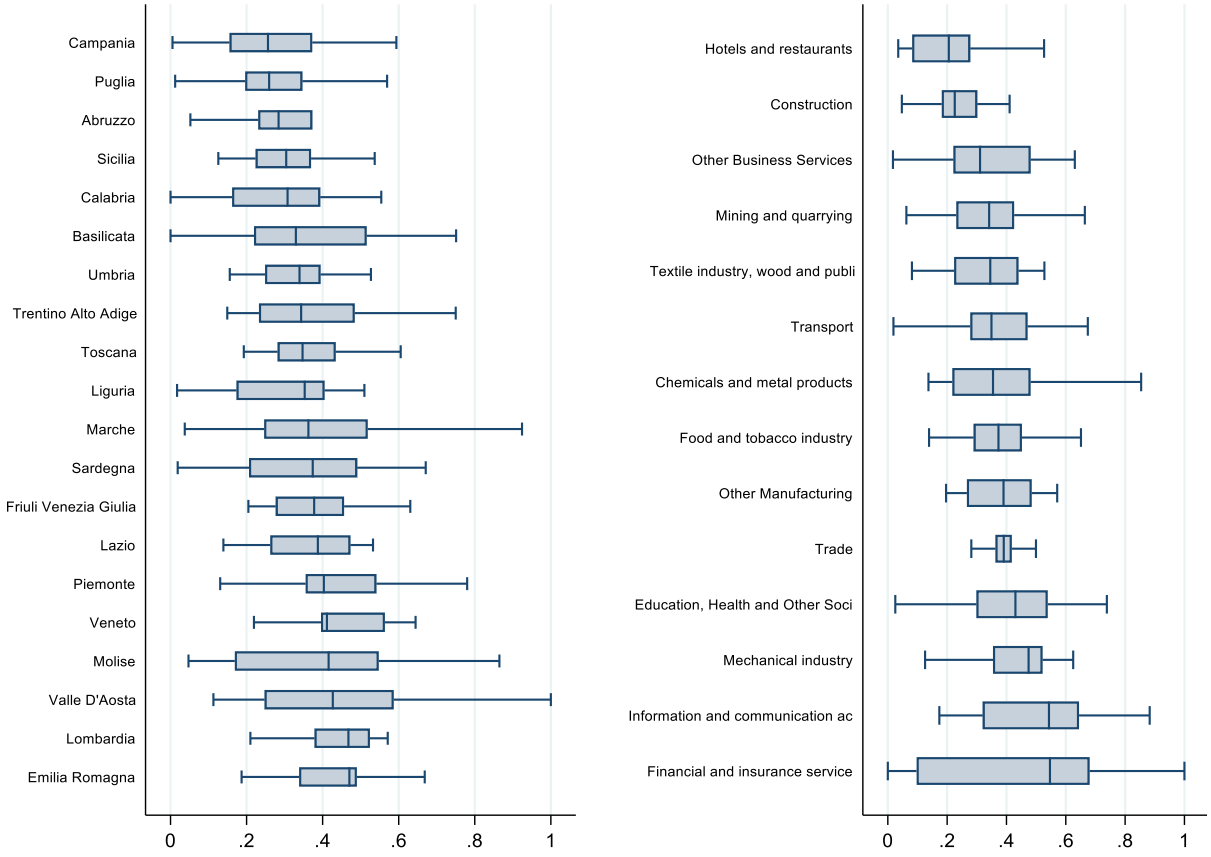
Given their potential, these technologies have attracted great interest among policy-makers and several incentive schemes have been introduced to foster their diffusion in an attempt to upgrade the productive infrastructure of national economies. Unsurprisingly, diffusion rates have been uneven across firms, and heavily dependent on adopters characteristics (Graetz and Michaels 2018; Gal *et al.* 2019; Cirillo *et al.* 2020a). The emergent firm-level evidence seems to indicate that the adoption of these new technologies generates positive performance outcomes (Acemoglu *et al.* 2020; Domini *et al.* 2021; Koch *et al.* 2021, Cirillo *et al.* 2021), thus validating the policy interest towards this particular group of technologies. Naturally, different economic contexts provide different opportunities for investment, and in a context as diverse as the Italian economy, it is essential to examine the regional and sectoral patterns of diffusion in order to gain insights into the drivers of structural change. To achieve this objective, we exploit rich firm survey data on the adoption of the new digital technologies and provide 1) detailed descriptive analyses of diffusion across regions and sectors and 2) new econometric evidence of the drivers of diffusion where the units of analysis are region-sector pairs.

1. The diffusion of I4.0 investments: a descriptive overview

The empirical analysis presented in the following Sections is based on the *V Rilevazione Imprese e Lavoro* (RIL) survey conducted in 2018 on a representative sample of Italian companies operating in the non-agricultural private sector. The RIL survey collects a rich set of information about workforce composition, workplace characteristics, structure of industrial relations (trade union representation, supplementary agreements to the CCNL, etc.), productive specialization and other variables proxying firm strategies (such as the propensity to introduce product and process innovations). The V wave of the RIL-Inapp survey included a new set of questions specifically designed to collect information

1 For simplicity in this article we use the label 'Industry 4.0' techs, although 'Industry 4.0' is a political project implemented in Italy in analogy with 'Industrie 4.0 platform', 'Advance manufacturing platform' and 'Made In China 2025' in order to boost high-tech automation in the manufacturing of Germany, the United States and China respectively (see in this regard Pardi 2019).

Chart 1. Share of firms investing in I4.0 techs by regions and sectors



Note: the image above is a boxplot which is a standardized way of displaying the distribution of I4.0 adopters. It provides insights on the minimum, first quantile, median, third quantile and maximum of the share of firms adopting I4.0 techs for each region/sector.

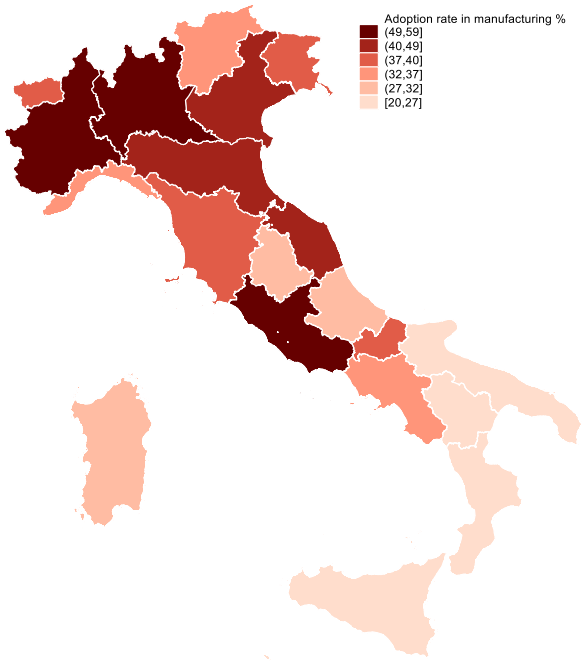
Source: Authors' elaborations on RIL 2018 data

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?". Respondents were presented with the following options: Internet of things (IoT), Robotics, Big data analytic, Augmented reality and Cybersecurity.

By relying on companies' replies to this new set of questions, in this Section we provide a brief descriptive overview of investments in I4.0 technologies discussing their distributions across Italian regions and economic sectors. The sector-region unit of analysis allows us to evaluate the existence of patterns of dispersion/concentration of I4.0 investments in the Italian economy.

