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INDUSTRY 4.0 ADOPTION AND INTERNATIONALIZATION: DOES SIZE MATTER?

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Abstract

Industry 4.0 technologies (I4.0) have the ability to transform the competitiveness of manufacturing firms, providing opportunities to redesign their production and market activities at the international level. However, little is known regarding if and how both small and larger firms exploit such opportunities. Drawing on an original database of Italian firms that have adopted 4.0 technology, this paper explores which new technologies firms adopt, their motivation for doing so, and the impact of this investment. To fill a gap in the literature, it distinguishes between small and medium-large firms, and between global and domestic small firms. The results suggest that small and medium-large firms differ in terms of number and the type of technology adopted, which is shaped by their reasons for doing so and in turn influences the effectiveness of the technology. Starker differences emerge when comparing small firms engaging with global sourcing and global markets, suggesting that a firm's strategy might play a greater role than size in explaining 4.0 adoption patterns.

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1. Introduction

The fourth industrial revolution is generating new opportunities for manufacturing firms in terms of value creation and the ability to control their value chain activities. This is the result of the adoption of new digital technologies, collectively known as *Industry 4.0* (Reinhard *et al.*, 2016). On the one hand, Industry 4.0 (hereafter I4.0) can influence firms' internationalization strategies (Strange and Zucchella, 2017). Scholars suggest global firms might relocate their production processes due to changes in location advantages (Ben-Ner and Siemsen, 2017). The adoption of new technologies may enable firms in high-cost countries (i.e. Europe or US) to reshore their manufacturing activities as the new technologies enable improvements in production processes as well as in relationships and control along their value chain (Ancarani *et al.*, 2019; Dachs *et al.*, 2019). Moreover, the new technologies allow firms being closer to the final markets, reducing the time to market response and increasing interaction with the final customers (Laplume *et al.*, 2016). Additive manufacturing (AM), such as 3D printing, is considered one of the driver of this relocation of manufacturing activities, where the geography of production is based on the ability to personalize the product working shoulder-to-shoulder with the customer and to redesign entire value chains at the global level (Rehnberg and Ponte, 2016). On the other hand, firms can exploit technologies such as robotics and other automation technologies to drive production efficiency and productivity, or implement AM to increase production variety based on new market requests (Martinelli, 2018). In bespoke production processes, economies of scope are more beneficial than economies of scale. In so doing, I4.0 allows small firms getting advantages from the adoption of new technologies reducing the differences with large firms. However, so far little is known about how firms implement I4.0 technologies with respect to the differences in how small firms and large firms invest in I4.0 technologies respect, by taking into account different forms of internationalization strategies. The paper aims at addressing this gap by exploring how firms adopt I4.0 technologies, considering for different size and internationalization strategies (upstream and downstream). Based on an original dataset of more than 1,200 Italian firms, the paper provides empirical analysis on which types of technologies firms are using, the motivation that lead to the investment in I4.0 and the outcomes of those investments. The results of the exploratory multivariate analysis suggest small and large firms differ in terms of number and type of technology adopted when investing in I4.0. However, our analysis indicates the firm's strategy is also relevant, as it can lead to different patterns of adoption in relation to their competitive strategy and degree of internationalization.

The paper is structured as follows: the second section is dedicated to theoretical background and focuses on the difference adoption pattern between

small and large firms and on the relationship between internationalization of small firms and I4.0 technologies. In this section our research questions are presented. The third section presents the methodology used for the empirical study. The fourth section highlights the results we gathered from the study. The final section discusses the results and presents implications from a theoretical, managerial and policy making perspective.

2. Theoretical background

2.1. Differences in I4.0 adoption between small and larger firms

I4.0 embraces a set of technologies—from advanced robotics to 3D printing, from big data to Internet of things (IoT)—that affect the organization of a firm's production processes and value chain activities involving both suppliers and customers. The growing literature on the topic emphasizes the rise of a new industrial revolution where firms can create value in radically new ways (Piccarozzi *et al*., 2018; Roblek *et al*., 2016): more customized product, increase service quality, build innovative products by using new materials, new forms and new processes.

