# Industry 4.0 in Italy: microeconomic behavior and industrial policy

**OCT. 2018**

**THE PRESENT ANALYSIS WAS DEVELOPED ON BEHALF OF ITALIAN**

**MINISTRY OF ECONOMIC DEVELOPMENT**

MET

**SUMMARY**



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## Introduction

This document outlines the main results of an innovative research project aiming at quantifying the diffusion - among Italian firms - of those technologies that are associated to the so-called "Industry 4.0" paradigm. For the Italian case, indeed, the availability of statistical information related to this topic is limited, even in spite of the great interest – both among scholars and policy makers – with reference to the economic consequences of the widespread digitalization of the production processes.

The analyses described in this report try to fill this gap by means of a micro-founded approach. This approach relies on the MET Survey – the last wave was conducted between October 2017 and February 2018. In particular, the MET sample is composed by approximately 24000 Italian firms, representative of the entire population of Italian industrial and production services firms. Moreover, the survey was conducted among all Italian regions by also including small businesses – i.e. firms reporting less than 10 employees - . By reporting detailed information on firms' industrial sector, location and size, MET Survey data allow for the elaboration of sound descriptive analyses with reference to different phenomena. For descriptive and methodological information, see www.met-economia.it.

A large section of the MET Survey focuses on the "Industry 4.0" phenomenon. More specifically, the survey tries to assess the degree of digitalization of Italian firms with reference to a wide range of digital technologies. In particular, the information collected allows not only for the assessment of the current use of these technologies, but also for the identification of those businesses planning to introduce 4.0 technologies in the near future. Further, MET Survey data allows for the identification of those firms that are directly involved in the production processes of digital technologies.

In more detail, the MET Survey considers the following technologies:

- ✓ Collaborative and interconnected robots(Advanced Manufacturing Solutions
- ✓ 3d printers (Additive Manufacturing)
- ✓ Augmented reality
- ✓ Experimentation simulations and virtual tests (Simulation )
- ✓ Nanotechnologies and smart materials (Smart technology / materials )
- ✓ Electronic communication in the network between machinery and products (Industrial Internet of Things )
- ✓ Electronic integration of data and information throughout the company's various production phases ( Horizontal Integration)
- ✓ Electronic sharing with customers / suppliers of information on the status of the distribution chain (inventory, tracking , etc.) (Vertical Integration)
- ✓ Management of large amounts of data on open systems ( Cloud )
- ✓ Detection and analysis of large amounts of data (Big data / Analytics)
- ✓ Computer security during network operations and on open systems (Cyber Security)

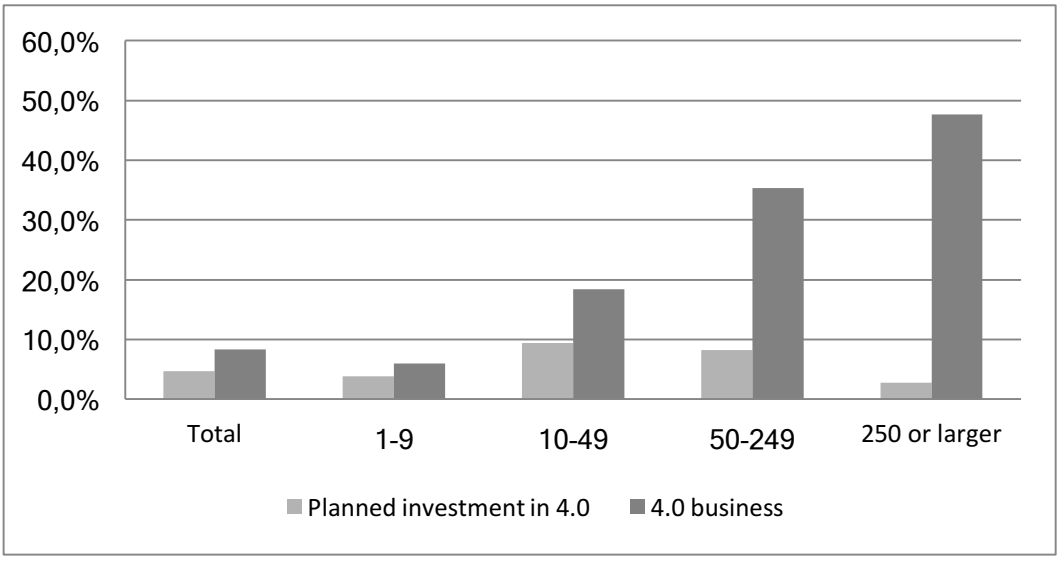
Besides those aspects that are directly related to the usage of 4.0 technologies, the survey also makes possible to investigate on the role of several other relevant variables - with particular reference to the economic difficulties and constraints that could have hindered a more pronounced digitalization of the production processes in Italy. The framework presented in this document is completed by an analysis of firms' behavior – by paying particular attention to those that are related to firms competitiveness, such as the level of R&D expenditure and firms presence in international markets.

## 1. The spread of Industry 4.0 technologies

As for the spread of Industry 4.0 technologies, MET Survey data show that 8.4% of Italian businesses make use of at least one of the technologies considered (hereafter, "4.0 businesses", as shown in Figure 1.1). Further, the data show that 4.7% of businesses - even if not currently using any of the above mentioned technologies - are planning to introduce new technologies on the coming three years. Therefore, firms that are both not using and not planning the introduction of any of the considered technologies (i.e. traditional businesses), represents the vast majority of Italian firms - i.e. 86.9%.

Not surprisingly, MET data show that the propensity to introduce 4.0 technologies increases with firm size. In particular, 4.0 businesses represent 18.4% of small firms (i.e. 10 to 49 employees), while among medium-size firms (50 to 249 employees) their share almost doubles, representing more than one third of firms in this class size – i.e. 35.5%.

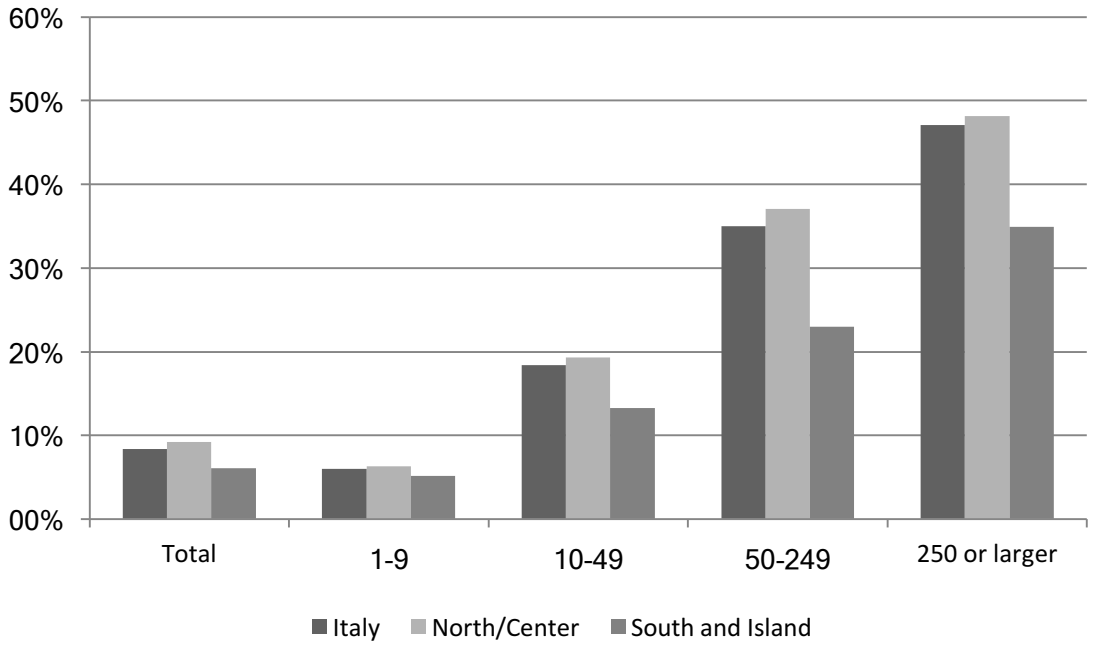
**Figure 1.1 The spread of 4.0 technologies by firm size (percentages)**




The evidence is that the digitalization of the production processes will increase in the near future. As already mentioned, the share of non 4.0 businesses reporting to plan the introduction of 4.0 technologies in the near future is 4.7%, and it is worth noting that this share is higher among small and medium-size businesses (respectively, 9.4 and 8.2%).

As expected, the spread of 4.0 technologies is more pronounced in Central and Northern Italy (9.2%) when compared to Southern Italy (6.1%). Although the share of 4.0 businesses is systematically higher in Central and Northern Italy, we can see that the positive relationship between 4.0 technologies and firm size similarly apply in the southern part of the country. Nevertheless, 4.0 businesses that located in southern regions are disproportionally underrepresented when considering medium-size firms, where their share is largely below 30%.

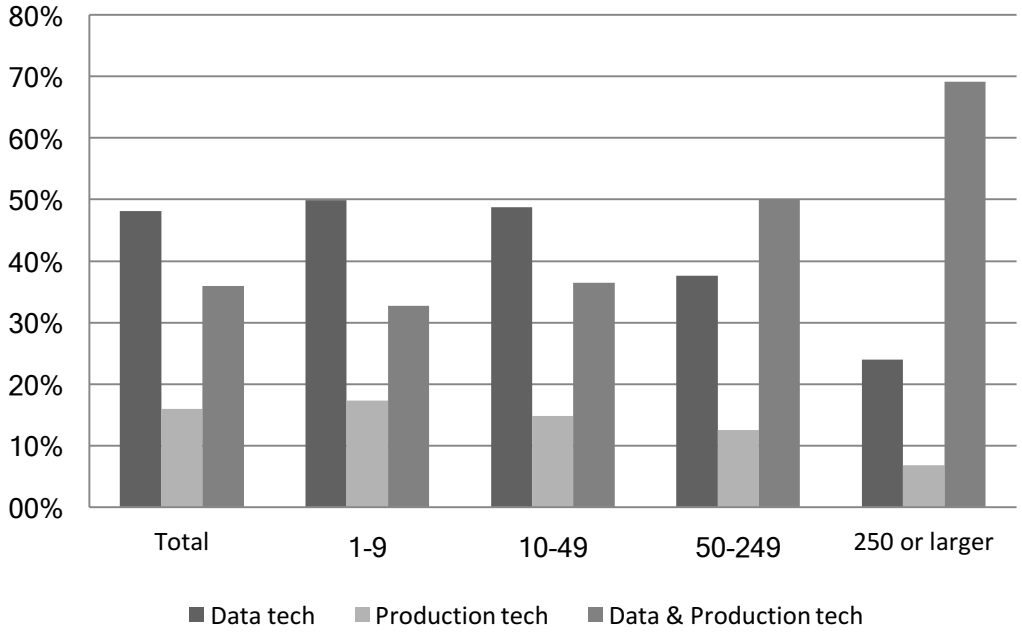
**Figure 1.2. 4.0 businesses by macro-area e and firm size (percentages).**




The data also show a striking asymmetry between 4.0 technologies that are directly related to production (interconnected robots, additive manufacturing, simulation, augmented reality and smart materials) and 4.0 technologies that are mostly related to the exploitation of information and data (horizontal/vertical integration of information, cloud computing, big data, analytics, etc.).

According to this breakdown, 4.0 businesses can be associated to three distinct groups. Barely half of these firms make use of data management technologies only, whereas more than one third (36%) introduced both technologies directly related to production (including planning and simulation activities) and those related to data management. Conversely, the smallest group is composed by firms introducing production technologies only (16%). The first group is predominant among small and micro businesses, whereas above the threshold of 50 employees is the second group to be predominant – representing more than a half of medium-size businesses and almost 70% of large businesses.