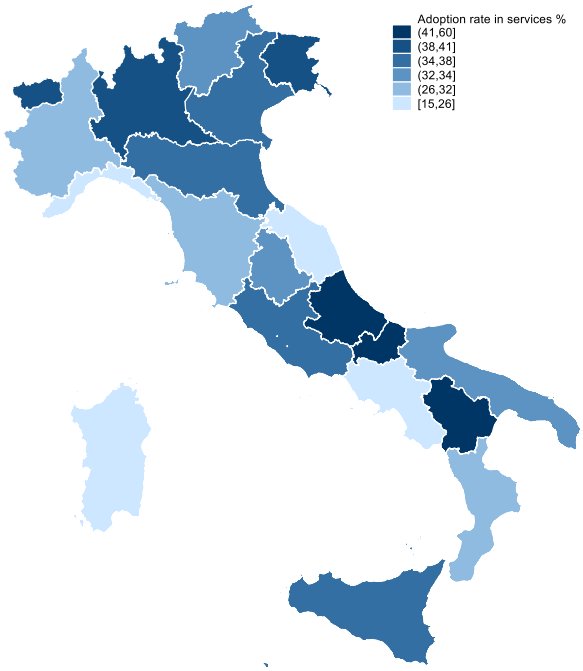
As discussed in Cirillo *et al.* (2020a), the I4.0 paradigm still has limited diffusion among Italian firms, with 26% of firms reporting the adoption of at least one of these new enabling technologies between 2015 and 2017. However, some geographical concentration patterns and sectoral heterogeneity can be clearly seen in relation to I4.0 adoption. As shown in Chart 1, the share of firms declaring an investment in I4.0 technologies between 2015 and 2017, is relatively higher in northern regions (Valle d'Aosta, Lombardy and Emilia Romagna) as compared to Centre and Southern ones. A similar ranking results from the

Figure 1. Adoption rate in manufacturing (%)



Source: Authors' elaborations on RIL 2018 data

Figure 2. Adoption rate in service (%)



Source: Authors' elaborations on RIL 2018 data

regional disaggregation of the Digital Economy and Society Index provided by the European Commission[2].

Chart 1 also shows a prevalence of I4.0 investments in manufacturing sectors related to Mechanical activities, whereas Information and Communication, and Financial and Insurance are the service sectors with higher shares of firms investing in I4.0.

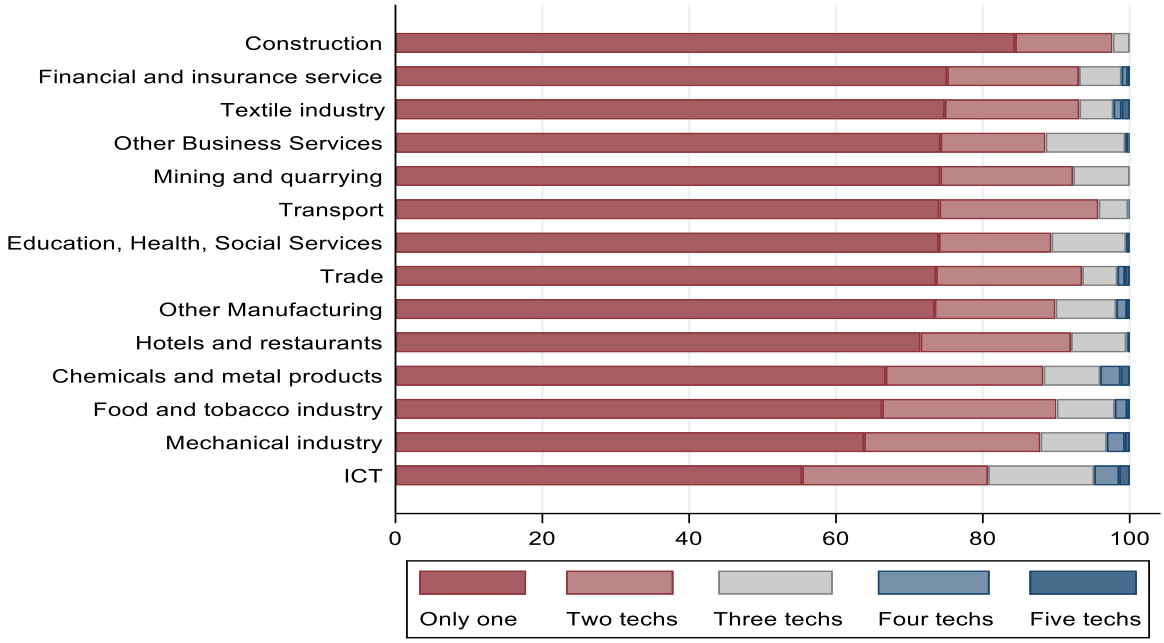
Moreover, Chart 1 indicates relatively higher dispersion of investments for specific regions (e.g., Valle d'Aosta, Marche, Molise and Basilicata) and sectors (e.g., Chemicals, Information and Communications, and Financial services) as compared to the others. This evidence suggests the coexistence of few innovative firms adopting new I4.0 technologies with a large population of non-adopters. Emilia Romagna and Lombardy are the Italian regions registering the highest median level of adoption rates, and the lowest dispersion rates, which suggest a rather uniform degree of adoption by firms located in those areas[3]. Similarly, we detect high dispersion in the adoption rates of I4.0 techs also at the sectoral level. This is consistent with the high degree of firms' heterogeneity characterizing the structure of the Italian economy at both geographical and sectoral levels (Bugamelli *et al.* 2012; Costa *et al.* 2020) and with the 'neo-dualism' that has been identified between few high-performing firms and a large group of low-performing laggard firms (Dosi *et al.* 2012, 2019).

By aggregating the adoption rate of I4.0

2 According to the regional disaggregation of the Digital Economy and Society Index (DESI 2020), in Italy the best performance is achieved by Lombardy, and the worst one by Calabria. Among the eleven regions scoring above the national average, eight regions are in the North (Lombardy, Emilia-Romagna, Friuli Venezia-Giulia, Veneto, Liguria, Piedmont and the autonomous provinces of Trento and Bolzano) and three are in the Centre (Lazio, Tuscany and Umbria). All the other regions are below the Italian average and located in the South. It is worth pointing out that the DESI index captures slightly different – although highly correlated – dimensions of digitization processes compared to I4.0 investments. In fact, DESI includes five domains related to connectivity, human capital, use of internet services, integration of digital technologies and digital public services, whereas our measure of I4.0 adoption refers to both digitization and automation type of techs.

3 This picture is highly consistent with the one in Bratta *et al.* (2020) on the entire population of Italian firms. Focusing on fiscal data and having access to information concerning the uptake of Industry 4.0 fiscal incentives, the authors found that the highest shares of investments benefitting from hyper depreciation are in Northern Italy, with Lombardy (33.2%), Veneto (17.5%) and Emilia Romagna (15.6%) at the top of the ranking.

Chart 2. Share of firms by number of I4.0 technologies adopted across sectors



Source: Authors' elaborations on RIL 2018 data

technologies at a sectoral level in manufacturing (Figure 1) and service (Figure 2) sectors, we can more clearly illustrate the strong geographical heterogeneity between Northern and Southern areas of the country, and the way in which this reflects different patterns of sectoral specializations. As we can see, Piedmont, Lombardy (North-North West) and Lazio (Centre) are characterized by higher adoption rates in manufacturing sectors, followed by Veneto, Emilia Romagna (North East) and Marche (Centre), whereas higher adoption rates in service sectors are recorded in Abruzzo, Molise and Basilicata (South), followed by Valle D'Aosta, Lombardy (North-North West) and Friuli-Venezia Giulia (North East).