Recent research often focuses on the new cyber-physical systems that have the ability to reconfigure operations (Agostini and Filippini, 2019; Dalenogare *et al*., 2018; Klotzer *et al*., 2017). Factories become "smart": more flexible and able to adapt automatically to events (maintenance, customized orders, breakdowns, etc.). This allows firms to increase productivity and control production more effectively. Many processes can be automated, changing the role of workers that now overlook and maintain machines more than being physically involved in production. Ubiquitous connectivity increases data availability and transparency of manufacturing activities and offers the possibility to further develop product and process innovation (Babiceanu and Seker, 2016). Moreover, these technologies allow greater flexibility and an increase in product variety, particularly when combined with AM. 3D printing solutions reduce barriers to customized production and enable customers to be involved in the production process (Petrick and Simpson, 2013).

According to literature on Industry 4.0 (Mittal *et al*., 2018; Rauch *et al*., 2018), also small firms can exploit this new set of technologies, applying them to several processes and even traditional machines (i.e. retrofitting is the practice of transforming an analogic machine into a digital one adding sensors and computing power) and this allows firms to facilitate access to and exchange of information on key processes. Small firms could improve their operational performance goals, including quality, flexibility, productivity, cost reduction, and delivery time. Yet small firms have to deal with

barriers to the adoption of I4.0, including expensive technological investments given the number of tools to be adopted (Frank *et al*., 2019; Reinhard *et al*., 2016) and do not have the resources for capability development (Moeuf *et al*., 2018, Schröder, 2016). In addition to resource scarcity, small firms may lack specific digital strategies related to prior investments in information and communication technology (ICT) (Moeuf *et al*., 2018).

Mittal *et al*. (2018), in their review of studies on the relationship between small and medium-sized (SMEs) and I4.0, explore nine levels of maturity in I4.0 adoption. Maturity model suggests the existence of different steps to reach a more sophisticated stage of I4.0 implementation and use. Although small firms often reach different levels of I4.0 maturity as the larger firms (Sartal *et al*., 2017), they could differ regard the data management activities. Moreover, at the managerial level, I4.0 implementation relates to the assessment of small firms' goals, strategic vision, and changes in operations and other business areas (Agrawal *et al*., 2018). This suggests small firms might follow the investment path of larger firms, adopting the same range of technologies, but implementing I4.0 in a differ manner. Prior studies on technological investments that consider the relationship between digital technologies in the context of ICT and firm strategy indicate this is not necessarily the case (McAfee, 2004). In fact, firms may decide to take into account their specific needs and their competitive environment, and invest in the right technological solutions (Chen and Kamal, 2016). In this respect, there is a strategic alignment between IT and the business (Strnadl, 2006; Wu *et al*., 2006). It follows that this could also occur when small firms consider I4.0 technologies.

2.2. Industry 4.0 and internationalization

Small firms' I4.0 investment strategies should be further explored, taking into account firms' internationalization strategies. Technology has always influenced internationalization of firms in a complementary way (Nosi *et al*., 2017). The rise of digital technologies affects a firm's ability to control distributed production processes and to share information from a distance with multiple actors within the value chain (Alcácer *et al*., 2016). Digital technologies have led to the development of the "iBusiness firm," which exploits the connectivity potentialities of technologies to coordinate a geographically dispersed network of suppliers in order to co-create a product with the customers (Brouthers *et al*., 2016).

Recent studies on I4.0 discuss how it offers firms the opportunity to rethink where and how value is created. According to Strange and Zucchella (2017), the range of I4.0 technologies can radically reshape the configuration of international firms, influencing their location and ownership. Automation may push firms to reshore their activities due to a change in

location advantages (Müller *et al*., 2017). The use of new technologies increases the levels of productivity making labor cost (Ancarani *et al*., 2019).