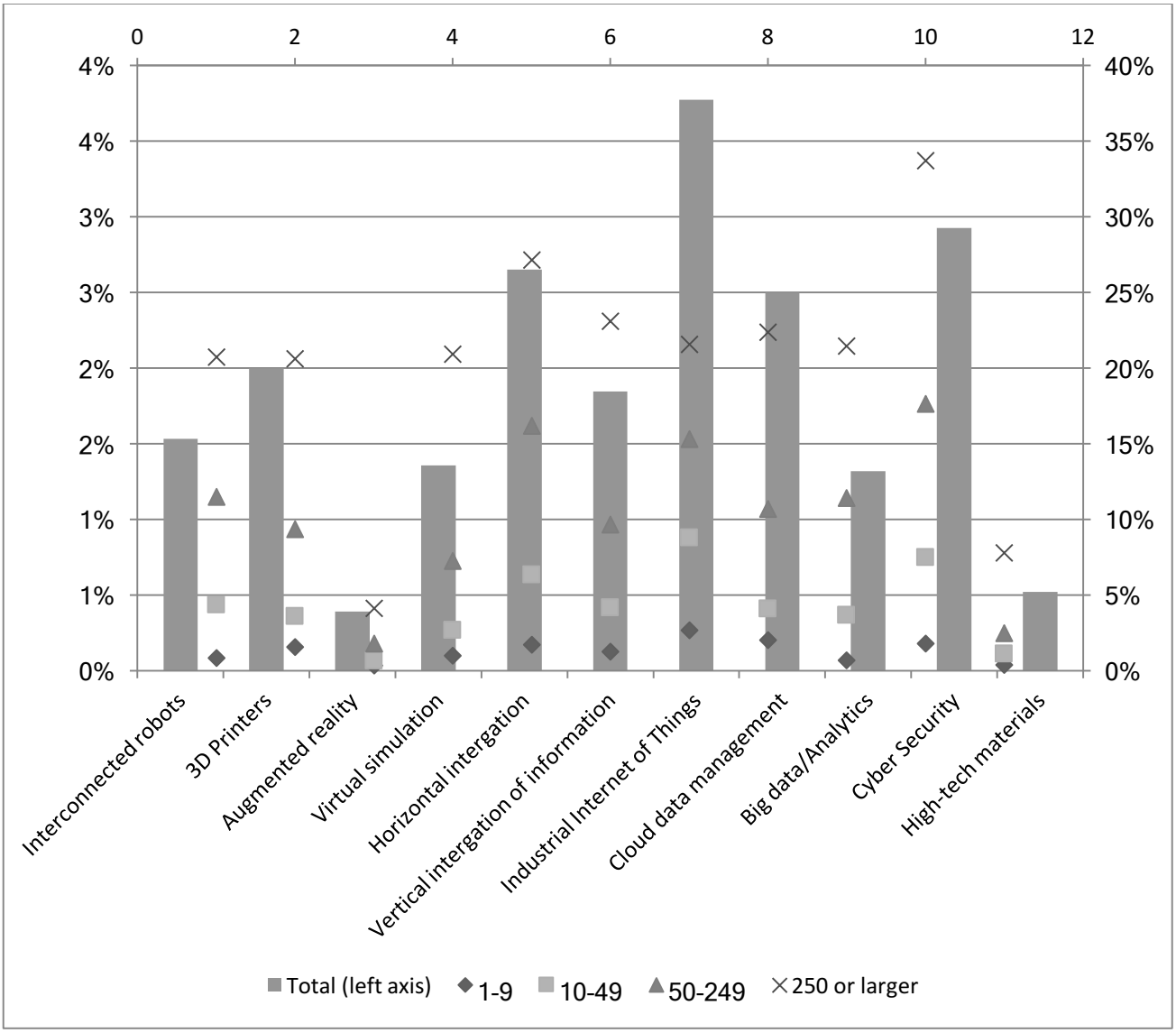
**Figure 1.3. Type of technology used among 4.0 businesses (percentages)**




More in detail, it is worth noting that - among all technologies considered –the digitalization of the production processes in Italy mostly involves cyber security technologies, horizontal integration and the internet of things.

Among medium-size and large firms, the most of the investments are directed towards cyber security technologies and vertical/horizontal integration of data and information. For what concerns interconnected robots, 3D printers and virtual simulations, the data show that these technologies are relatively relevant among large businesses only.

**Figure 1.4. 4.0. technologies used by firms class size (percentages)**




In most cases, the involvement in 4.0 technologies appears to be limited to the use of few applications (Figure 1.5) . Indeed, 62.4% of 4.0 businesses make use of one (37.3%) or at most two technologies ( 25.1%). Above 50 employees the "toolbox" expands, but it is only in large businesses that it is possible to observe an integrated system of different technologies at work. In fact, over 60% of large companies use at least four different 4.0 technologies.

Among businesses employing up to two technologies, data acquisition and information management is predominant – i.e. 59.8% of businesses among firms using only one technology and 65.4% among those using two technologies (Figure 1. 6). When using three technologies, the probability of observing both strictly productive and information management technologies increases significantly (56.9%). Above three technologies, the use of both types is predominant.

Consistently with the smart factory paradigm, the usage of production technologies is closely related to the exploitation of data produced along the production process. On the one hand, from two technologies used onward, businesses that make use of production technologies only result to be

rather marginal. On the other hand, among businesses using only one production-type technology 3D printers are predominant.

**Figure 1.5. Number of 4.0 technologies used by firm class size (shares on the left axis, average numbers on the right axis).**

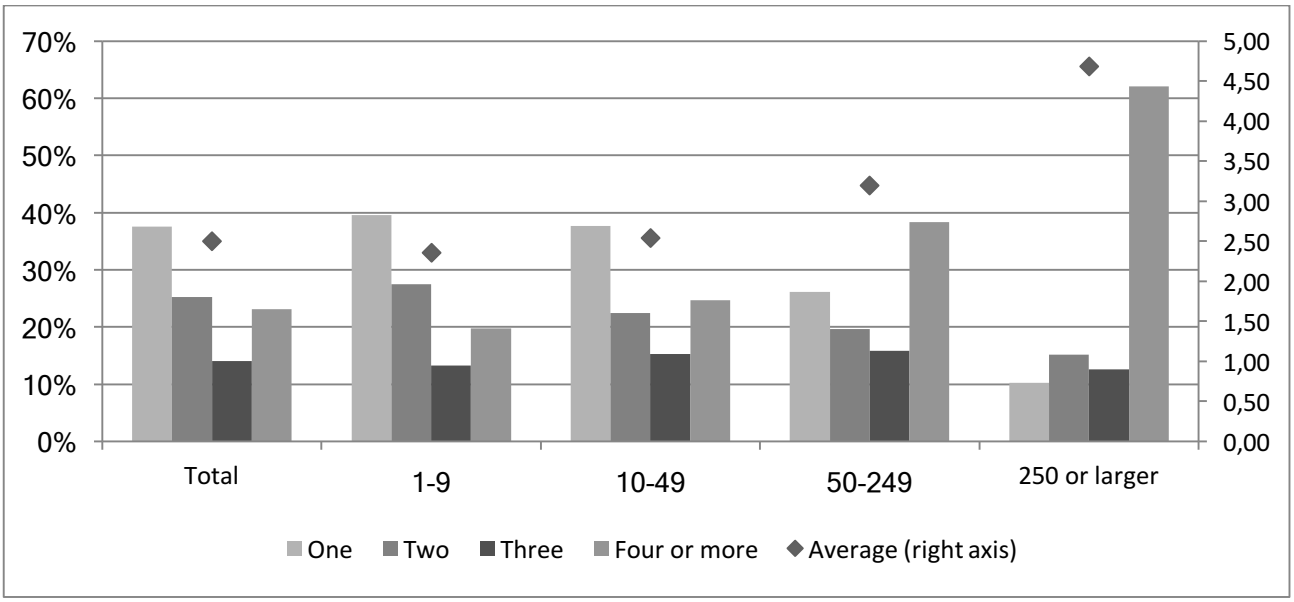
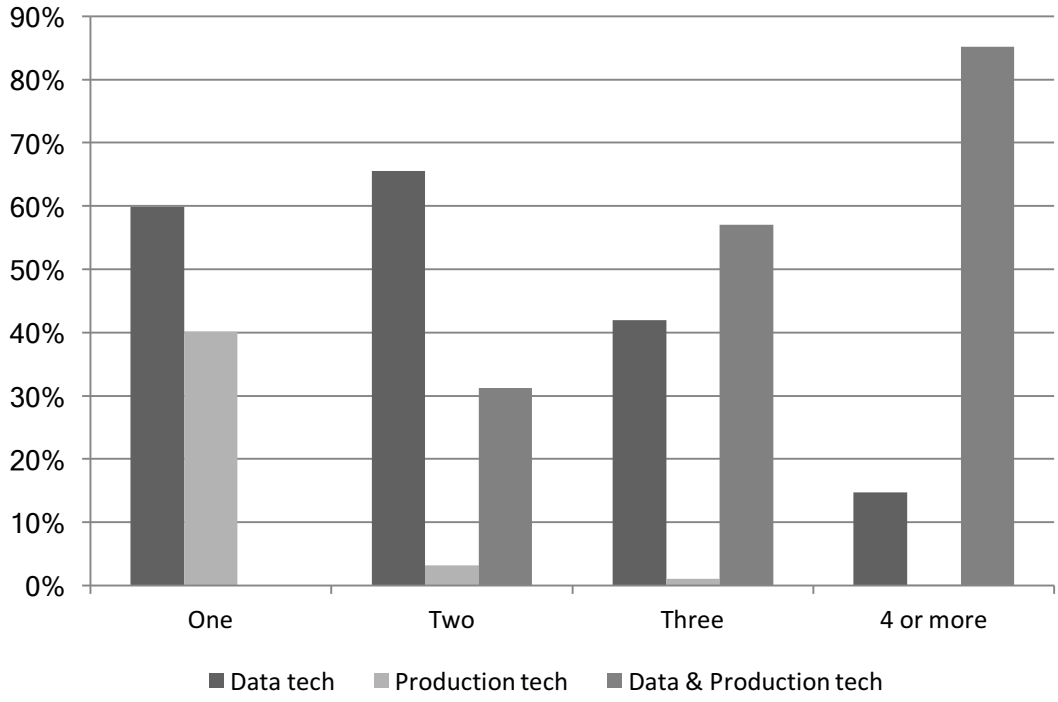
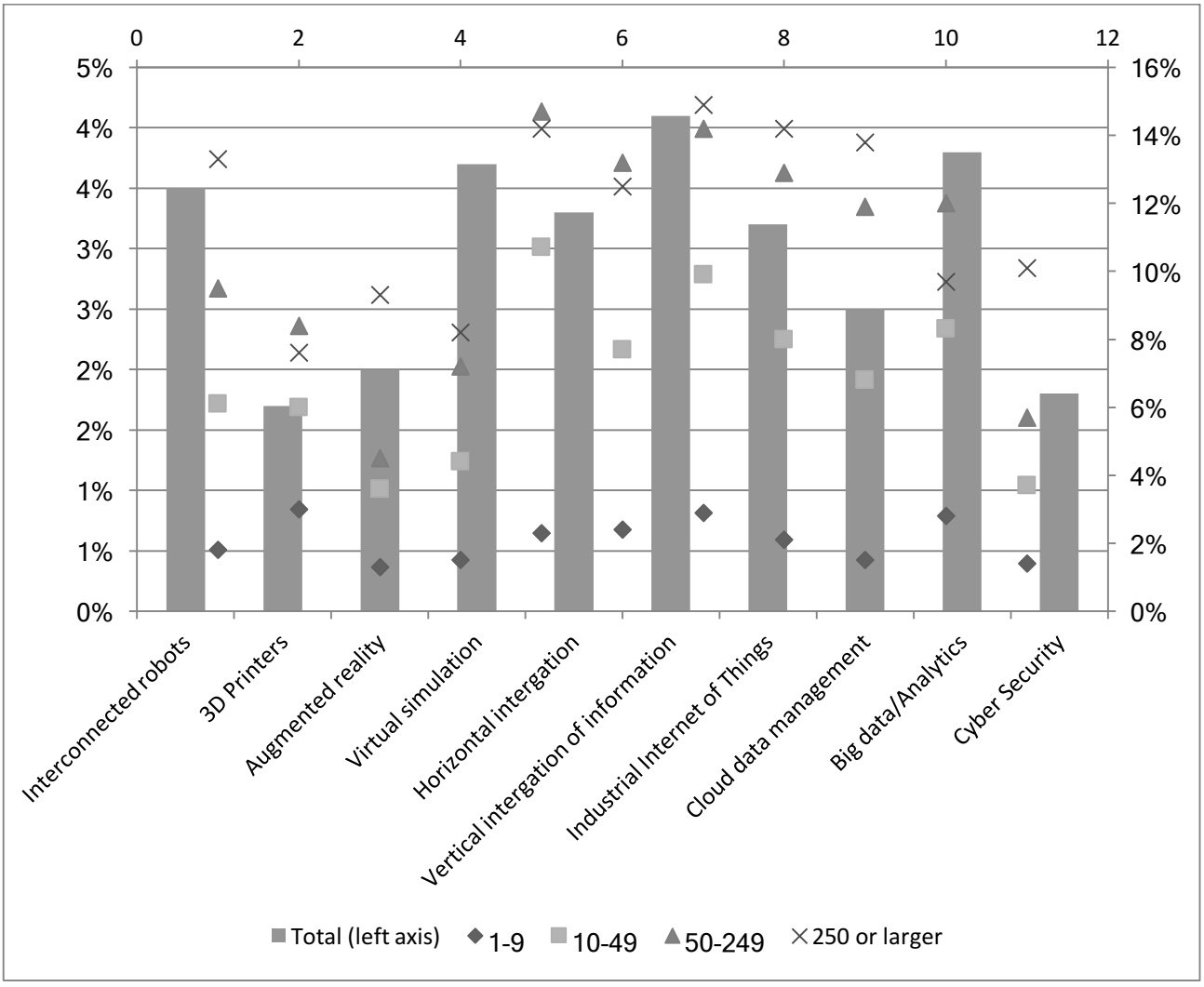



**Figure 1.6. Type of 4.0 technology used by number of applications (percentages).**



As for non 4.0 businesses that are planning to introduce new technologies over the next three years, it is possible to observe that the propensity to innovate applies towards all of the considered technologies (Figure 1. 7). In other words, if compared to the current usage, the analysis of the planned interventions does not show a substantial variation in terms of preferences. The Internet of Things and the vertical/horizontal integration of information are among the most indicated technologies, whereas - in relative terms – a certain increase is detectable in the use of robots, 3D printers and smart materials.