Charts 2 and 3 provide a clear indication of the prevalence of a *single-technology*, rather than a *multi-technology*, adoption strategy for Italian firms at both geographical and sectoral levels. Focusing on firms declaring to have invested in at least one I4.0 technology, we computed the number of I4.0 investments realized (from 1 to 5 technology types) and plot in Charts 2 and 3 the share of firms by the number of investments performed in new technologies across sectors and regions. Overall, those regions and sectors characterized by higher adoption rates (Figure 1 and 2) are also the same reporting, on average, a higher adoption of more than one type of technology. Indeed, Chemicals, Mechanics, Food and Tobacco, Information and

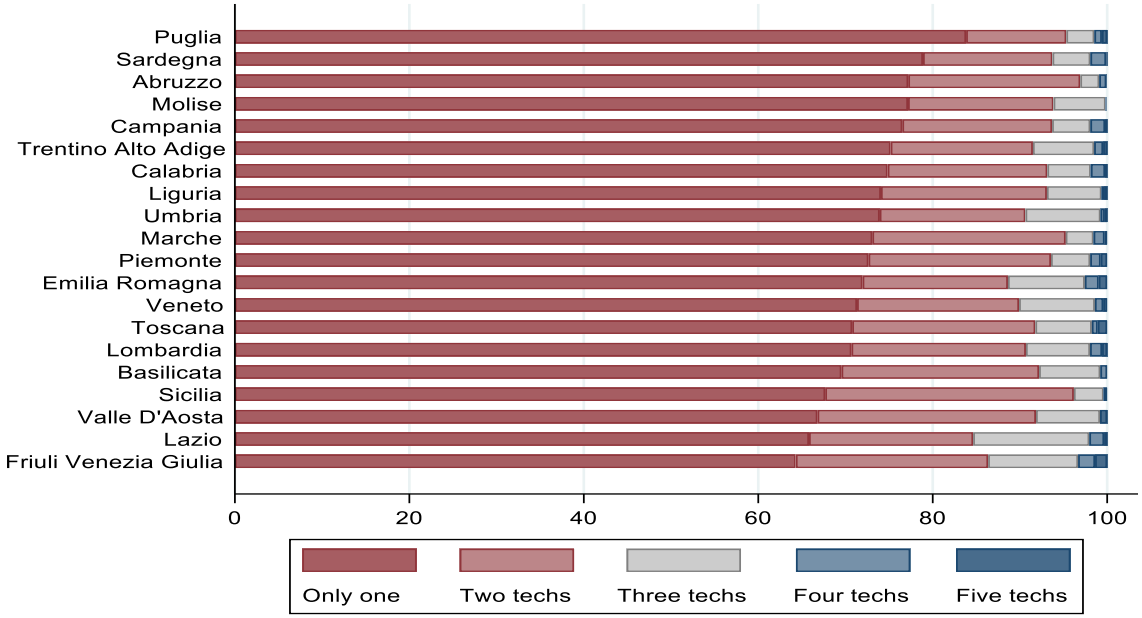
Table 1. Share of firms investing in I4.0 by type of tech and macro-region (%)

Macroregion	At least one tech	IoT	Robotics	Big Data Analytics	Augmented reality	Cyber security
North West	36.72	6.75	4.51	5.23	2.30	32.68
North East	37.70	7.28	4.70	5.48	1.89	32.95
Center Italy	35.90	7.96	4.19	6.67	3.37	29.77
Southern Italy	24.52	4.80	1.64	3.06	1.00	21.15
Total	**33.62**	**6.62**	**3.74**	**5.03**	**2.09**	**29.15**

Note: percentages calculated on companies with at least 5 employees.

Source: Authors' elaborations on RIL 2018 data

Chart 3. Share of firms by number of I4.0 technologies adopted across regions



Source: Authors' elaborations on RIL 2018 data

Communication, and Financial services present a relatively higher share of firms pursuing a *multi-technology* adoption strategy, with prevalent firm location in Piedmont, Emilia Romagna, Lombardy, Friuli-Venezia Giulia, Veneto and Valle d'Aosta (North), Lazio, Marche and Tuscany (Centre), and Basilicata and Sicilia (South).

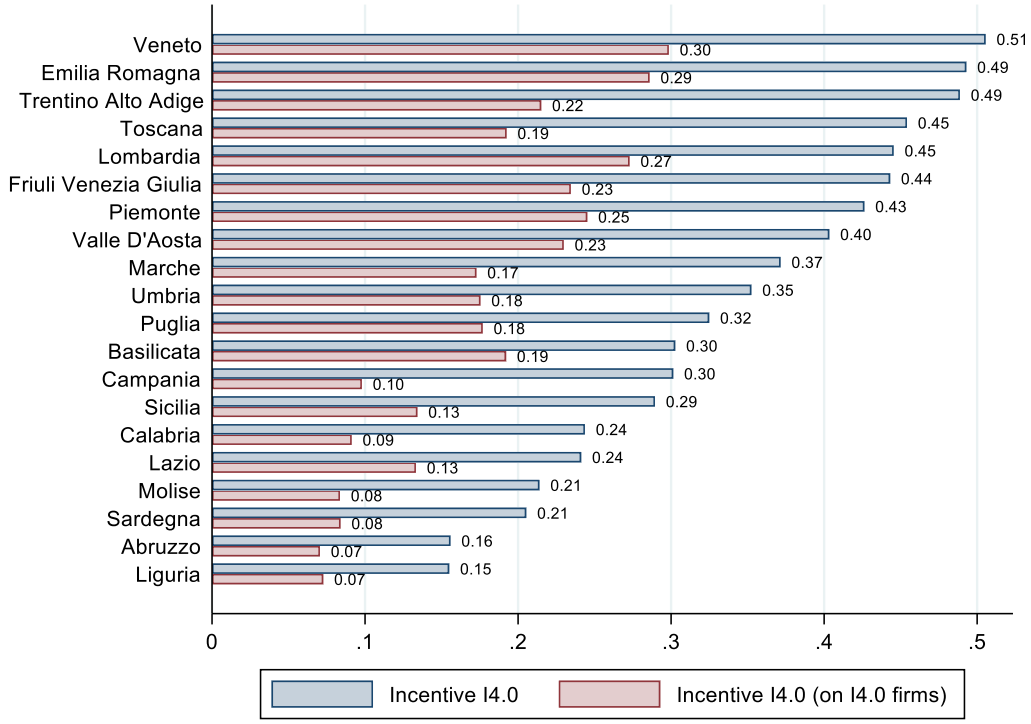
Table 1 distinguishes between firms investing in "at least one" I4.0 technology and firms adopting a specific type of technology, that is 'IoT', 'Robotics', 'Big Data Analytics', 'Augmented Reality' or 'Cybersecurity'. Data related to the adoption of at least one I4.0 confirm a certain degree of geographical heterogeneity among the Italian firms. Indeed, North West and North East macro-regions present higher shares of firms adopting at least one I4.0 technology, i.e. respectively the 36.72% and 37.70%, as compared to Centre (35.90%) and Southern areas (24.52%). Among the different types of I4.0 technologies, Cybersecurity is the most frequently adopted. Indeed, 29.15% of total firms investing in I4.0 reported adopting this type of technology, among which 32.68% and 32.95% are located, respectively, in the North West and North East against the 29.77% and 21.15% located respectively in Centre and Southern macro-regions. This is in line with results presented in Cirillo *et al.* (2020a) about the prevalence of investments and adoption in Cybersecurity rather than in standard production technologies that would pave the way for a radical digital transformation.

Charts 4 and 5 provide insights about the diffusion of specific I4.0 incentives related to the *Piano Nazionale Industria 4.0* policy scheme (see footnote 11) among Italian companies across, respectively, regions and sectors[4].

In charts 4 and 5 the incidence of I4.0 incentives is computed on two different populations of firms: (i) firms making any investment in 2017 (i.e. any type of investment, including, but not limited, to I4.0); (ii) firms introducing at least one I4.0 technology (IoT, Cybersecurity, Augmented Reality, Big Data Analytics, or Robotics), over the 2015-2017 period, and which also made any investment in 2017. Therefore, the light red bar in both graphs represents a subpopulation of the light blue bar. To some extent the light red bar proxies the share of early adopters accessing I4.0 incentives in 2017.

4 In RIL 2018 there is a specific question on incentives (including those of the National Plan of I4.0) which is addressed exclusively to those firms that have invested in 2017.