Most research focuses on 3D printing, which allows firms reducing their distance from the market and enables them to move their production activities close to buyers for customized production (Ben-Ner and Siemsen, 2017; Petrick and Simpson, 2013). In this manner, firms can reduces transportation costs, reduce delivery time and increase customer's satisfaction. At the same time, 3D printing affects the division of labor within the value chain; manufacturing processes can embark upon multiple paths of development, from substitution to complementarity (Rehnberg and Ponte, 2018). The role of firms within the value chain may vary depending on the impact of 3D printing on power distribution as well on the level of integration obtained. Large global firms may coordinate a distributed network of small factories as well as new independent producers, often according to the industry considered (Laplume *et al*., 2016).

The availability of the extensive amount of information collected through big data and IoT transforms a firm's relationship with the market, as the firm can know their customers better (McKinsey Global Institute, 2015; Uden and He, 2017). This reduces both the geographical and cognitive distance firms have from their customers, which can improve the process of product development through customers' interaction with the product. This new digital connectivity, or *digital ubiquity*, becomes the strategy through which firms control and empower their distributed activities and network of partners (Iansiti and Lakhani, 2014). At the same time, "smart" products reconfigure the entire value chain and the competitiveness of firms (Porter and Heppelmann, 2014).

Past research emphasizes that small firms differ both from medium and large firms in their forms of internationalization (Coviello and McAuley, 1999; Coviello *et al.* 2002). Smaller firms tend to internationalize upstream mainly through global sourcing, and rely more on export and flexible downstream investments abroad (Di Gregorio *et al*., 2009; Fernandez and Nieto, 2006). Moreover, studies Global Value Chains (GVC) stress that firms and in particular SMEs can internationalize through export, being part of Global Value Chains governed by global lead firms (De Marchi et al., 2018). Recent studies suggest the internationalization processes in a digital world will be more network-centered, emphasizing the relationship view of connections among dispersed actors (consistent with the Uppsala model) (Coviello *et al*., 2017).

Despite the relevant role that the different I4.0 technologies can have on internationalization strategies, however, the relationship between internationalization of small firms and I4.0 technologies is unclear. Limited knowledge is available on whether small firms differ from large firms in their adoption of I4.0 technologies, considering for their international com-

petitiveness and their strategical purposes. Studies discussing about the impact of I4.0 on international firms do not explicitly examine firm size (one notable exception is Chiarvesio and Romanello, 2018), or eventually adopt the perspective of Multinational Enterprise (MNEs) (Hannibal and Knight, 2018). In this respect, the aim of the paper is to explore the relationship between I4.0, international strategies and firm size, through the following main research question: is there a difference in I4.0 adoption paths between small and larger international firms?

To further develop our investigation we also consider that not all firms are internationalized, but they carried out their production activities domestically. From this point of view, even domestic firms can be interested in investing in Industry 4.0 technologies to achieve the benefits promised in such new technological scenario (Roblek et al. 2016). This could be particularly relevant for firms located in high-cost countries (de Treville et al., 2017). In this respect, our second research question investigates whether there is any difference in terms of adoption between internationalized small firms and small firms operating only domestically (both upstream and downstream).

3. Methodology

3.1. Sample and measurements

To answer the above-mentioned research questions, we use data collected through an original survey targeting Italian manufacturing firms coming from sectors in which the export rate is high (primarily automotive, fashion, and furniture and home products) located in the North of Italy. In 2016 the Italian government adopted the "National Plan for Industry 4.0" to provide financial and fiscal support to manufacturing firms adopting I4.0 technologies (Mise, 2018), which makes Italy an interesting setting to understand investments in I4.0 technologies. The country, however, is quite heterogeneous in terms of gross domestic product potential, innovation capabilities and internationalizations attitude (Berman *et al.*, 2019; De Marchi and Grandinetti, 2016; Missiaia, 2019): accordingly we decided to focus just in the most competitive part of the country, where we expect investments in new technologies is a more recurrent strategy.