**Figure 1.7. Three-years planned investments in 4.0 technologies by class size (share of total left axis, share of class size right axis).**




Overall, 10.0% of businesses (including those not currently involved) is planning to adopt at least one technology in the next three years (see Figure 1. 8). This share is considerably higher among firms with 10-49 employees (22.5%), and increases up to about one third of cases among medium-size and large businesses. Furthermore, firms located in Southern Italy show a lower propensity to innovate also with respect to planned investments (8.1% vs 10, 6%) - with gaps particularly pronounced among medium-size businesses.

**Figure 1.8. Businesses planning to adopt at least one 4.0 technology over the next three years by class size and geographical area.**

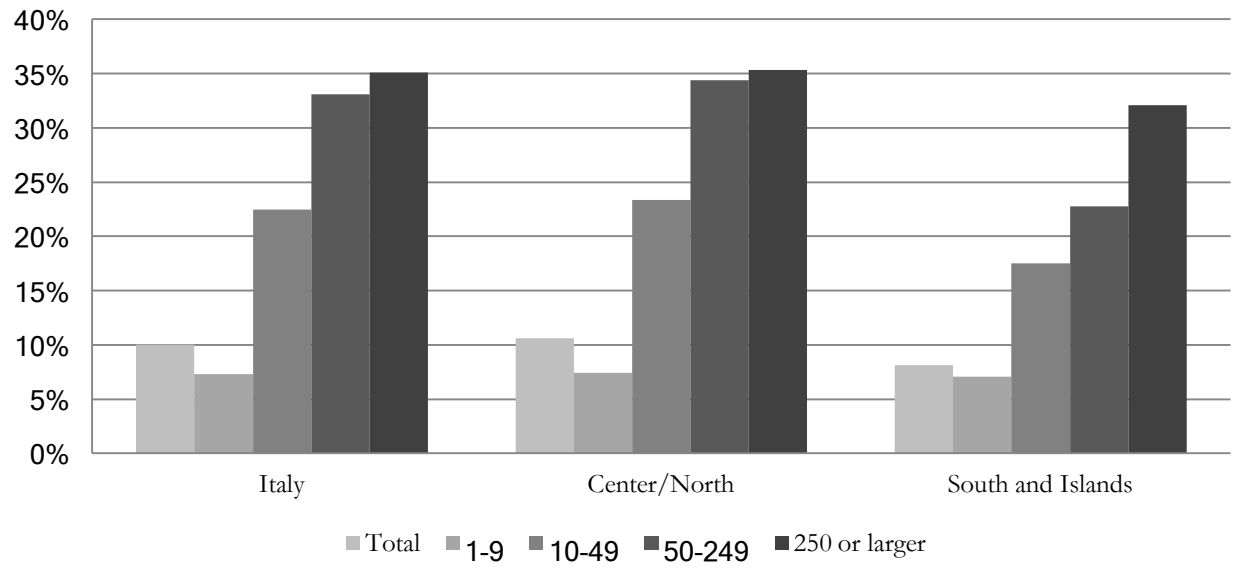
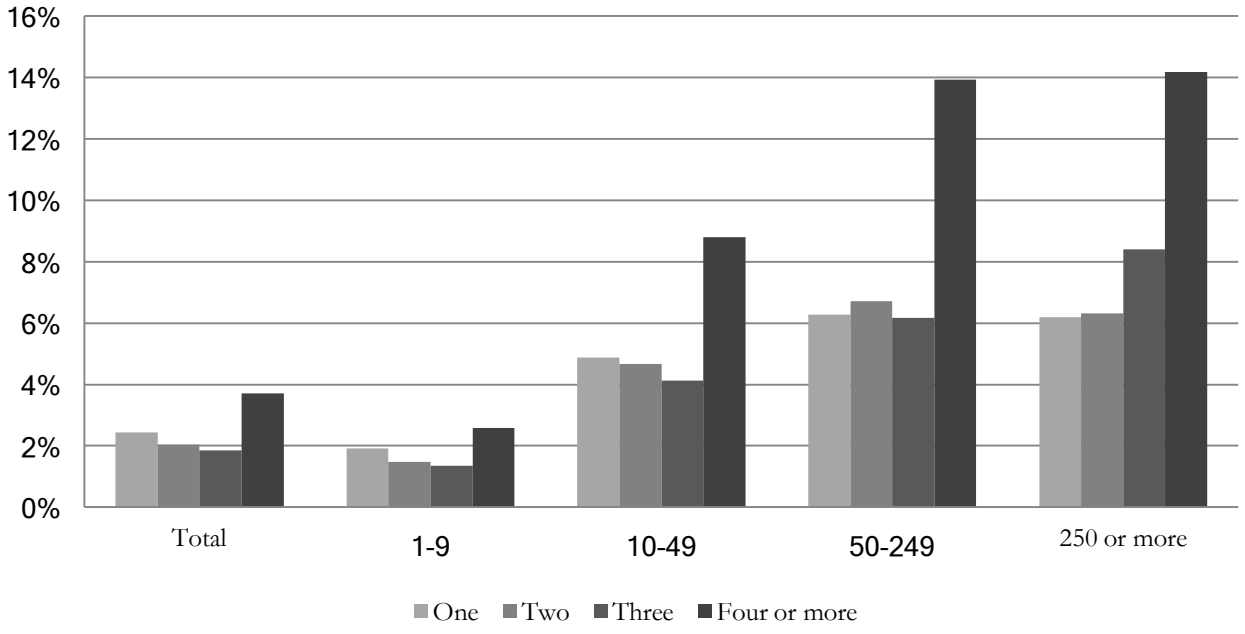



**Figure 1.9. Firms planning to adopt 4.0 technologies over the next three years by number of planned applications.**

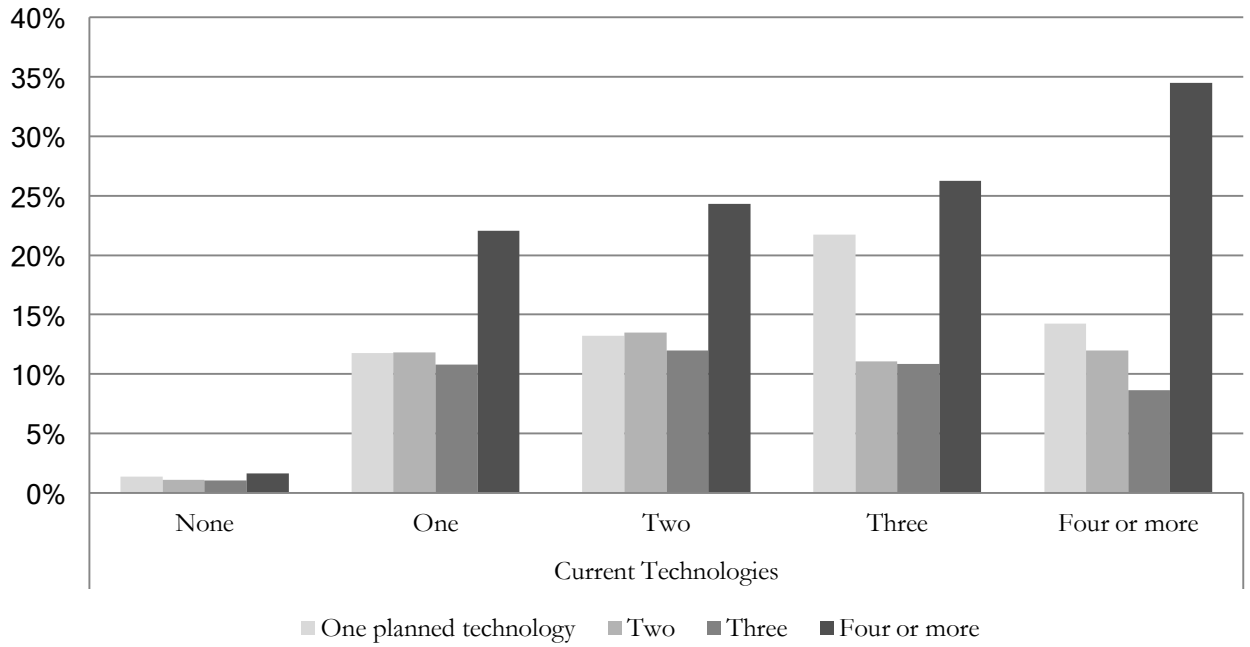



As for the number of planned interventions, data indicate the existence of a significant segment of firms planning a large number of programs (Figure 1. 9). Relatively to the whole sample, among the 10% of firms declaring to plan 4.0 technologies adoption in the near future, 3.7% plans to implement 4 or more different technologies, while more than a half of these (5.5%, as well relatively to the total sample) at least three of them. When considering firms above 50 employees, it comes out that one out of five businesses is planning to adopt at least three technologies.

Interesting evidences can be recovered by crossing data on the current usage of 4.0 technologies with those concerning the planned adoption. The bar chart displayed in Figure 1 .10 reports business share of the total sample by considering different classes, divided according the number of technologies that will be implemented in the next three years. These shares - at the same time - are grouped in analogous classes that take into account, differently, the *current* usage of 4.0 technologies (horizontal axis).

This exercise highlights the strong relationship between the two dimensions: among firms not using 4.0 technologies, we have very low shares of businesses that are planning to adopt them over the next three years. Conversely, businesses that are currently using 4.0 technologies show a high propensity to expand the current set of technologies. In addition, among those businesses which are planning to invest in technology, we have a high propensity to do so with reference to larger sets of technologies - in many cases, at least three of them. Even among firms that are marginally involved in the phenomena, there is a non- negligible segment of businesses that are in transition to the new smart factory paradigm.