Chart 4. Share of firms benefiting from I4.0 subsidies by regions*



*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

A relatively larger role is played by I4.0 incentives in those regions (Chart 4) and sectors (Chart 5) where, on average, higher I4.0 adoption rates are reported between 2015 and 2017. This may highlight how the I4.0 policy incentive scheme, which is a 'neutral' measure potentially accessible by all firms investing in I4.0 technologies, may have not redressed pre-existing gaps in the distribution of technological capabilities among Italian regions and sectors, and more specifically between Northern and Southern areas, and between high and medium-low tech sectors.

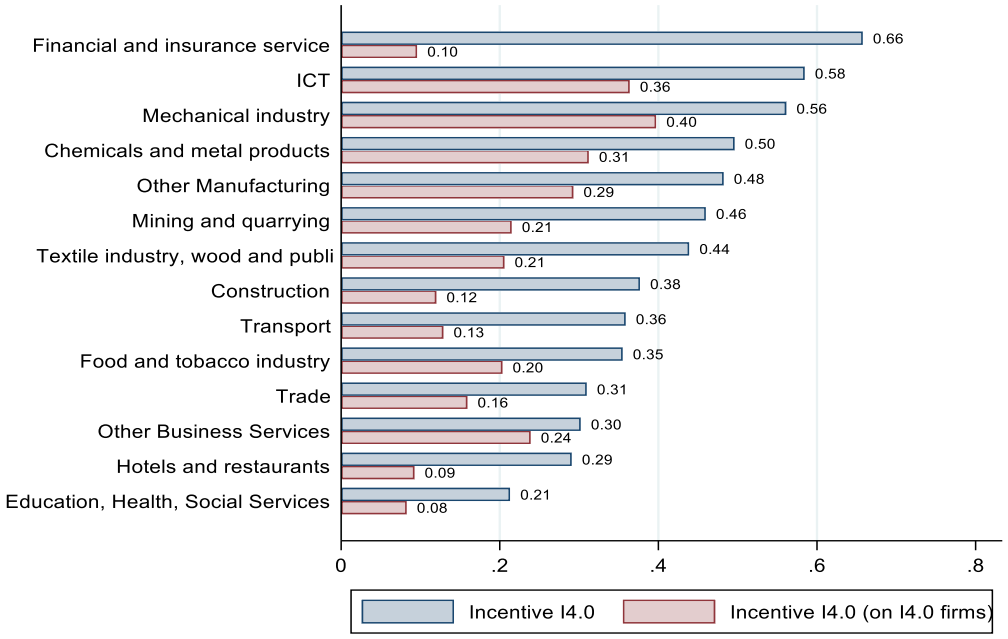
Has the I4.0 policy incentive scheme affected the behavior of firms leading them to introduce new enabling techs? Although a pure evaluation exercise is not feasible due to the lack of a proper control group since the hyper-depreciation policy (and most of I4.0 measures) was a universal policy, which targeted all private companies; in what follows we exploit a specific question that has been introduced in the RIL 2018 survey. Investing firms that have received incentives were asked if in absence of such incentives would have: (i) made the investment anyway, for the same amount; (ii) made the investment anyway, for a smaller amount; (iii) not have made the investment.

Table 2 and Table 3 show the distribution of firms by behavioral choices and, respectively, regions and sectors. The latter have been ordered according to the highest share of companies in the region/sector declaring that in absence of incentives would have realized the investment anyway for the same amount[5].

As expected, a large proportion of firms having introduced I4.0 techs, accessing to the fiscal incentive scheme and declaring that would have made the investment even in the absence of fiscal incentive are located in Northern regions: Lombardy, Veneto, Piedmont and knowledge-intensive service

5 Tables 2 and 3 can be directly linked with evidence in Charts 4 and 5 (light red bars) referring to the same population of firms.

Chart 5. Share of firms benefiting from I4.0 subsidies by sectors



Source: Authors' elaborations on RIL 2018 data

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

Table 3. Distribution of firms by investment choices in absence of I4.0 incentive and sectors (%)

Sectors	made the investment anyway, for the same amount	made the investment anyway, for a smaller amount	not have made the investment
Financial and insurance*	85.56	13.24	1.2
Other Business Services	80.21	12.9	6.89
ICT	73.58	21.05	5.37
Mining and quarrying*	73.33	21.04	5.63
Transport	66.32	23.99	9.69
Food and tobacco	60.69	28.28	11.03
Trade	56.91	26.07	17.03
Education. Health	55.78	38.57	5.65
Construction	51.1	38.75	10.15
Mechanical industry	49.45	37.44	13.1
Other Manufacturing	48.57	36.07	15.36
Hotels and restaurant	46.23	45.44	8.32
Chemicals and metal products	44.3	40.13	15.56
Textile industry, wood	43.59	34.9	21.51
Total	**57.4**	**30.31**	**12.3**

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

sectors (ICT, Financial and insurance activities, etc.).

Among those regions where the incentive policy scheme seems to have affected investment choices of firms: Puglia and Sicily and manufacturing – both high-tech (chemicals and metal products) and low-tech industries (textiles). However, we do not know if these firms using fiscal incentives had never invested in 4.0 technologies before[6].

All in all, pure descriptive evidence seems to suggest that: (i) the uptake of incentive schemes have reached firms located in those regions and sectors having already experienced a path toward digitalization; (ii) these companies in most of cases would have realized the I4.0 investment anyway; (iii) there is a non-negligible share of companies located in Central and Southern regions that in absence of incentives would not have realized the investment[7]. This picture is in line with results in Bratta *et al.* (2020) on fiscal data showing that firms investing in subsidized 4.0 technologies in 2017, besides being more profitable, more productive and less dependent on external funds to finance their activities, were also more prone than the average Italian company to invest and take advantage from the related fiscal incentives (Bratta *et al.* 2020, p.15).

2. Exploring regional and sectoral determinants of I4.0 investments

In light of the descriptive evidence we have discussed, in this Section we take a step forward in the analysis. More in detail, we explore which factors are more likely associated with the concentration of I4.0 investments. These factors can be related to the local productive structure and to the agglomeration of firms with specific features in terms of corporate governance, quality and types of industrial relations, degree of internationalization and innovativeness.

We estimated two different regressions having

6 According to the Ministry of Finance data on the uptake of fiscal incentives matched with the ICT survey run by the Italian National Statistical Office, around 85% of firms that benefitted from hyper-depreciation in 2017 had never invested in advanced digital technologies before.

7 Due to the construction of the questionnaire, we are not able to perfectly match investments in I4.0 with the incentive plan since the question on I4.0 investments refers to 2015-2017 while the question on incentives on I4.0 to 2017. Furthermore, incentives of the Industry 4.0 Plan include a wide range of measures such as R&D tax credit, tax depreciation allowances known as super-depreciation which is less generous than hyper-depreciation and not targeting exclusively investments in advanced digital technology but basically all kinds of new machinery and equipment (Bratta *et al.* 2020).

as dependent variables, respectively: (i) the share of firms investing in at least one I4.0 tech in each Italian sector-region pair; (ii) the average number of I4.0 techs adopted in each Italian sector-region pair. The estimates have been computed by applying standard Ordinary Least Squares (OLS) and robust standard errors. In order to assess which factors are more likely associated with the geographical distribution of I4.0 investments, we introduce as explanatory variables a broad set of covariates that can be grouped into three main set of firm/territorial characteristics: (i) corporate governance profiles (share of firms in the sector-region pair with managers having a degree and high-school diploma with respect to share of firms whose management has elementary or lower-level education; share of firms with family-ownership management); (ii) prevailing type of industrial relations in the sector-region (share of firms having a local trade union representative - RSA and RSU[8]; share of firms in the sector-region that have signed opt-out clauses with respect to national or sectoral collective agreements[9]); (iii) degree of internationalization of firms for each sector-region pair (share of exporting firms; share of firms signing agreements with foreign companies; share of firms outsourcing production abroad); (iv) input and output of innovation at the sector-region level (share of firms investing in R&D; share of firms introducing product and process innovations; share of firms with public procurement contracts). In addition to the aforementioned drivers, we also include a set of controls proxing industrial structure of the sector-region such as average value-added per employee and average size of firms. Finally, we include the average number of trained employees in the sector-region over total employment as a proxy for the availability of a qualified and trained workforce at the sectoral/regional level.