The population consists of 7,714 manufacturing firms (73.5% small firms) drawn from the Aida–Bureau van Dijk database, which contains comprehensive economic and financial information on companies in Italy. The specialization considered refers to medium-tech and low-tech industries characterizing the Italian economic system. In fact, we sampled firms in eleven *Made in Italy* industries (automotive, clothing, electronic appliances, eyewear, furniture, jewelry, leather/footwear, lighting, rubber

and plastics, sports equipment and textiles), most of which have an annual turnover higher than one million euros. However, in the eyewear, jewelry, lighting, and sports equipment sectors, we also selected firms with a lower turnover, because those industries are characterized by a strong presence of industrial districts, where even small firms can be competitive due to their high specialization within the local value chain (Becattini *et al*., 2009).

We distributed a structured questionnaire designed and conducted using computer-assisted web interviewing (CAWI) technology to entrepreneurs, chief operation offers, and managers in charge of manufacturing and technological processes. We collected 1,229 questionnaires (15.9% of population; 84.9% small firms), 205 of which had adopted at least one of seven I4.0 technologies (16.7% of sample; 71.7% small firms). The questionnaire aimed to determine, through a dichotomous variable (*yes* or *no*), the adoption of certain I4.0 technologies (Almada-Lobo, 2016; Dalenogare *et al*., 2018): (1) robotics, (2) AM, (3) laser cutting, (4) big data/cloud, (5) 3D scanner, (6) augmented reality (AR), and (7) IoT and intelligent products. These technologies are those that support the strategic needs of manufacturing firms both in Business to Consumer (B2C) and in Business to Business (B2B) markets (Bonfanti *et al*., 2018). The questionnaire also sought to assess the firm's *upstream* (percentage of products created abroad and of suppliers located abroad) and *downstream* (percentage of export on turnover) international strategies.

Moreover, basing on the literature (Agostini and Filippini, 2019; Liao *et al*., 2017), we explored the reasons underlying the firm's decision to adopt (using a 5-point Likert scale, from *not at all important* to *very important*) or not adopt (dichotomous variable, *yes* or *no*) the I4.0s technologies. Finally, we assessed through a dichotomous variable (*yes* or *no*) both the value chain activities where firms focused their I4.0 investment and the effect of adoption, measured in terms of business results achieved with the new technologies (Dalenogare *et al*., 2018). The use of different measures (percentage, binary and Likert scale) for the different variables investigated minimize the existence of a common method bias, considering the single respondent design (Podsakoff *et al*., 2003).

3.2. Descriptive statistics of adopting firms

In order to analyze the differences in I4.0 adoption and strategy between small and large firms, we divided the sample between small and medium-large (ML) firms. This choice is motivated by the fact that research shows that, in the process of technology adoption, small firms differ from medium firms, and the process of the latter is closer to the larger firms (Bharati and Chaudhury, 2006; Dosi *et al*., 2008). According to EU size classes based on turnover, small firms are those with an annual turnover of less than 10

million euros, while ML firms have an annual turnover greater than 10 million euros. We obtained two groups of adopting (and non-adopting) firms (European Union, 2015). We focus on the adopting firms, of which there are 147 small firms (71.7%) and 58 ML firms (28.3%).

The descriptive statistics reported in Tab. 1 show no particular differences between the two groups of adopting firms. The only significantly differences pertain to international activities upstream (suppliers) and downstream (export). ML firms are more international than small ones.