**Figure 1.10. Number of 4.0 technologies to adopt in the near future by number of 4.0 technologies currently used (percentages).**

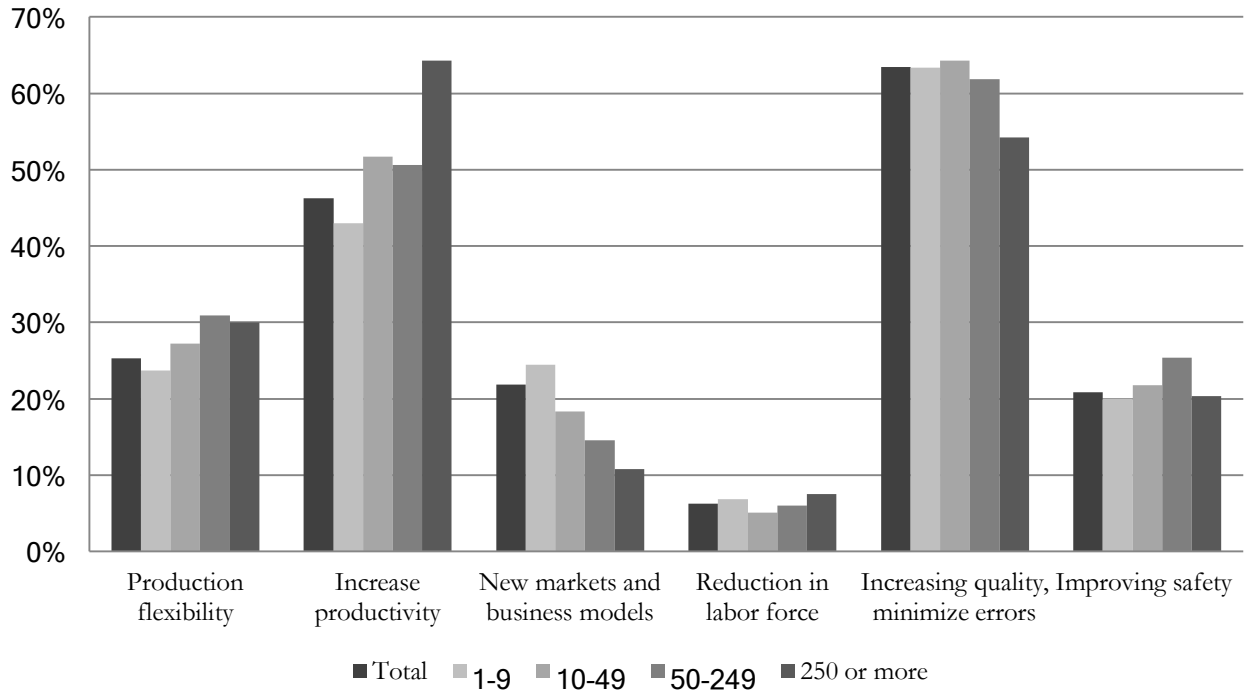



Besides the trend detectable in the spread of the industry 4.0 phenomenon, interesting evidences can be recovered when looking at the goals that entrepreneurs intend to achieve by means of future investments in 4.0 technologies. In the public debate it is generally assumed that the use of industry 4.0 technologies in production is expected to increase firms' competitiveness (cost optimization, error minimization, higher supply flexibility, etc.). The benefits expected, however, also include factors that are not directly related to cost minimization strategies, since firms may also be interested in increasing product variety and/or customization as well as in penetrating in new markets.

MET Survey data substantially confirm the above mentioned assumptions by showing some interesting facts (Figure 1. 11). First, it is interesting to observe that the prevailing aim deals with product quality improvement and error minimization (63,4 %). Differently, increase in productivity result to be the second most expected result - indicated by 43,3% of businesses using 4.0 technologies. The remaining items mentioned in the questionnaire are indicated for a fraction of businesses substantially smaller. Larger flexibility in production is indicated by 25.3% of respondents, while the opportunity to penetrate new markets from 21.9%. As for safety improvements the share scores to 20.9 %. Finally, it is worth noting that only 6.3 % of businesses expect a negative effect on the labor demand.

When assessing the role of firm size, few significant differences are observed. Productivity gains and larger flexibility in production are relatively more indicated among larger firms, while the possibility of entering into new business models tend to be more indicated among smaller enterprises. In addition, among largest companies we have higher expectations of a reduction in the labor demand - more in the case of those already using 4.0 technologies (7.4% vs. 4.2 % of those who only planned the adoption). Further, the share of firms expecting a drop in the labor demand is higher among businesses declaring to use both production data/information 4.0 technologies compared to the same figure among businesses using only data/information technologies (9.2% vs. 5.8%).

**Figure 1.11. Main goals to achieve by using 4.0. technologies (percentages).**




*N.B. Total may be above 100% because firms could choose up to two options.*

## 2. Propensity to innovate and current constraints

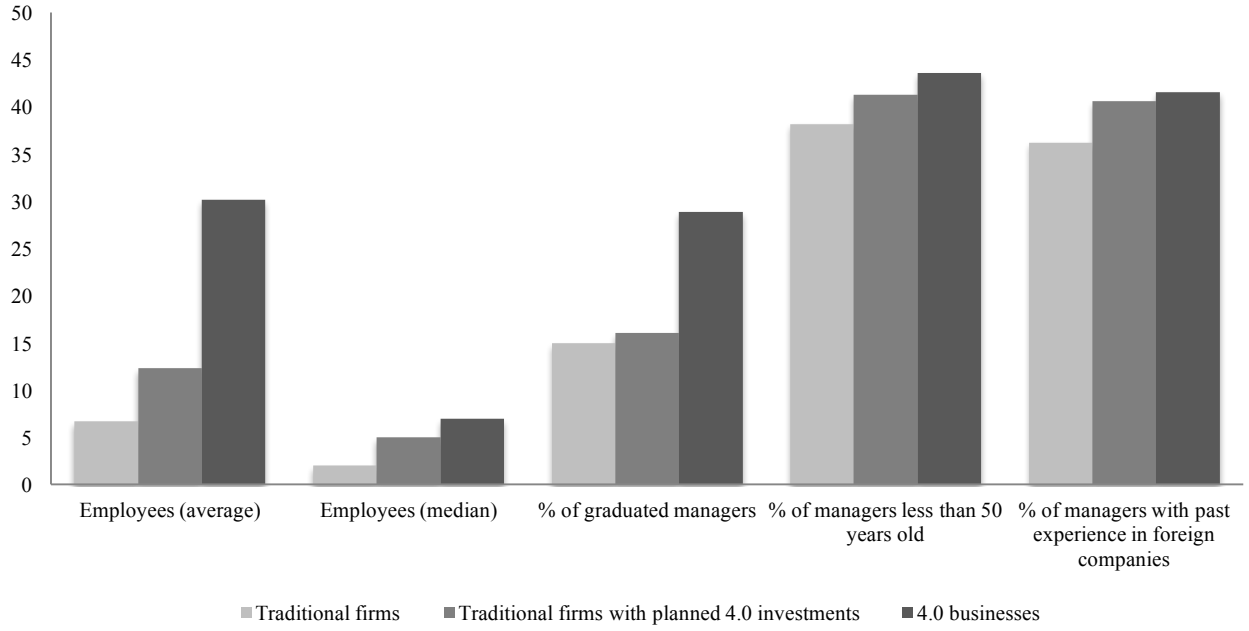
After the assessing the magnitude of the spread of industry 4.0 technologies in Italy, it may be useful to examine some characteristic elements of 4.0 businesses' profile, also with reference to agents that are not directly involved in the digitalization process of production.

The graph below summarizes some distinctive features – i.e. firms' average size and managerial profile.

4.0 businesses are significantly larger in size when compared to non 4.0 ones, though - as we have seen - a considerable amount of small and medium enterprises are involved in the phenomena. This is also reflected in summary statistics, as the average number of employees in the first group is 30 .1 - compared to the 12.3 of those businesses planning future operations and to the 6.7 of "traditional businesses" . Despite the large average size, the typical profile of 4.0 businesses seems to be mostly related to "small" companies, with median values that fall even below the threshold of 10 employees.

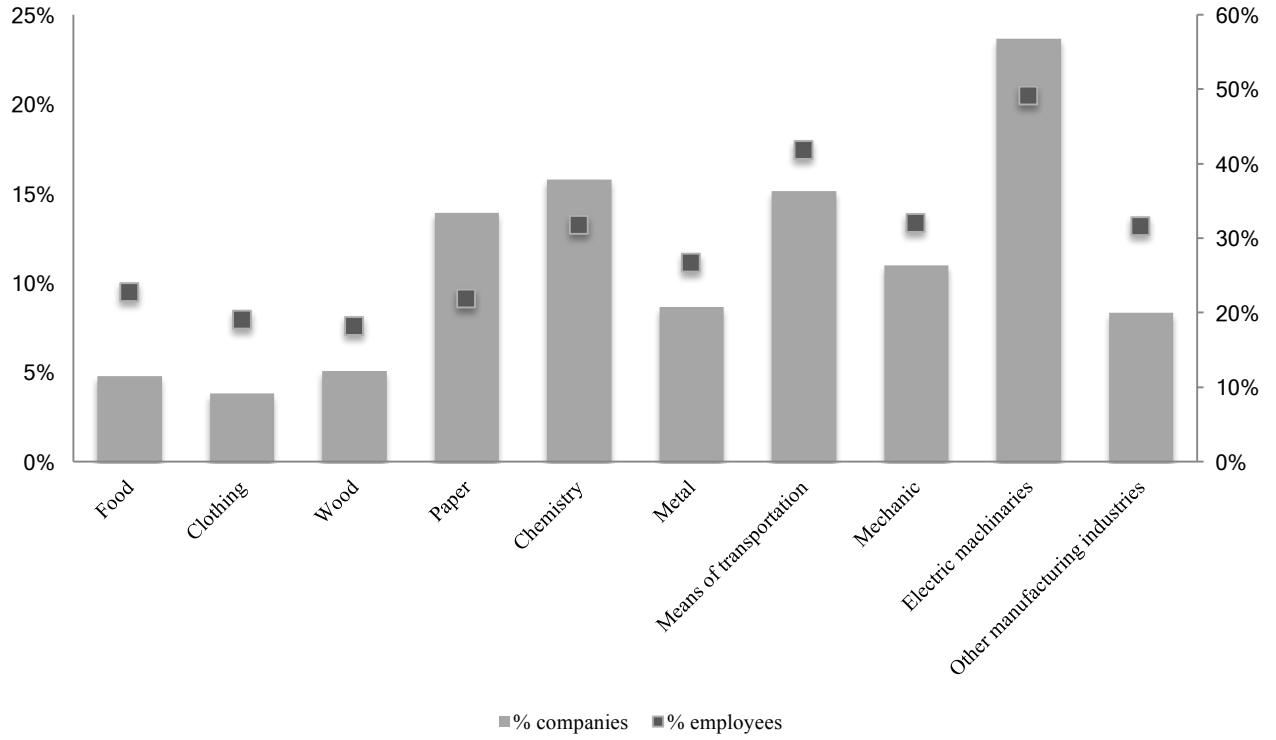
Not surprisingly, data show that as firm size is increase, managers results to be younger and more skilled. More specifically, among 4.0 companies senior managers who hold a degree represent 28.9% of the total - compared to the 15% observable in the case of traditional companies (16.1% of those who have planned interventions). As for managers' age, data show that 43.6% of top managers in 4.0 businesses are below 50, compared to the 38.2% in non 4.0 businesses. Finally, 41.6% of these managers had previous experience in other firms, while in the case of traditional businesses this figure drops to 36.2%.

**Figure 2.1. Businesses characteristics profiles: average size and human capital formation (percentages).**



As for the industry-level analysis, data depict a heterogeneous picture partly confirming some well-known fact. In Figure 2.2, the spread of the industry 4.0 phenomenon is described as both the within-sector share of 4.0 firms on the total number of firms (in that sector) and the share of 4.0 firms employment on total industry-level employment. The highest propensity to use 4.0 technologies is observable in the electrical machines and electronic equipment sector, in which 23.7% of firms is making use of 4.0 technologies. In terms of employment, this figure share accounts for 49.1% of the within-sector total employment. The use of Industry 4.0 technologies is intensive also in the production of vehicles sector (15.1% as a share of total businesses and 41.7% as a share of total employment), as well in the chemicals and plastic sector (were the figures are, respectively, 15.8% and 31.7%). In the mechanical sector, as well as in the iron and steel sector, the phenomenon is somehow less pronounced - whereas in the remaining industries data show a lower propensity to use 4.0 technologies, with the lowest figures appearing in traditional "made in Italy" economic activity branches, like in the case of the wood and furniture (18.1% of employment, 5.1% of businesses), food (respectively, 22.7% and 4.8%) and apparel (19% and 3.8%).