Tables 4 and 5 illustrate the correlations between the incidence of firms' investment in at least one I4.0 technology (i.e., our dependent variable) and a set of variables indicating the shares of firms with different characteristics populating each Italian sector in a specific region (i.e., the unit of analysis is given by the intersection of fourteen economic sectors in twenty regions). Moreover, we include among controls a set of region dummy variables for regions in Table 4 and for sectors in Table 5, allowing us to detect inter-regional variability (Table 4) among covariates in affecting the geographical concentration of I4.0 investments, and inter-sectoral variability (Table 5) among the same set of covariates with respect to our dependent variable[10].

The four columns in Table 4 show the results of four models that differ from one another because of the stepwise inclusion of a variable capturing the share of firms that received a general government subsidy (column 2), a I4.0 subsidy (column 3), a specific I4.0 subsidy named 'Super Ammortamento'[11].

Among the main factors associated with the share of I4.0 investments across sectors and regions (Table 4) both corporate governance features and innovative behavior play a major role. More in detail, the share of family-controlled firms is significantly and negatively correlated with the incidence of

8 RSA and RSU are two trade union representation bodies for employees, both public and private. RSUs - Rappresentanza Sindacale Unitaria - are elected by all workers present in the company, regardless of their membership of a trade union. In contrast, RSAs - Rappresentanza Sindacale Aziendale - are elected by members of a specific trade union. Thus, RSUs have the general representation of workers and participate in company bargaining, whereas RSAs protect only trade union members and until a few years ago do not participate in company bargaining (Keune 2011).

9 Opening clauses (opt-out clauses) are derogation clauses giving firms the chance to deviate from norms set under intersectoral or sectoral agreements, including minimum wages, when firms suffer from temporary economic hardship.

10 The inclusion of sectoral dummies allows to compare different sectors (i.e., manufacturing in Veneto vs. construction in Veneto, etc.), whereas the inclusion of regional dummies sheds lights on between regions heterogeneities (i.e., manufacturing in Veneto vs. manufacturing in Puglia).

11 The set of I4.0 incentives includes: i) 'Super Ammortamento' (a 140% fiscal bonus over the depreciation charges for investments in new capital goods purchased or leased over October 2015- December 2017); ii) 'Iper Ammortamento' (that is a 250% fiscal bonus over the depreciation charges for investments in new tangible assets, devices and technologies enabling the 4.0 transformation over December 2017- June 2018); iii) the contribution provided by Ministry of Economic Development for interest payments on bank loans requested to invest in equipment, machinery or capital-goods related to production and digital technologies implementation (so-called Nuova Sabatini); iv) the patent box; v) 50% tax credit on incremental expenses in R&D; vi) Start-up and PMI measures for small innovative companies. These measures are part of a more general plan designed by the Italian Ministry in 2016 and subsequently relaunched under the name of *Piano Nazionale Industria 4.0,* https://bit.ly/3068e2J

I4.0 investments, indicating a weaker technological dynamic of those sectors/regions characterized by a relevant presence of family-controlled companies.

Conversely, innovative activities are among the strong predictors of I4.0 investments. That is, even controlling for regional specific features that can influence the share of investments in I4.0, the presence of firms persistently investing in R&D and having introduced in the last three years product innovations is positively associated with the share of I4.0 adopters. This confirms, on the one hand, the positive role of stronger innovative efforts on the adoption of new enabling technologies and, on the other hand, the path dependency of technological trajectories of sectors following over time the development of specific technologies.

Industry 4.0 technologies have the potential to reconfigure production processes on a global scale, enabling coordination and synchronization among suppliers in fragmented and geographically dispersed production chains (Garibaldo 2017; Freddi *et al.* 2018; Gaddi *et al.* 2020). However, the degree of internationalization of the sector-region is not associated with the distribution of I4.0 investments. More specifically, neither the share of firms exporting (positively) nor the degree of outsourcing (negatively) are related with the adoption of new technologies. While a negative association emerges between the share of companies signing commercial agreements with international companies and the diffusion of I4.0 investments, we cannot speculate further on this result because we do not have detail information on the specific typology of agreements.

Table 4 also shows that industrial relation features do not appear to be a significant driver of I4.0 investments at the sectoral-regional level, arguably because of the specificities of each industry with respect to the industrial relation framework applied to regulate the workforce-management interface.

Conversely, the share of trained workers over total employment level is positively associated to the share of I4.0 adopters, suggesting the existence of positive externalities between the availability of a trained workforce at the sectoral/regional level and the propensity of firms to be engaged in new enabling technologies.

Significance level and signs do not change when we include a control for the share of firms receiving some forms of incentives (columns 2, 3, 4). The 'Super Ammortamento' scheme – that is the more coherent in terms of timing of incentive (October 2015 - December 2017) with respect to the introduction of I4.0 techs (2015-2017) although not targeting exclusively investments in advanced digital technology but basically all kinds of new machinery and equipment – is significantly related with our dependent variable, meaning that sectors/regions registering higher share of firms having access to 'Super Ammortamento' are also those showing a higher share of I4.0 firms.

Table 5 mainly confirms the relationships detected in Table 4. However, the inclusion of sectoral dummies gives us the opportunity to control for sectoral specific factors affecting the share of I4.0 firms. Corporate governance features and innovation patterns of sectors are significant predictors of geographical/sectoral distributions of I4.0 investments. Moreover, industrial relations turn out as a further significant element affecting the share of I4.0 adopters. In fact, the share of firms with trade union representation bodies – RSA – proxying the strength of specific trade union at the company level, is positively associated with I4.0 investments. This pattern supports previous evidence on the strategic role that trade union within the enterprise may have in the process of implementing new technologies by defining suitable organisational practices (Russo *et al.* 2019; Cirillo *et al.* 2020b) and contributing to create a collaborative environment between management and workforce.

Table 5 also highlights a negative relationship between the share of firms outsourcing productions abroad and I4.0 investments. Firms outsourcing productions are more likely to pursue *cost competitiveness* strategies than *technological competitiveness* (Vivarelli 1995; Vivarelli and Pianta 2000). Therefore, when comparing sectors across regions, we detect that those sector-region pairs characterized by higher proportions of outsourcing companies register on average a lower share of I4.0 adopters.

Finally, as in Table 4, the inclusion of variables proxying the share of companies benefiting from government incentives does not change magnitude nor sign of the coefficients. The proportion of companies receiving 'Super Ammortamento' incentives is still positively related to the share of I4.0 investments at the sectoral-regional level even when we control for sectoral specific features.