Tab. 1: Descriptive statistics of the adopting firms, considering for different size classes

Export	Small firms	ML firms	Sig.
% Export on turnover (2016)	41.9%	55.5%	0.023
% First export country	25.9%	32.3%	
Research & Development (R&D)			
% R&D expenditure on turnover (2016)	6.3%	5.5%	
Production and supply chain			
Share of B2B firms	60.8%	60.3%	
Share of B2C firms	39.2%	39.7%	
Production of bespoke products	47.0%	46.0%	
Production of standard products	33.0%	36.4%	
Production of customizable products	20.0%	17.6%	
% of production (in value) realized in the region	61.8%	63.9%	
% of production (in value) realized in Italy	31.5%	25.0%	
% of production (in value) realized abroad	6.7%	11.1%	
% of suppliers located in the region	38.1%	28.5%	
% of suppliers located in Italy	47.0%	48.1%	
% of suppliers located abroad	14.9%	23.4%	0.072

Note: Small firms N = 147; ML firms N = 58. All variables are measured as percentage value. Source: our elaboration.

4. Results

4.1. Differences in I4.0 adoption between small and medium-large firms

We perform a three-step analysis to determine the differences in I4.0 adoption and degree of internationalization between small and ML firms. All statistical analyses were performed using SPSS software (version 25.0). Firstly, we compare I4.0 adoption strategies of small and ML firms; secondly, we compare small and ML internationalized firms; thirdly, we compare global and domestic small firms.

Tab. 2 reports the results analysis small and ML firms highlighting few differences. Statistically significant differences refer to the adoptioin of spe-

cific technologies: ML firms have higher investments in robotics (55.2% vs. 38.5% of small firms) and big data/cloud (53.4% vs. 34.5% of small firms). Furthermore, ML firms adopt higher average number of technologies (2.54) than small firms (2.05). As far as the value chain activities where firms focus the I4.0 investment are concerned, differences refer to use of I4.0 in the production processes and the management of supply chain activities.

In terms of motivation of adoption, ML firms differ from small ones as they are more likely to adopt I4.0 technologies mainly to compete in the international arena (3.86 ML vs. 3.30 small firms). Both groups aim at increasing efficiency and stated that new technologies allowed them improving their production efficiency. From the international point of view, ML have improved competitiveness in 31.6% of the cases (vs. 17 % of small firms) and are more likely (13%) than small firms (4.5%) to reconsider how they divide production between Italy and other countries (also this difference is statistically significant).

Instead, small firms implement I4.0, in a significantly higher percentage, in the prototyping and marketing processes. Data shows small firms more often invest in I4.0 to exploit new marketing opportunities (3.34) than ML firms (2.94). Even if there are no significantly differences for small firms in terms of impacts respect to the ML ones, it is interesting to see that 54.9% of small firms state they adopt I4.0 technologies to improve customer service, while 44.7% of ML firms claim they do so for this reason. This step of analysis reveals ML firms seem to be more focused on process and value chain management when choosing to adopt I4.0 technologies, while small firms are more concerned with the marketing activities, in term of new products development, new market opportunities and customer service.

Tab. 2: I4.0 technologies adoption rate of small and medium-large (ML) firms

Variables	**Small firms**	**ML firms**	
I4.0 technologies adoption [a]	*%*	*%*	***Sig.***
Robotics	38.5	55.2	0.030
Additive manufacturing (3D Printing)	33.1	37.9	
Laser cutting	47.3	41.4	
Big Data/Cloud	34.5	53.4	0.012
3D scanner	16.2	24.1	
Augmented reality	14.2	12.1	
IoT & Smart products	20.3	29.3	
Average num. of I4.0 techs adopted [c]	2.04	2.53	0.016
Value chain activities where focused the I4.0 investment [a]	*%*	*%*	***Sig.***
New products development	44.6	46.5	