**Figure 2.2. 4.0 businesses by economic sector (within-sector share of total firms on the left axis - within-sector share of employment on the right axis).**

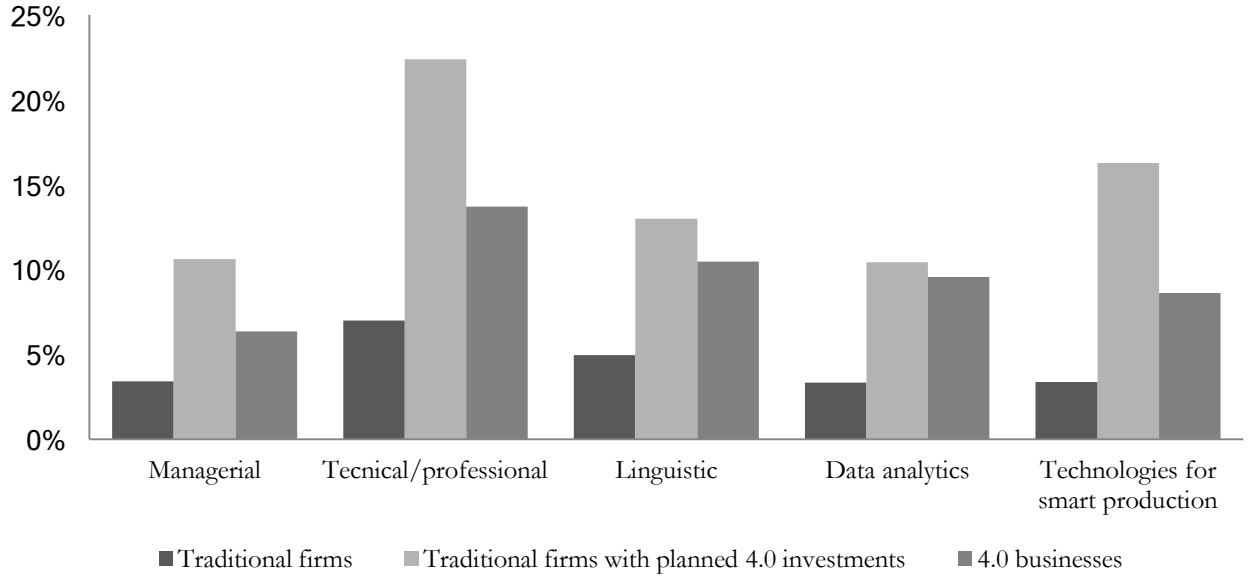



Another issue which is interesting to assess is whether firms are facing some constraint in matching the skills they are looking for in the labor market. It comes out that among traditional businesses there is little evidence of such constraints (Figure 2.3). Nevertheless, this outcome may be partly driven by

some structural weaknesses of traditional firms, which may find difficult to identify their constraints and, therefore, their strategies to face these challenges.

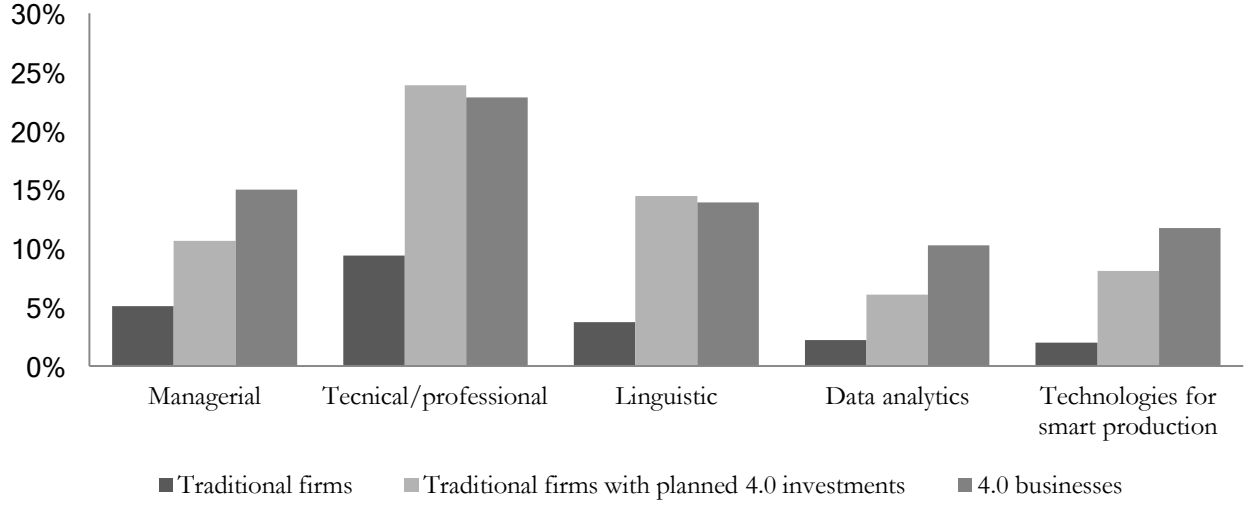
As for businesses planning the future adoption of 4.0 technologies, we find a higher perception of these of constraints (Figure 2.3). For 10.6% of them, the lack of adequate skill-levels arises in the case of managerial occupations, while for 22.4% these constraints are mostly perceived for what concerns technical/professional skills. As for skills directly related to the implementation of 4.0 technologies, 16.3% of firms in this group declares to face some constraint.

**Figure 2.3. Share of businesses declaring to face skills constraints by 4.0 profile and type of skill demanded (percentages).**




Similarly, it is interesting to assess whether 4.0 businesses are improving their position with reference to their perceived constraints (Figure 2.4). By looking at both 4.0 businesses and businesses planning the future adoption, indeed, data document a higher level of dynamism. In particular, 22.9% declare to cope with those constraints related to technical/professional skills and 15% with those related to managerial skills. Further, 13.9% improved its profile for what concerns foreign language skills, 11.7% improved its ability to manage 4.0 technologies and 10.2% improved its skill profile in the field of big data management.

**Figure 2.4. Share of businesses declaring to have solved skills constraints by 4.0 profile and type of skill demanded (percentages).**

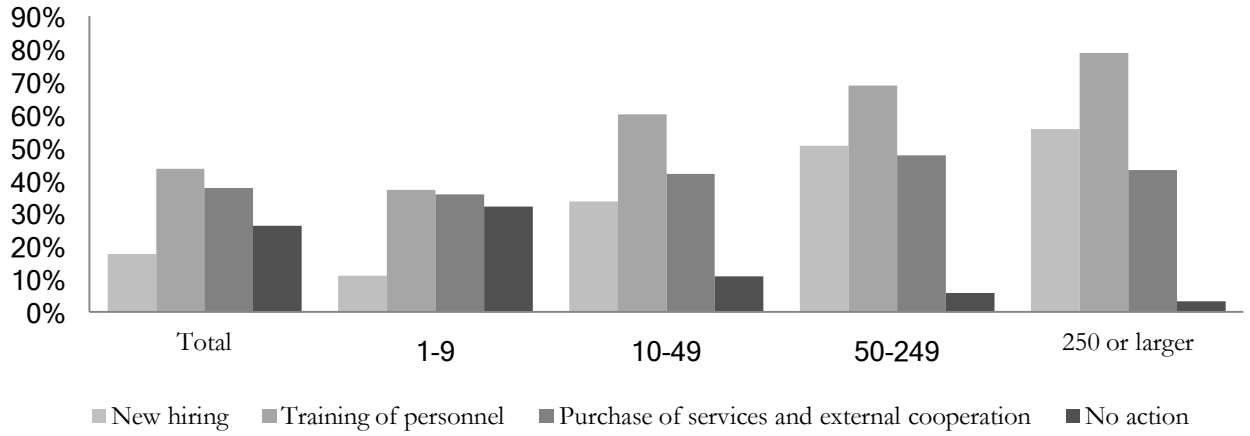



In order to overcome their difficulties, firms mainly rely on human capital formation measures (43.6%) and on outsourcing strategies (37.7%, see Figure 2.5). In 26.2% of cases, firms still have not put forward any corrective intervention, while only 17.7% of businesses declare to have start a new hiring program. When looking at the role of firm size, data show different trends between large and small firms. Large firms mostly rely on human capital formation and new hiring, while small and micro businesses are mainly orientated towards outsourcing solutions.

It is worth noting that this aspect represent a striking constraint for smaller firms, since about one third of micro businesses declare to not be able to cope with their constraints (11% in the case of small businesses).

When assessing the role of innovation (Figure 2.6), it comes out that 4.0 businesses have a relatively higher propensity to hire new personnel (29.5 vs 14.2% of traditional businesses) and to implement human capital formation measures (65.2% vs 37.9%).

**Figure 2.5. Strategy used by businesses to solve lack of skills constraints by class size and type of skill demanded (percentages).**




*N.B. Total may exceed 100% as more than one answer was allowed.*

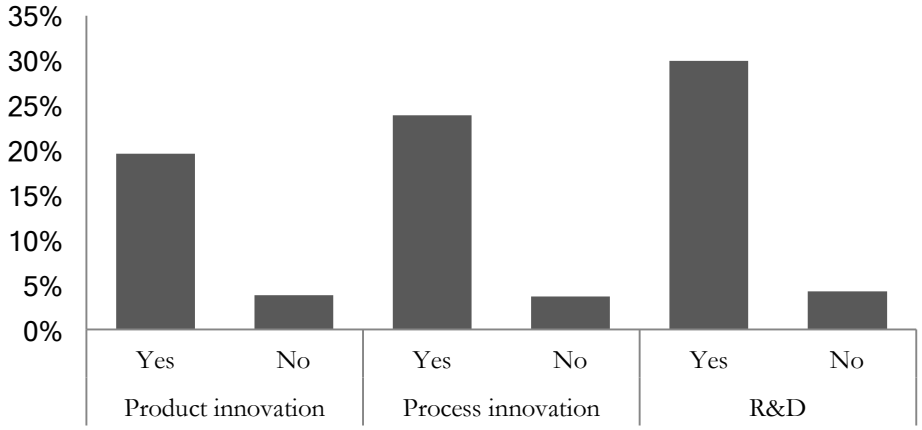
**Figure 2.6. Strategy used by businesses to solve lack of skills constraints by 4.0 profile and type of skill demanded (percentages).**


The overall picture indicates the presence of higher dynamism and a better strategic profile for 4.0 businesses. The most visible aspect of this trend may be observed, naturally, by analyzing firms innovation paths.

Figure 2.7 show reports the share of 4.0 businesses on the total sample, by distinguishing between firms which have (or have not) introduced process innovation or product innovation strategies and if they have (or have not) conducted Research and Development activities. It comes out a strong positive relationship between 4.0 technology adoption and process innovation strategies. However, it is worth noting that product innovation strategies are also strongly linked to 4.0 businesses, as well as in the case of R&D activities.

Analogously, data show that 30% of firms investing in R&S is currently make use of 4.0 technologies, whereas in the case of process innovation the share is of 23.9% (19.6% in the case of product innovation). Conversely, the figure for firms which do not innovate and do not invest in R&D is close to a negligible 4%.

**Figure 2.7. Usage of at least one 4.0 technology by innovation strategy and R&S activity profile (percentages).**




A more complete picture of 4.0 businesses degree of dynamism may be observed in Table 2.1. For each of the businesses groups (adopting 4.0 technologies, planning to adopt, and traditional businesses), Table 2.1 show the spread of a set of behaviors that are typically related to firm degree of competitiveness. More specifically, the table considers the innovations introduced, R&S activities (distinguishing between firm starting to invest and firms with constant investments), the field in which they mostly invest (traditional capital, ICT capital, human capital) and the presence on the international market.

It comes out that the technological profile of Italian firms is closely related to the above-mentioned behaviors. Indeed, 4.0 businesses are much more oriented towards the introduction of both process and organizational innovations, as well as to invest in R&D on an ongoing basis. As for businesses planning to adopt 4.0 technologies, similarly, it can be observed a higher propensity to start to invest in R&D.

When looking at ordinary investments, the different behavior of 4.0 businesses do not arise with reference to physical capital investments. On the contrary, a clear pattern is detectable only for what concerns human capital and ICT capital. Similarly, a clear positive relationship is recovered with reference to the presence on international markets. In relative terms, the share of 4.0 businesses exporting their products is 2.5 times larger than that of traditional businesses declaring to have access to the international market.

In sum, the evidence is that 4.0 businesses do follow a comprehensive approach to improve their degree of competitiveness. Further, such a dynamic behavior highlights the great existing divide between Italian 4.0 businesses and traditional businesses.

**Table 2.1. Businesses 4.0 profiles by innovation strategy, type of current investments and international trade activity (as a share of firms with the same 4.0 profile).**

| | Traditional firms | Traditional firms with planned 4.0 investments | 4.0 businesses |
|---|---|---|---|
| With product innovations | 23,5 | 61,7 | 67,7 |
| With process innovations | 17,1 | 59,6 | 66,1 |
| With organizational innovations | 18,1 | 45,2 | 54,6 |
| With new R&D projects (entrants) | 4,5 | 12,2 | 15,5 |
| With prolonged R&D projects | 6,4 | 25,2 | 41,7 |
| With investment in machineries | 30,7 | 64,1 | 72,7 |
| With ICT investments | 10,0 | 25,6 | 47,6 |
| With expenditure in personnel training | 7,7 | 24,1 | 34,1 |
| Exporters | 19,4 | 39,1 | 49,6 |

The higher degree of dynamism among 4.0 businesses in terms of competitiveness strategies is also reflected in better economic performances. As for employment growth, 36.2% of 4.0 businesses declared to have experienced an increase in the labor demand (16.4% in the case of traditional businesses), though the share of those declaring to have experienced a decrease (17.8%) is slightly higher of that observed in the case of other typologies of firm. By and large, this outcome seems to confirm the general interpretation according to which firms make use of 4.0 technologies in order to save on labor.