Table 4. OLS estimates of a linear regression equation. Dependent variable: share of firms investing in at least one I4.0 technology (I)

	(1)	(2)	(3)	(4)
	b/se	b/se	b/se	b/se
Share of firms with graduate management	0.092	0.089	0.085	0.096
	(0.093)	(0.091)	(0.091)	(0.091)
Share of firms with high-school management	0.114	0.104	0.104	0.110
	(0.084)	(0.082)	(0.083)	(0.080)
Share of family firms	-0.295**	-0.296**	-0.297**	-0.288**
	(0.120)	(0.120)	(0.120)	(0.121)
Share of firms with RSA (union representatives)	0.171	0.159	0.160	0.158
	(0.130)	(0.126)	(0.127)	(0.128)
Share of firms with RSU (union representatives)	-0.148	-0.160	-0.153	-0.144
	(0.177)	(0.181)	(0.181)	(0.178)
Share of firms signing opting out clauses	-0.099	-0.163	-0.154	-0.168
	(0.206)	(0.199)	(0.204)	(0.182)
Share of trained employees (log)	0.080***	0.081***	0.081***	0.075***
	(0.026)	(0.026)	(0.026)	(0.026)
Share of firms exporting	-0.047	-0.056	-0.054	-0.072
	(0.071)	(0.070)	(0.070)	(0.070)
Share of firms signing commercial agreements with foreign companies	-0.275*	-0.281**	-0.277*	-0.229
	(0.144)	(0.141)	(0.142)	(0.142)
Share of firms performing outsourcing	-0.386	-0.487	-0.465	-0.570
	(0.580)	(0.566)	(0.573)	(0.590)
Share of firms investing in R&D	0.196***	0.197***	0.196***	0.198***
	(0.059)	(0.059)	(0.059)	(0.060)
Share of firms introducing process innovations	0.149	0.145	0.144	0.148
	(0.103)	(0.104)	(0.105)	(0.102)
Share of firms introducing product innovations	0.336***	0.325***	0.331***	0.337***
	(0.107)	(0.109)	(0.108)	(0.106)
Share of firms accessing to public procurement	0.060	0.054	0.055	0.058
	(0.057)	(0.057)	(0.057)	(0.058)
Share of firms receiving incentives		0.126		
		(0.112)		
Share of firms receiving I4.0 incentives			0.101	
			(0.116)	
Share of firms using 'Super Ammortamento' plan				0.249*
				(0.146)
Regional dummies	YES	YES	YES	YES
Constant	0.245	0.272	0.265	0.256
	(0.175)	(0.170)	(0.171)	(0.171)
Number of observations	280	280	280	280
Adj. R-Square	0.438	0.442	0.439	0.449

Notes: controls include average firm size, average firm value added and share of firms hiring employees; clustered standard errors in parentheses: * statistical significance at 10%, ** at 5%, *** at 1%.

Source: Authors' elaboration on RIL 2018 data

Table 5. OLS estimate of a linear regression equation. Dependent variable: share of firms investing in at least one I4.0 technology (II)

	(1)	(2)	(3)	(4)
	b/se	b/se	b/se	b/se
Share of firms with graduate management	-0.067	-0.068	-0.069	-0.053
	(0.100)	(0.099)	(0.099)	(0.098)
Share of firms with high-school management	-0.065	-0.068	-0.071	-0.057
	(0.076)	(0.075)	(0.076)	(0.075)
Share of family firms	-0.329***	-0.336***	-0.328***	-0.306***
	(0.107)	(0.108)	(0.108)	(0.108)
Share of firms with RSA (union representatives)	0.257*	0.245*	0.246*	0.249*
	(0.145)	(0.142)	(0.143)	(0.145)
Share of firms with RSU (union representatives)	0.133	0.141	0.150	0.171
	(0.168)	(0.170)	(0.171)	(0.168)
Share of firms signing opting out clauses	-0.202	-0.320	-0.327	-0.333
	(0.228)	(0.228)	(0.231)	(0.206)
Share of trained employees (log)	0.086***	0.082***	0.082***	0.071***
	(0.024)	(0.024)	(0.024)	(0.023)
Share of firms exporting	-0.113	-0.123	-0.124	-0.144*
	(0.075)	(0.076)	(0.075)	(0.075)
Share of firms signing agreements with foreign companies	-0.212	-0.211	-0.211	-0.155
	(0.130)	(0.131)	(0.131)	(0.121)
Share of firms performing outsourcing	-0.830	-0.988*	-0.957*	-1.014*
	(0.574)	(0.569)	(0.563)	(0.600)
Share of firms investing in R&D	0.092	0.101	0.099	0.098
	(0.067)	(0.066)	(0.066)	(0.064)
Share of firms introducing process innovations	0.130	0.124	0.122	0.129
	(0.123)	(0.124)	(0.125)	(0.123)
Share of firms introducing product innovations	0.307***	0.299***	0.304***	0.318***
	(0.113)	(0.115)	(0.113)	(0.112)
Share of firms accessing to public procurement	0.098	0.097	0.103	0.096
	(0.071)	(0.072)	(0.072)	(0.071)
Share of firms receiving incentives		0.163		
		(0.104)		
Share of firms receiving I4.0 incentives			0.164	
			(0.113)	
Share of firms using 'Super Ammortamento' plan				0.306**
				(0.126)
Sectoral dummies	YES	YES	YES	YES
Constant	0.441***	0.463***	0.451***	0.415**
	(0.164)	(0.163)	(0.163)	(0.161)
Number of observations	280	280	280	280
Adj. R-Square	0.432	0.440	0.439	0.451

Notes: controls include average firm size, average firm value added and share of firms hiring employees; clustered standard errors in parentheses: * statistical significance at 10%, ** at 5%, *** at 1%.

Source: Authors' elaboration on RIL 2018 data

Table 6. OLS estimate of a linear regression equation. Dependent variable: Average number of I4.0 investments (I)

	(1)	(2)	(3)	(4)
	b/se	b/se	b/se	b/se
Share of firms with graduate management	0.339**	0.333**	0.325**	0.346**
	(0.140)	(0.140)	(0.140)	(0.139)
Share of firms with high-school management	0.157	0.139	0.136	0.149
	(0.109)	(0.108)	(0.109)	(0.104)
Share of family firms	-0.349*	-0.352*	-0.352*	-0.336*
	(0.194)	(0.195)	(0.196)	(0.191)
Share of firms with RSA (union representatives)	0.201	0.181	0.179	0.179
	(0.210)	(0.213)	(0.214)	(0.210)
Share of firms with RSU (union representatives)	-0.235	-0.257	-0.246	-0.229
	(0.204)	(0.206)	(0.209)	(0.208)
Share of firms signing opting out clauses	-0.361	-0.473*	-0.475*	-0.482**
	(0.250)	(0.248)	(0.251)	(0.237)
Share of trained employees (log)	0.114***	0.116***	0.117***	0.105**
	(0.044)	(0.044)	(0.044)	(0.044)
Share of firms hiring	0.076	0.056	0.061	0.052
	(0.094)	(0.101)	(0.100)	(0.100)
Share of firms exporting	-0.036	-0.053	-0.052	-0.081
	(0.097)	(0.097)	(0.097)	(0.098)
Share of firms signing agreements with foreign companies	-0.086	-0.097	-0.091	-0.004
	(0.230)	(0.233)	(0.232)	(0.227)
Share of firms performing outsourcing	-0.129	-0.306	-0.295	-0.454
	(1.055)	(0.987)	(1.008)	(1.002)
Share of firms investing in R&D	0.304***	0.306***	0.303***	0.307***
	(0.105)	(0.104)	(0.104)	(0.104)
Share of firms introducing process innovations	0.128	0.121	0.118	0.126
	(0.154)	(0.153)	(0.155)	(0.152)
Share of firms introducing product innovations	0.579***	0.559***	0.567***	0.580***
	(0.182)	(0.179)	(0.179)	(0.176)
Share of firms accessing to public procurement	0.119	0.109	0.109	0.115
	(0.082)	(0.082)	(0.083)	(0.083)
Share of firms receiving incentives		0.222		
		(0.158)		
Share of firms receiving I4.0 incentives			0.211	
			(0.168)	
Share of firms acceding to 'Super Ammortamento' plan				0.440**
				(0.207)
Regional dummies	YES	YES	YES	YES
Constant	0.213	0.260	0.255	0.231
	(0.260)	(0.259)	(0.260)	(0.256)
Number of observations	280	280	280	280
Adj. R-Square	0.429	0.434	0.433	0.443

Notes: controls include average firm size, average firm value added and share of firms hiring employees; clustered standard errors in parentheses: * statistical significance at 10%, ** at 5%, *** at 1%.

Source: Authors' elaboration on RIL 2018 data

Table 7. OLS estimate of a linear regression equation. Dependent variable: Average number of I4.0 investments (II)

	(1)	(2)	(3)	(4)
	b/se	b/se	b/se	b/se
Share of firms with graduate management	-0.001	-0.003	-0.004	0.023
	(0.142)	(0.140)	(0.141)	(0.141)
Share of firms with high-school management	-0.120	-0.126	-0.131	-0.106
	(0.100)	(0.099)	(0.100)	(0.098)
Share of family firms	-0.369**	-0.380**	-0.366**	-0.329*
	(0.177)	(0.180)	(0.180)	(0.173)
Share of firms with RSA (union representatives)	0.348*	0.328*	0.329*	0.333*
	(0.193)	(0.193)	(0.192)	(0.187)
Share of firms with RSU (union representatives)	0.233	0.247	0.263	0.299*
	(0.176)	(0.177)	(0.182)	(0.173)
Share of firms signing opting out clauses	-0.660**	-0.862***	-0.878***	0.883***
	(0.277)	(0.269)	(0.274)	(0.243)
Share of trained employees (log)	0.105***	0.099***	0.097***	0.079**
	(0.034)	(0.034)	(0.034)	(0.034)
Share of firms hiring	0.234**	0.207*	0.211*	0.203*
	(0.117)	(0.121)	(0.120)	(0.118)
Share of firms exporting	-0.027	-0.045	-0.046	-0.080
	(0.095)	(0.094)	(0.094)	(0.092)
Share of firms signing agreements with foreign companies	-0.027	-0.026	-0.026	0.070
	(0.209)	(0.215)	(0.216)	(0.196)
Share of firms performing outsourcing	-0.904	-1,175	-1,126	-1,218
	(0.983)	(0.904)	(0.913)	(0.935)
Share of firms investing in R&D	0.091	0.106	0.103	0.100
	(0.095)	(0.094)	(0.094)	(0.093)
Share of firms introducing process innovations	0.119	0.109	0.105	0.118
	(0.194)	(0.191)	(0.192)	(0.186)
Share of firms introducing product innovations	0.523**	0.510**	0.518**	0.542***
	(0.206)	(0.200)	(0.201)	(0.195)
Share of firms accessing to public procurement	0.219**	0.217**	0.226**	0.216**
	(0.091)	(0.091)	(0.093)	(0.091)
Share of firms receiving incentives		0.280*		
		(0.145)		
Share of firms receiving I4.0 incentives			0.288*	
			(0.162)	
Share of firms acceding to 'Super Ammortamento' plan				0.525***
				(0.172)
Sectoral dummies	YES	YES	YES	YES
Constant	0.374	0.413	0.391	0.329
	(0.253)	(0.255)	(0.254)	(0.247)
Number of observations	280	280	280	280
Adj. R-Square	0.468	0.478	0.477	0.491

Notes: controls include average firm size, average firm value added and share of firms hiring employees; clustered standard errors in parentheses: * statistical significance at 10%, ** at 5%, *** at 1%.

Source: Authors' elaboration on RIL 2018 data

Table 8. OLS estimate of a linear regression equation. Dependent variable: share of firms investing in at least one I4.0 technology by macro-regions

	(1)	(2)	(3)	(4)
	Center-North	South	Center-North	South
	b/se	b/se	b/se	b/se
Share of firms with graduate management	0.187*	-0.120	0.213**	-0.119
	(0.100)	(0.133)	(0.107)	(0.133)
Share of firms with high-school management	0.092	0.012	0.112	0.012
	(0.112)	(0.105)	(0.107)	(0.105)
Share of family firms	-0.247	-0.212	-0.264*	-0.201
	(0.151)	(0.158)	(0.158)	(0.163)
Share of firms with external management	-0.321*	0.057	-0.319*	0.056
	(0.180)	(0.229)	(0.193)	(0.232)
Share of firms with RSA (union representatives)	0.739***	-0.169	0.655***	-0.163
	(0.162)	(0.106)	(0.184)	(0.112)
Share of firms with RSU (union representatives)	0.099	-0.378	0.113	-0.381
	(0.150)	(0.335)	(0.155)	(0.337)
Share of firms signing opting out clauses	0.145	-0.212	0.020	-0.215
	(0.187)	(0.296)	(0.191)	(0.296)
Share of trained employees (log)	0.111***	0.052	0.106***	0.052
	(0.039)	(0.032)	(0.039)	(0.032)
Share of firms exporting	-0.080	-0.128	-0.119	-0.128
	(0.082)	(0.112)	(0.081)	(0.112)
Share of firms signing agreements with foreign companies	0.005	-0.201	0.024	-0.199
	(0.149)	(0.245)	(0.145)	(0.246)
Share of firms performing outsourcing	-0.149	-1.483**	-0.136	-1.541**
	(0.836)	(0.646)	(0.871)	(0.671)
Share of firms investing in R&D	0.155*	0.196**	0.154*	0.198**
	(0.081)	(0.077)	(0.079)	(0.079)
Share of firms introducing process innovations	0.027	0.156	0.025	0.155
	(0.130)	(0.149)	(0.131)	(0.150)
Share of firms introducing product innovations	0.415***	0.431**	0.444***	0.427**
	(0.111)	(0.181)	(0.111)	(0.183)
Share of firms accessing to public procurement	0.057	0.092	0.053	0.090
	(0.068)	(0.094)	(0.069)	(0.094)
Share of firms using 'Super Ammortamento' plan			0.316	0.050
			(0.218)	(0.194)
Constant	0.233	0.290	0.265	0.282
	(0.185)	(0.243)	(0.192)	(0.244)
Number of observations	168	112	168	112
Adj. R-Square	0.447	0.376	0.466	0.369

Notes: controls include average firm size, average firm value added and share of firms hiring employees; clustered standard errors in parentheses: * statistical significance at 10%, ** at 5%, *** at 1%.

Source: Authors' elaboration on RIL 2018 data

As a further test, we explore the correlations between sectoral-regional features and the average number of I4.0 investments, with 0 being the lowest value – when all firms in the sector-region do not invest in enabling techs – and 5 the highest value – all firms of the sector-region invest in all I4.0 type of techs (Internet of Things, Robotics, Big data analytics, Augmented reality and Cybersecurity). To some extent, Table 6 and 7 shed lights on those factors influencing the simultaneous adoption of I4.0 technologies and therefore predicting at the sectoral-regional level the prevalence of a *multi-adoption* model.

The share of family-owned firms and the share of trained employees still show, respectively, a negative and positive correlation with the incidence of a *multi-technology* adoption strategy, both when we account for regional characteristics (Table 6) and when we account for sectoral features (Table 7). The positive association between the share of firms introducing product innovations and the number of I4.0 investments is also confirmed, while the share of firms investing in R&D activities is positively correlated with the incidence of multiple I4.0 investments when controlling for region-specific factors (Table 6). As shown in Table 4 and 5, a higher share of firms having trade union representatives (RSA) positively correlates with a higher number of I4.0 technologies when controlling for sectoral specific characteristics (Table 7).

However, the exploration of the determinants of a multi-technology adoption model at the sectoral-regional level suggests the significance of two further features concerning both the corporate governance structure of firms and the type of prevailing industrial relations. These are: (i) the share of firms having a management with a tertiary education level which positively relates to the adoption of more than one I4.0 tech; (ii) the share of firms signing opt-out clauses that are derogation clauses in sectoral/national collective agreements. The higher the share of firms derogating, the lower the average number of I4.0 investments realized by each firm at the sectoral-regional level[12]. Opt-out clauses indicate a non-collaborative trade union-management type of environment at the workplace level.

Controlling for sector specific effects (Table 7), three further sectoral-regional features emerge as significant drivers of multi-technology adoption: (i) the share of firms hiring employees; (ii) the share of firms with public procurement contracts (share of enterprises providing products or services to the public administration) and (iii) the share of firms that have received a subsidy for general investments (column 2) or for a specific investment related to the 'Piano Nazionale Impresa 4.0' (column 3).