For what concerns another important indicator of business success – i.e. firms revenues - the better performances of 4.0 businesses appear even more pronounced. Further, it is possible to observe that economic indicators are better also for what concerns those firms that are directly involved in the production of 4.0 technologies – among which more than a half of respondents declared to have increase their business. As for businesses declaring to have not planned any future investment in 4.0 technologies, on the contrary, economic performances are considerably less virtuous (30% of respondents declared to have suffered a loss in their revenues).

**Figure 2.8. Employment variation in the last three years by 4.0 profile (percentages).**

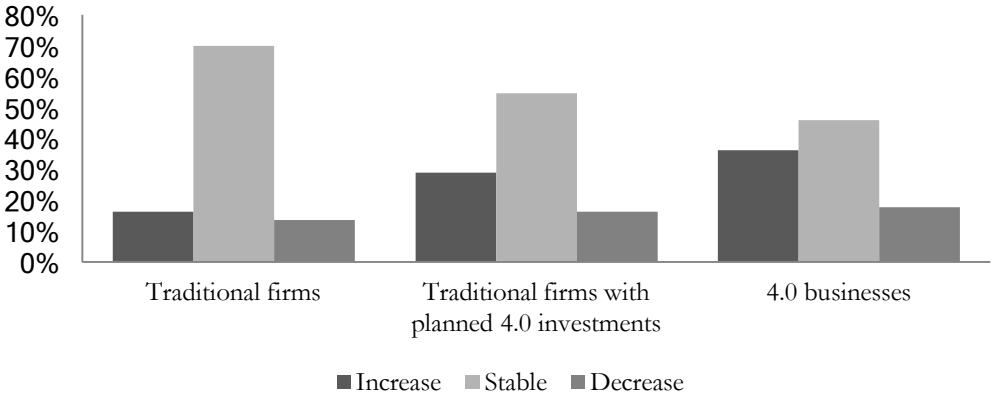
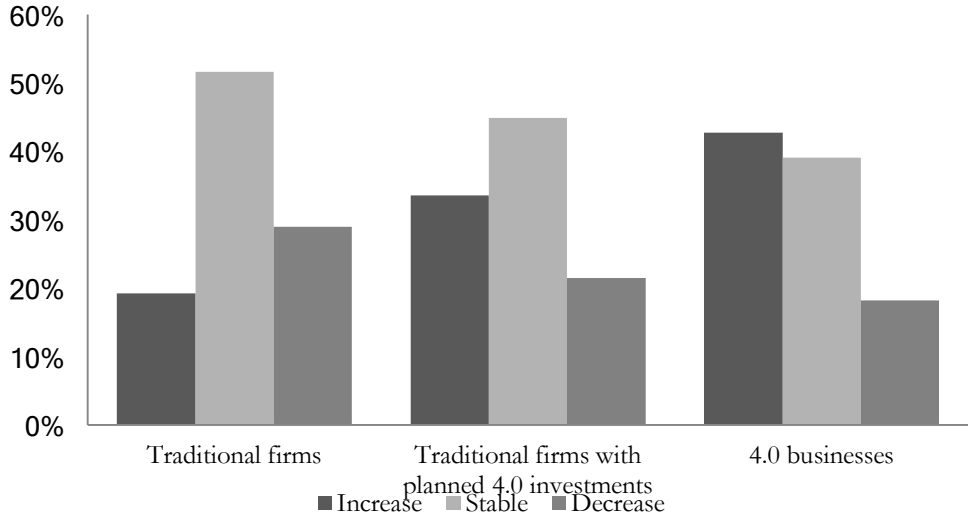


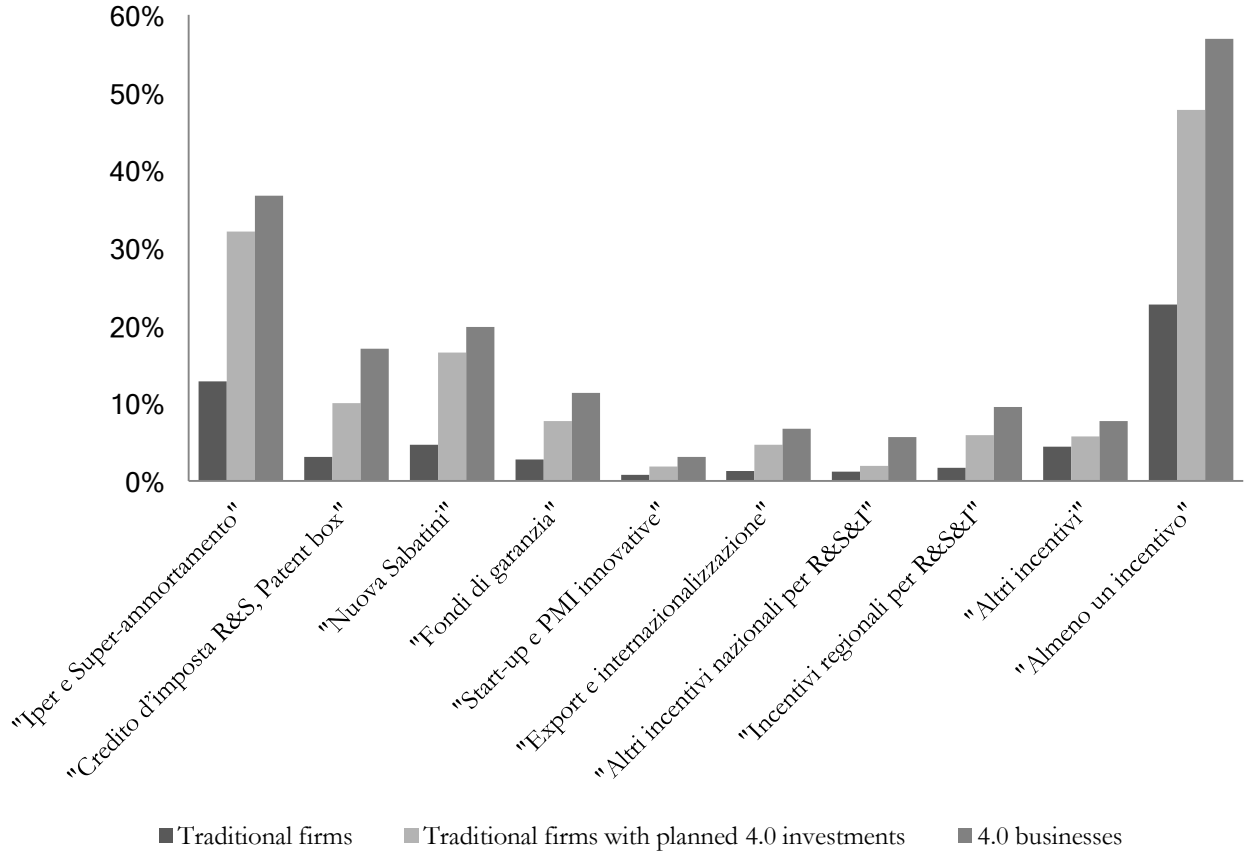

**Figure 2.9. Revenues in the last three years by 4.0 profile (percentages).**




## 3. Firms 4.0 and public aids.

In the scenario described in this document, the role of public policies seems to have been rather effective - by widely supporting businesses efforts to innovate. Indeed, the share of respondents declaring to have benefit from at least one public policy is, among 4.0 businesses, 56.9% - compared to the 22.7% observable among traditional businesses. In general, all firms have mainly relied on the "Super-depreciacion" and "Iper-depreciacion" policies (36.8% in the case of 4.0 businesses, 12.8% among traditional businesses), the R&S expenditure tax-credit policy (17% vs. 3.1%), the new "Sabatini" policy (19.8% s. 4.7%) and the guarantee fund policy (11.3% vs. 2.8%).

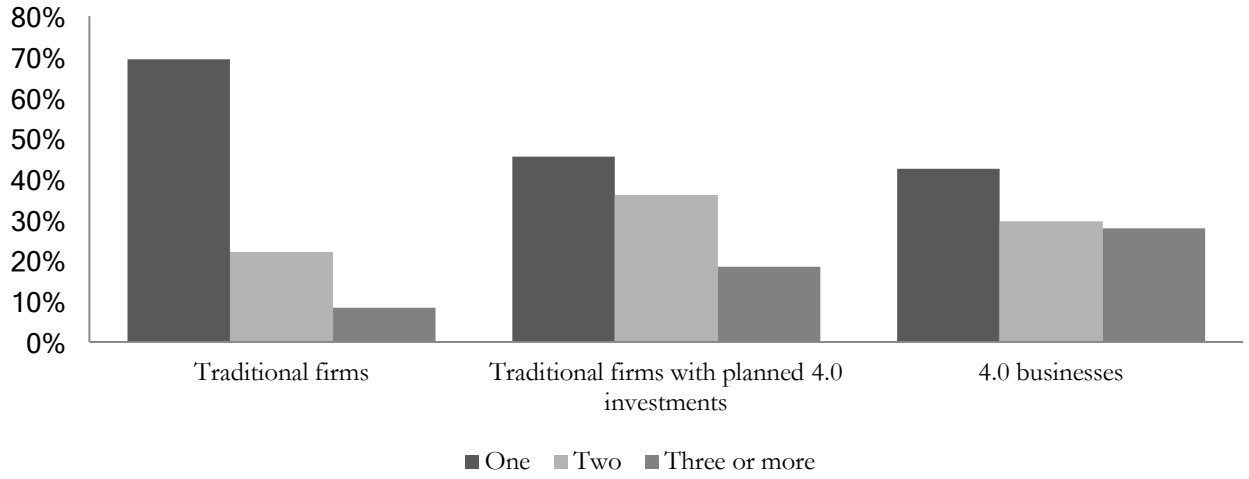
**Figure 3.1. Usage of public aids by 4.0 profile (percentages).**




Further interesting evidences may be recovered by looking at the number of policies used (Figure 3.2). Among 4.0 businesses, it is indeed observable a pretty high propensity to cumulate a number of public policies. In particular, among those that did benefit from public policies, 29.7% of businesses did benefit from at least 2 policies (36% among businesses planning future adoption), while more than a quarter (27.9%) did benefit from at least 3 policies (18.4% for future planners). In more detail, it comes out that a large share of firms did benefit from at least 2 policies that are put forward within the "Industria 4.0" policy plan.

As for traditional businesses declaring to have benefit from some policy, differently, the share of those who applied for just one policy is 70%.

**Figure 3.2. Number of public aids used by 4.0 profile (businesses share of total aided firms, percentages).**




More detailed evidences may be recovered by analyzing the most salient characteristics of those businesses who did benefit from the two main measures put forward to sustain investments in 4.0 technologies – namely, R&S tax-credit and Super/Iper depreciacion policies. Table 3.1 reports the spread of a set of competitiveness drivers (innovations introduced, R&D activities, investments and export) conditioning either on firms technological profile either on the use of these two different public policies.

It comes out that, for all types of business, both policies considered have sustained firms efforts in enhancing the degree of competitiveness as well as the technological profile. When using both types of policies, firms improved their competitiveness with reference to all the considered drivers - with a particularly wide gap between businesses planning to adopt new technologies and traditional businesses. It is also worth noting that, even when not immediately employed in 4.0 technology investments, these policies have still supported firms innovation in general (e.g. skills).