Finally, Table 8 shows the results of the same models presented in Tables 4 and 5 (without the inclusion of regional and sectoral dummies) for Southern and Central-North Italian regions. The main drivers are still significant when we break down the sample in macro-regions. However, patterns related to corporate governance and availability of a trained workforce lose significance in the South.

Outsourcing and introducing new enabling technologies appear to be substitute strategies, and indeed the presence of companies outsourcing production significantly compresses the share of I4.0 adopters at the sector-region level when focusing on the South of Italy. Conversely, the share of firms adopting product innovations and investing in R&D is always significant and positively associated to the sectoral-territorial incidence of I4.0 both in Northern and Southern Italy.

Conclusions

What can we conclude from the evidence produced in these empirical analyses? First of all, the general levels of diffusion of the new digital technologies are modest. Secondly, the strong heterogeneity characterizing sectors and regions in the Italian context is fully reflected also in the diffusion patterns of such new technologies. This

12 Opt-out clauses provide companies through various kinds of derogation the possibility to deviate from pay or other type of norms set under inter-sectoral or sectoral agreements. The reasoning behind such deviations is that they are an instrument that may permit companies to overcome temporary economic difficulties without resorting to (mass) layoffs (Eurofound). In Italy derogation clauses are not applied with respect to wages, however they are used when firms are more likely to experience financial crises.

does not come as a surprise given the structure and evolution of the Italian regional economies in Europe over the last century (Viesti 2021a). There is indeed strong path-dependence in the trajectories of production upgrading for those sectors that are more inclined to introduce further innovations. However, against this background, some indications can be found in the data suggesting that the diffusion of new digital technologies has been triggered in most sectors and regions. Regarding the sectoral and geographical profile of these diffusion patterns, services do not appear to lag behind manufacturing in terms of adoption rates (arguably due to the role of cybersecurity in the ICT sector), while showing less geographical dispersion than manufacturing between North and South.

The emergent evidence on the performance effects of Industry 4.0 indicates that firms derive productivity gains from adoption (Cirillo *et al.* 2021), and that the policy incentive scheme that recently subsidized I4.0 investments in Italy was successful in lowering the financial barriers to adoption faced by firms (Cirillo *et al.* 2020a). This was, however, not sufficient to eliminate the enduring divides in productive capacities found across geographical areas. As clearly highlighted by Bratta *et al.* (2020), the hyper-depreciation measure introduced by Industry 4.0 National Plan concerned about 7 billion euros of private investments, out of which 83% originated from the manufacturing sector and the majority of recipient firms were small- and medium-sized, located in Northern regions[13]. In line with our results, and working on the entire population of Italian companies, the authors highlight how firms that invested in (subsidized) digital technologies in 2017 were *ex-ante* more productive, more likely to invest in R&D and in the acquisition of machinery and equipment, and had higher returns on investments as well as lower levels of indebtedness. Indeed, one should bear in mind that eligibility for the fiscal incentive was granted to all firms with a registered office in Italy, regardless of their business activities or company size, and there was no cap on the amount of investments benefitting from the tax depreciation allowance. This made the Industry 4.0 Plan a 'neutral' policy scheme that was unlikely by design to revert the long-term industrial specialization of regions or to re-orient the technological path of laggard regions.

Furthermore, it should be acknowledged that the Industry 4.0 Plan was also 'neutral' from a technological point of view since firms have received money to invest in new assets without a specific targeted approach (see the case of the super-depreciation scheme). Firms were able to adopt those technologies that are more suitable to interact with their specific technological endowment, internal knowledge-base, organizational capabilities or other idiosyncratic characteristics. In this respect, those firms that had already undertaken an innovation-oriented trajectory may be more responsive to the adoption of new digital technologies and thus to the incentives vis-à-vis those companies characterized by less dynamic innovative patterns.

All in all, our results suggest that sectoral and geographic agglomerations of adopters are associated with robust innovation activities and good human capital endowments. We would interpret these two factors as pre-conditions and key elements for the adoption. Interestingly, our results also point to the importance of institutional and organizational factors as facilitators of diffusion and it is plausible that the direction of causes and effects goes from governance to digitalization rather than the other way round. The broader picture emerging from the data highlights the role of skills, which are arguably as important as general (ICT) infrastructure in favoring the adoption of new digital technologies. On this basis, the different coverage degree of digital infrastructure among North and South geographical areas may represent an *ex ante* barrier to the diffusion of new digital technologies that may exacerbate, in turns, regional divergences in terms of adoption rates. Indeed, along with the fiscal incentives for I4.0

13 It should be acknowledged that such amount is significantly below the ex-ante estimate of the Italian Government of around 10 billion euros (Bratta *et al.* 2020).

technologies, strong investment programs for a widespread diffusion of key infrastructures, such as broadband and optical fiber, across different regions should arguably be implemented in order to re-shape divergent technological trajectories of the Northern and Southern regions, and to facilitate digitalization throughout the Italian productive structure.

Overall, the experience of the incentive scheme points to the importance of more targeted innovation policy measures with precise objectives on which economic activities to relaunch and for a more active industrial policy (Mazzucato 2018; Pianta *et al.* 2020; Pianta 2021). Indeed, industrial policies more than pure incentive schemes can be used to reduce geographical disparities which are often the result of declining filières and weak sectoral specialization of 'peripheral' regions. The need remains to strengthen regional innovation systems and shape the policy mix in such a way as to coordinate investments plans and avoid fragmented interventions of highly uneven impact. Considering the crisis events tend to exacerbate disparities between 'core' e 'periphery'[14], this is especially relevant in light of the opportunities provided by the Italian National Recovery and Resilience Plan, which includes the objective to foster digital capabilities by means of fiscal incentive schemes[15] without addressing the problem of resource allocation criteria for the territorial distribution of funds (Viesti 2021b).

At the time of writing, the economic consequences of the Covid-19 pandemic are unfolding rapidly, and the upgrading of the industrial capacity of the Italian economy through new digital technologies becomes clearly urgent. As shown by the *ad hoc* survey run by the Italian National Statistical Office (2020) on the situation and prospects of enterprises in the emergency of Covid-19, the use of technology has had a major boost since the Covid crisis, with an acceleration in the digital transformation of companies and a change in key business processes such as internal communication within the company (also in a context of widespread smart working), external communication and the marketing channels for products and services. This impact has obviously been highly heterogeneous *across* sectors and company sizes, and strongly dependent on prior diffusion. The upgrading of digital capabilities in the economic system and the spread of ICTs and innovation even in backward regions would be particularly useful for new adopters of digital technologies, and not only for persistent innovators, so that more firms can be included in the ongoing restructuring of local and global value chains. Value chains are showing concurrent processes of transformation that are themselves more and more dependent on digital technologies able to connect in a modular but integrated way different phases of production and service delivery. They may therefore play a key role not only in the short-term recovery process, but also in the long-term development of regional competitive advantage. In this regard, an integrated approach between industrial, fiscal, public demand, education and labour policies, is crucial to reduce the opportunities for financial speculation and the transfer of businesses, research and production abroad, and instead to give priority to the real economy and to the expansion of skilled employment (Cresti *et al.* 2020).

To conclude, in this contribution we have tried to shed new light on the uneven distribution of investments in new enabling technologies across Italian regions and sectors, on the interplay between I4.0 policy scheme and adoption rates, and, ultimately on the main drivers of structural change. We have not addressed the role of heterogeneity in firm performances *within* regions and sectors, and the coexistence in the same region/sector of leading and lagging-behind firms. An increasing dispersion in firm performances might play a crucial role in explaining the developmental trajectories of 'core' vs. 'peripheral' areas, and therefore deserves attention in future research.

14 See for example Mina and Santoleri (2021) for a detailed analysis of the effect of the 2008 crisis on firms across European regions.

15 See Mission 1, Component 2 - Digitisation, innovation and competitiveness in the production system of the Italian PNRR.

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