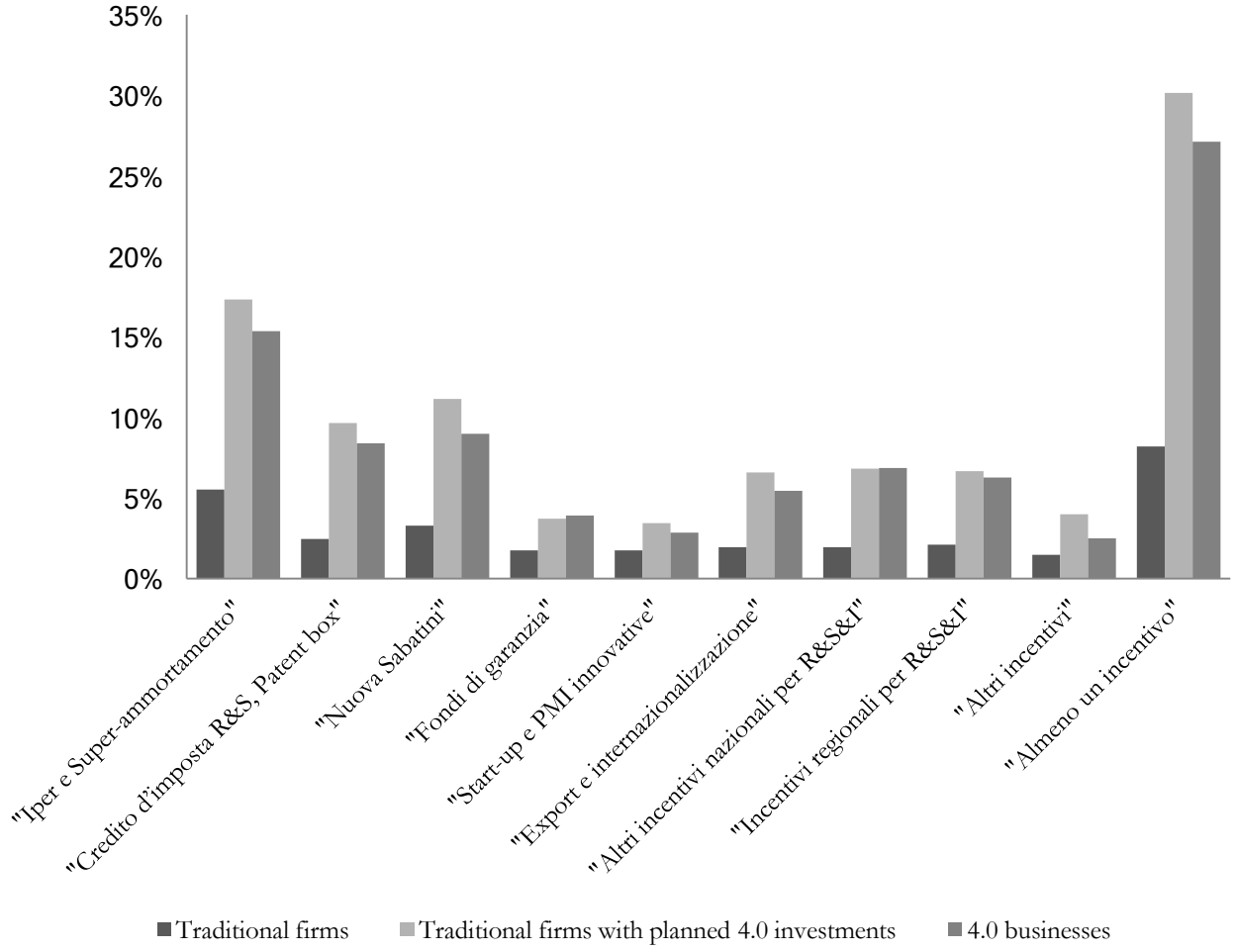
It is worth reminding the reader that these outcomes may either reflect a genuine upgrading processes (determined, or at least eased by the considered policies) or mere opportunistic behaviors. Though rather interesting, disentangling the role of these two different phenomena is not, however, among the goals of this report.

**Table 3.1. Businesses type of innovation strategy, investments and international trade activity by current public aid used (as a share of firms with the same 4.0 profile).**

| | Traditional firms | | Traditional firms with planned 4.0 investments | | 4.0 businesses | |
|---|---|---|---|---|---|---|
| | Exploting Credito d'imposta for R&D and/or Iper/Super ammortamento | | | | | |
| | No | Yes | No | Yes | No | Yes |
| With product innovations | 20,1 | 43,5 | 53,1 | 76,8 | 63,6 | 73,1 |
| With process innovations | 14,0 | 35,6 | 51,2 | 74,3 | 57,0 | 78,1 |
| With organizational innovations | 15,5 | 33,3 | 37,5 | 58,8 | 50,5 | 60,1 |
| With new R&D projects (entrants) | 3,7 | 8,9 | 11,3 | 14,0 | 15,2 | 15,9 |
| With prolonged R&D projects | 4,9 | 15,1 | 15,6 | 42,2 | 35,9 | 49,3 |
| With investment in machineries | 24,7 | 65,5 | 50,5 | 88,0 | 62,2 | 86,8 |
| With ICT investments | 7,7 | 23,1 | 15,3 | 43,8 | 40,3 | 57,4 |
| With expenditure in personnel training | 5,9 | 18,4 | 13,9 | 42,0 | 26,7 | 44,0 |
| Exporters | 16,9 | 34,2 | 28,8 | 57,2 | 40,4 | 61,8 |

Businesses planning to adopt 4.0 technologies made a widespread use of public policies during the past three years (47.8%). Further, within this group it is observable the highest share of businesses planning to make use of at least one policy in the near future – i.e. 30.1% vs. 27.1% of 4.0 businesses (8.2% of traditional businesses). Also in this case, the most indicated policies are the Iper and Super depreciacion policies, the CIRS, and the new Sabatini policy.

**Figure 3.3. Businesses planning to use public aids (as a share of firms in the same 4.0 profile).**



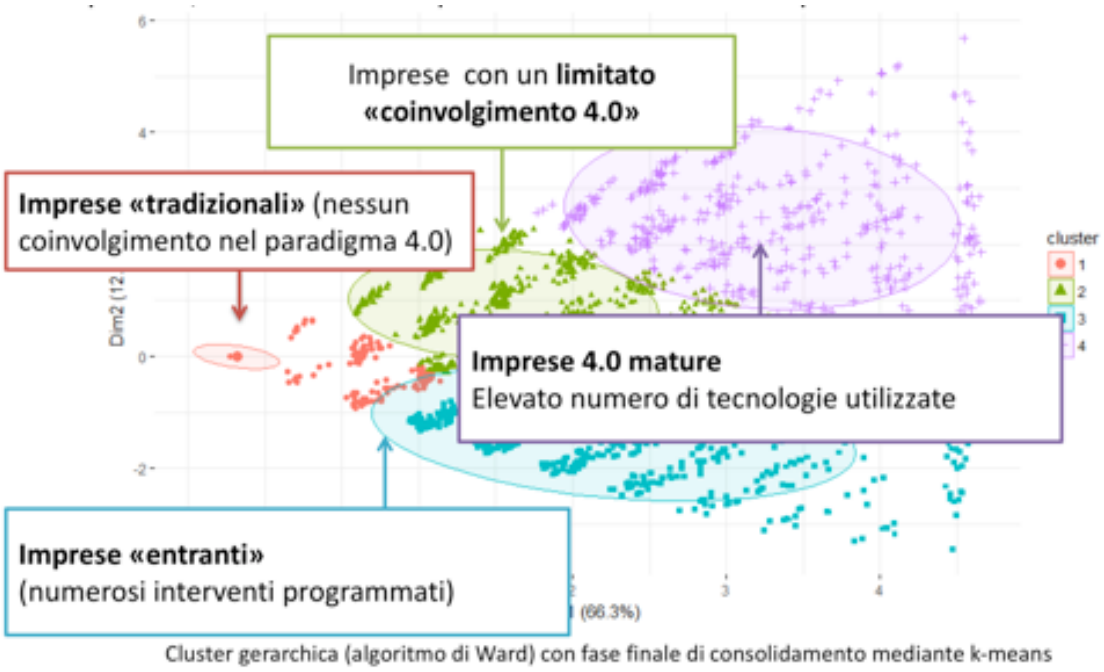
## 4. Firms profiles: a cluster analysis

To further investigate the behavior of Italian firms, this section clusters Italian businesses according to their involvement in the 4.0 paradigm. More specifically, a multidimensional approach aiming at identifying the relevant "structure" of data is used. The goal of this exercise is two-fold: 1) highlight the relationships between different relevant variables, 2) identify uniformities among different 4.0 businesses profiles. On the one hand, MCA analysis (multiple correspondence analysis) allowed for the identification of latency factors able to explain data variation. On the other hand, clusters analysis grouped observations according to the identified factors, by classifying firms in four homogenous groups. For a detailed explanation of the statistical aggregation process, see relevant literature (Arabie, P., & Hubert, L. (1994), Cluster analysis in marketing research. R. P. Bagozzi (Ed.), Advanced Methods of Marketing Research (pp. 160-189). Oxford: Blackwell and Greenacre, M., e Blasius, J. (2006). Multiple correspondence analysis and related methods. Chapman and Hall/CRC).

The analysis grouped observations in four different clusters (Figure 4.1), defined in the following categories.

- **"Traditional" businesses;**
- **"Incoming" businesses;**
- **"Limited 4.0 involvement" businesses;**
- **"Mature" 4.0 businesses.**

**Figure 4.1 Factor analysis.**



The first cluster is mainly composed by non-innovative businesses, without any R&D plan and, in particular, without any involvement in any 4.0 investment. The second cluster is characterized by the presence of traditional businesses moving towards the 4.0 paradigm (i.e. planning to adopt 4.0 technologies in the near future). The third cluster is composed by businesses with a limited usage of 4.0 technologies, mostly confined to data management technologies only. Finally, the fourth group is composed by highly-innovative and highly-internationalized firms, showing a substantial and well-established involvement in the 4.0 paradigm – mostly combining a great variety of 4.0 technologies, both for what concerns data management and production.

## 5. Multinomial logit

This section aims at empirically assessing the role of relevant firms characteristics in explaining differences in businesses 4.0 technological profile in the sample. In particular, a multinomial logit estimation strategy is used in order to regress businesses technological profile (as predicted by the cluster analysis - see section 4) on one-year lagged data recovered from 2017 MET Survey data. This exercise is carried on in order to evaluate the relative importance of different businesses behaviors and characteristics in predicting firms future technological path. More specifically, businesses 4.0 profile groups are expressed as an ordinal discrete variable, as follows:

**Y=0, Traditional businesses;**

**Y=1, Incoming businesses;**

**Y=2, Limited 4.0 involvement businesses;**

**Y=3, Mature 4.0 businesses.**

As reported in Table 5.1, all coefficients do show the expected sign and are statistically significant (in the majority of cases, at the one per cent level). In particular, all but the log business age covariate coefficient are positive, confirming the close relationship between firms propensity to innovate and their 4.0 technological profile. Remarkably, the (one year lag) R&D binary variable is the strongest predictor for the higher 4.0 technological profile, reflecting the well-known fact that investments in knowledge (and, more in general, in intangible goods) are the most important for increasing innovation in production.

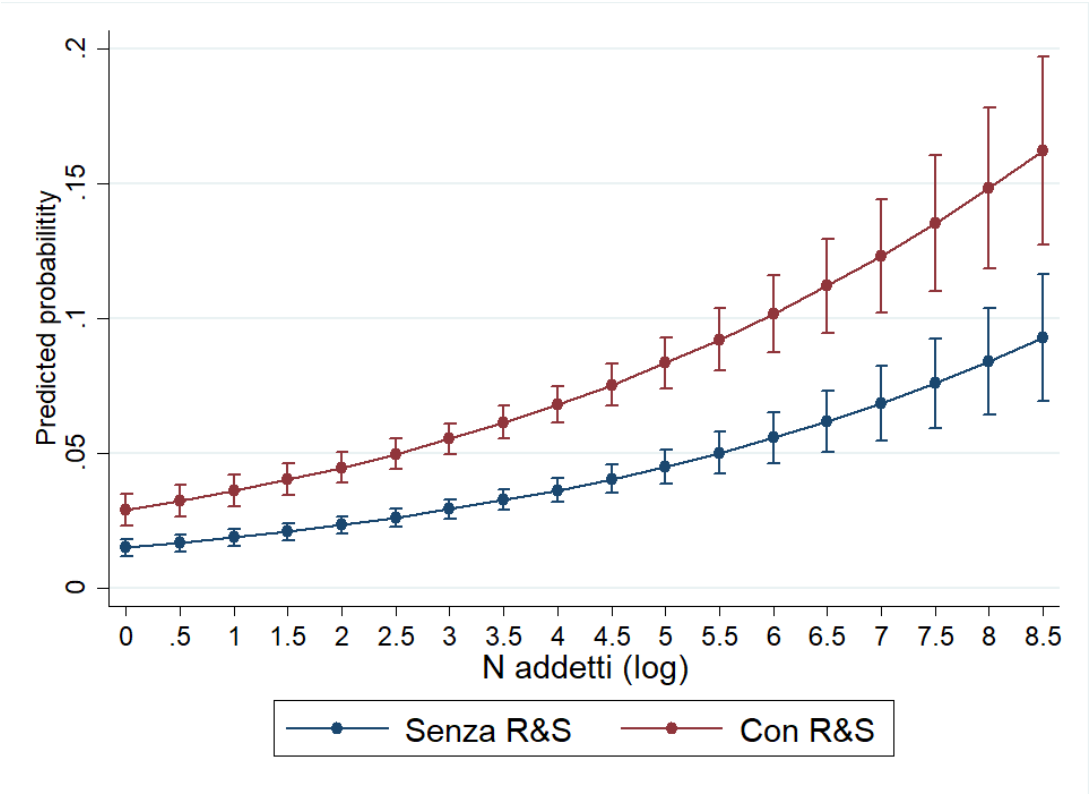
To understand in greater detail the magnitude of the effect of the lagged R&D indicator on businesses technological profile, Figure 5.1 reports the R&D marginal effect for different lagged firm size values – a covariate that we know to be positively and significantly correlated with the technological profile (see Table 5.1). As Figure 5.1 clearly shows, the higher the lagged business size, the higher the probability for businesses to belong to a higher technological profile. For instance, the predicted marginal effect of R&D is of a 1.7% higher probability to belong to a higher technological profile when the businesses size is 20 employees. For businesses with 50 employees, differently, the probability to belong to a higher technological profile increases of about 2% for those businesses with declared R&D activity.

**Table 5.1. Multinomial logit.**

| | Beta | SE | Z | p |
|---|---|---|---|---|
| **R&D activity (t-1)** | 0.692*** | (0.062) | 11.133 | 0.000 |
| **Product innovation (t-1)** | 0.254*** | (0.065) | 3.935 | 0.000 |
| **Process innovation (t-1)** | 0.620*** | (0.064) | 9.649 | 0.000 |
| **Organizational innovation (t-1)** | 0.293*** | (0.062) | 4.713 | 0.000 |
| **Human capital investments** | 0.484*** | (0.055) | 8.832 | 0.000 |
| **Principal-subcontractor tech. collaboration** | 0.582*** | (0.083) | 7.017 | 0.000 |
| **Export share of revenues (t-1)** | 0.002** | (0.001) | 2.353 | 0.019 |
| **Aids (Super-depreciacion and CIRS)** | 0.505*** | (0.055) | 9.113 | 0.000 |
| **(log) Employees (t-1)** | 0.205*** | (0.026) | 7.806 | 0.000 |
| **(log) Labor productivity (t-1)** | 0.173*** | (0.061) | 2.829 | 0.005 |
| **(log) Age (t-1)** | -0.081** | (0.037) | -2.219 | 0.027 |
| **Obs** | 9.490 | | | |

Note: Regression includes an intercept and controls for firms industrial-group membership, Bogliacino and Pianta (2016) revised Pavitt taxonomy categories, leverage, and Italian macro regions (South and Islands, Center, North-West and North-East). ***, p=<0.01; **, p=<0.05; *, p=<0.1.

**Figure 5.1. Marginal effects.**



## Summary

The descriptive analysis proposed for Italy provides a rich set of information allowing to draw some interesting considerations.

MET Survey data show that, at the beginning of 2018, 8.4% of Italian businesses make use of at least one of the technologies considered, i.e. “4.0 businesses”. Moreover, the data show that 4.7% of the firms - even if not currently using any of the above mentioned technologies - are planning to introduce new technologies on the coming three years. Therefore, firms that are both not using and not planning the introduction of any of the considered technologies (i.e. traditional businesses), represents still the vast majority of Italian firms - i.e. 86.9%.

As expected, the propensity to introduce 4.0 technologies increases with firm size. In detail, 4.0 businesses represent 18.4% of small firms (i.e. 10 to 49 employees), while among medium-size companies (50 to 249 employees) their share almost doubles, representing more than one third of firms in this class size – i.e. 35.5%. However, the diffusion of 4.0 technologies for small firms, above 10 employees has to be considered as relevant.

Evidence suggests that the digitalization of the production processes will increase in the near future. In fact, the share of non 4.0 businesses reporting to plan the introduction of 4.0 technologies in the near future is 4.7%, being even higher for small and medium-size businesses (respectively, 9.4 and 8.2%). The data also show a striking asymmetry between 4.0 technologies that are directly related to production (interconnected robots, additive manufacturing, simulation, augmented reality and smart materials) and 4.0 technologies that are mostly related to information and data exploitation (horizontal/vertical integration of information, cloud computing, big data, analytics, etc.).

According to this breakdown, 4.0 businesses can be associated to three distinct groups. Barely half of these firms make use of data management technologies only, whereas more than one third (36%) introduced both technologies directly related to production (including planning and simulation activities) and those related to data management. Conversely, the smallest group is composed of firms introducing production technologies only (16%). The first group is predominant among small and micro businesses, whereas above the threshold of 50 employees is the second group to be predominant – representing more than a half of medium-size businesses and almost 70% of large businesses.

The digitalization of the production processes in Italy mostly involves cyber security technologies, horizontal integration and the internet of things.

Among medium-size and large firms, the most of the investments are directed towards cyber security technologies and vertical/horizontal integration of data and information. For what concerns interconnected robots, 3D printers and virtual simulations, the data show that these technologies are relatively relevant among large businesses only.

In most cases, the involvement in 4.0 technologies appears to be limited to the use of few applications. Indeed, 62.4% of 4.0 businesses make use of one (37.3%) or at most two technologies ( 25.1%). Above 50 employees the "toolbox" expands, but it is only in large businesses that it is

possible to observe an integrated system of different technologies at work. In fact, over 60% of large companies use at least four different 4.0 technologies.

Among businesses employing up to two technologies, data acquisition and information management is predominant – i.e. 59.8% of businesses among firms using only one technology and 65.4% among those using two technologies. When using three technologies, the probability of observing both strictly productive and information management technologies increases significantly (56.9%). Above three technologies, the use of both types is predominant.

Consistently with the smart factory paradigm, the usage of production technologies is closely related to the exploitation of data produced along the production process. On the one hand, from two technologies used onward, businesses that make use of production technologies only result to be rather marginal. On the other hand, among businesses using only one production-type technology 3D printers are predominant.

Besides the trend detectable in the spread of the industry 4.0 phenomenon, evidences can be recovered when looking at the goals that entrepreneurs intend to achieve by means of future investments in 4.0 technologies. In the public debate it is generally assumed that the use of industry 4.0 technologies in production is expected to increase firms' competitiveness (cost optimization, error minimization, higher supply flexibility, etc.). The benefits expected, however, also include factors that are not directly related to cost minimization strategies, since firms may also be interested in increasing product variety and/or customization as well as in penetrating in new markets.

The prevailing aim deals with product quality improvement and error minimization (63,4 %). Differently, increase in productivity result to be the second most expected result - indicated by 43,3% of businesses using 4.0 technologies. The remaining items mentioned in the questionnaire are indicated for a fraction of businesses substantially smaller. Larger flexibility in production is indicated by 25.3% of respondents, while the opportunity to penetrate new markets from 21.9%. As for safety improvements the share scores to 20.9 %. Finally, it is worth noting that only 6.3 % of businesses expect a negative effect on the labor demand.

When assessing the role of firm size, few significant differences are observed. Productivity gains and larger flexibility in production are relatively more indicated among larger firms, while the possibility of entering into new business models tend to be more indicated among smaller enterprises. In addition, among largest companies we have higher expectations of a reduction in the labor demand - more in the case of those already using 4.0 technologies (7.4% vs. 4.2 % of those who only planned the adoption). Further, the share of firms expecting a drop in the labor demand is higher among larger businesses and those declaring to use both production data/information 4.0 technologies compared to the same figure among businesses using only data/information technologies (9.2% vs. 5.8%).

Another potentially interesting issue is whether firms are facing some constraint in matching the skills they are looking for in the labor market. It comes out that among traditional businesses there is little evidence of such constraints. Nevertheless, this outcome may be partly driven by some structural weaknesses of traditional firms, which may find difficult to identify their constraints and, therefore, their strategies to face these challenges.

On the other hand, we find a higher perception of these constraints for 4.0 firms: for 10.6% of them, the lack of adequate skill-levels arises in the case of managerial occupations, while for 22.4% these constraints are mostly perceived for what concerns technical/professional skills. As for skills directly related to the implementation of 4.0 technologies, 16.3% of firms in this group declares to face some constraints.

Similarly, it is interesting to assess whether 4.0 businesses are improving their position with respect to their perceived constraints. By looking at both 4.0 businesses and businesses planning future adoption data document, indeed, a higher level of dynamism. In particular, 22.9% declare to cope with those constraints related to technical/professional skills and 15% with those related to managerial skills. Furthermore, 13.9% of companies improved their profile concerning foreign language skills, 11.7% improved its ability to manage 4.0 technologies and 10.2% made improvements in the field of big data management.

In order to overcome their difficulties, firms mainly rely on human capital formation measures (43.6%) and on outsourcing strategies (37.7%, see Figure 2.5). In 26.2% of cases, firms still have not put forward any corrective intervention, while only 17.7% of businesses declare to have start a new hiring program. When looking at the role of firm size, data show different trends between large and small firms. Large firms mostly rely on human capital formation and new hiring, while small and micro businesses are mainly orientated towards outsourcing solutions.

It is worth noting that this aspect represent a striking constraint for smaller firms, since about one third of micro businesses declare to not be able to cope with their constraints (11% in the case of small businesses).

The overall picture indicates the presence of higher dynamism and a better strategic profile for 4.0 companies. The most visible aspect of this trend may be observed, naturally, by analyzing firms innovation paths.

We analyzed businesses on the total sample, by distinguishing between firms which have (or have not) introduced process innovation or product innovation strategies and if they have (or have not) conducted Research and Development activities. It comes out a strong positive relationship between 4.0 technology adoption and process innovation strategies. However, it is worth noting that product innovation strategies are also strongly linked to 4.0 businesses, as well as in the case of R&D activities.

Similarly, data show that 30% of firms investing in R&D is currently making use of 4.0 technologies, whereas in case of process innovation the share is 23.9% (19.6% for product innovation). Conversely, it is almost negligible (4%) for firms which do not innovate and do not invest in R&D.

Moreover, it comes out that the technological profile of Italian firms is strictly related to the above-mentioned behaviors. Indeed, 4.0 businesses are much more oriented towards the introduction of both process and organizational innovations, as well as to invest in R&D on an ongoing basis. Similarly, businesses planning to adopt 4.0 technologies present a higher propensity to start to invest in R&D.

When looking at ordinary investments, the different behavior of 4.0 businesses does not arise with reference to physical capital investments. On the contrary, a clear pattern is detectable only for what

concerns human capital and ICT capital. Similarly, a clear positive relationship is recovered with reference to the presence on international markets. In relative terms, the share of 4.0 businesses exporting their products is 2.5-times larger than that of traditional businesses declaring to have access to the international market.

In sum, the evidence is that 4.0 businesses do follow a comprehensive approach to improve their degree of competitiveness. Furthermore, such a dynamic behavior highlights the great existing divide between Italian 4.0 businesses and traditional businesses.

The higher degree of dynamism among 4.0 businesses in terms of competitiveness strategies is also reflected in better economic performances. As for employment growth, 36.2% of 4.0 businesses declared to have experienced an increase in the labor demand (16.4% in the case of traditional businesses), although the share of those declaring to have experienced a decrease (17.8%) is slightly higher of that observed in the case of other typologies of firm. Overall, this outcome seems to confirm the general interpretation according to which firms make use of 4.0 technologies so to save on labor costs.

Moreover, in order to reduce the effects of simultaneity and self-selection, we performed a two steps analysis: a first identification of clusters of at least partially comparable companies with MCA methodologies and a multinomial logit based on strategic behavior in 2015 and the technological options 4.0 in 2017/2018. The estimates, consistently with the expectations, show a very significant impact of the previous presence of innovative behavior and characteristics related to the quality of human capital on the technological options.

In the scenario described in this document, the role of public policies seems to have been rather effective - by widely supporting businesses efforts to innovate.

Indeed, the share of respondents declaring to have benefited from at least one public policy is, among 4.0 businesses, 56.9% - compared to the 22.7% of traditional businesses. In general, all firms have mainly relied on the “Super-depreciacion” and “Iper-depreciacion” policies – specifically targeted to 4.0 - (36.8% in the case of 4.0 businesses, 12.8% among traditional businesses), the R&S expenditure tax-credit policy (17% vs. 3.1%), the new “Sabatini” policy (19.8% s. 4.7%) and the guarantee fund policy (11.3% vs. 2.8%).