Prototyping	54.5	41.9	
Production activity	57.9	72.1	0.099
Production management	44.2	33.1	
Logistic & Supply Chain Management	8.3	18.6	0.062
Marketing	28.1	11.6	0.029
Spare parts & Post-sale services	2.50	11.6	0.017
Impacts of adoption [a]	*%*	*%*	***Sig.***
Production efficiency	61.3	60.7	
Productivity	60.5	54.5	
Products diversification	36.6	37.2	
Product customization	17.9	18.6	
Customer service	54.9	44.7	
New markets penetration	23.9	18.4	
Reorganization of activities Italy/ Abroad	4.5	13.2	0.063
International competitiveness	17.0	31.6	0.055
Environmental sustainability	17.9	13.2	
Motivations of adoption [b]	***Mean***	***Mean***	***Sig.***
Efficiency seeking	3.60	3.74	
Increasing variety	3.12	3.11	
Exploiting new marketing opportunities	3.34	2.94	0.092
Maintaining production in Italy	2.73	3.03	
Reshoring of production activities	1.57	1.87	0.094
Facing international competition	3.30	3.86	0.018
Imitating competitors	1.87	1.97	
Improving customer service	3.97	3.84	
Environmental sustainability	2.75	2.73	

Note: Small firms N = 147; ML firms N = 58; [a] Binary variable, Chi-square analysis; [b] 5-points Likert scale, [bc] Independent sample T-test analysis. Darker gray are the higher values of the statistically significant differences. Source: our elaboration.

4.2 Differences in I4.0 adoption between small and ML international firms

The second step of the analysis examines only the firm's internationalization strategies in order to determine if small firms differ from ML firms in their I4.0 approaches (technology, value chain, motivation, and impact of adoption). Based on the questions about export strategies, the location of suppliers, and the value of production from abroad, we divided the groups into global and domestic firms. For this analysis we take into consideration firstly the global firms with an upstream international strategy in terms of production and/or supply activities (*global sourcing*) and, secondly, those with a downstream international strategy, in terms of export (*global market*).

In so doing, of the 100 international adopting firms with a global sourcing strategy, 71% are small firms and 29% are ML firms. Within the global market group, 150 are adopting firms, 109 (72.7%) of which are small firms and 41 (27.3%) are ML firms. As Tab. 3 shows, even with the introduction of the degree of internationalization in terms of upstream and downstream strategies, results are in line with what has emerged from the comparison between the overall groups of small and ML firms reported in Tab. 2. Where they differ is that, on average, global firms (both upstream and downstream) report a more intense adoption of I4.0, meant as average number of new technologies and a significantly higher adoption of robotics and big data/cloud for the ML firms respect to the small ones.

The main important differences concern the value chain activities where firms focused the I4.0 investment. ML firms that source globally mainly use I4.0 technologies in production (72.4%) and also differ from the small ones for a higher investment in the management of the supply chain activities (24.1% ML vs 10.6% small firms), also in the case of global market firms (19.4% ML vs 7.1% small firms), and for post-sales services (13.8% ML vs 1.5% small firms). Small firms that source globally use I4.0 technologies primarily to create prototypes, while global market small firms focus on marketing. The strategy of the firm and the pattern of adoption are cohesive. ML firms are more motivated to become more competitive by adopting new technologies that give them greater control over production and supply activities. Small firms adopt new technology in order to respond to frequent demand changes.

Tab. 3: I4.0 differences between international small and medium-large (ML) adopting firms

	Global sourcing		*Global market*	
Variables	**Small firms**	**ML firms**	**Small firms**	**ML firms**
I4.0 technologies adoption [a]	%	%	%	%
Robotics	31.0**	58.6**	41.3°	58.5°
Additive manufacturing (3D Printing)	36.6	34.5	31.2	36.6
Laser cutting	46.5	44.8	46.8	46.3
Big Data/Cloud	38.0*	62.1*	37.6°	56.1°
3D scanner	15.5	27.6	17.4	26.8
Augmented reality	14.1	17.2	14.7	14.6
IoT & smart products	22.5	37.9	19.3	29.3
Avg num. of I4.0 techs adopted [b]	2.07*	2.89*	2.08*	2.68*
Value chain activities and I4.0 investment [a]	%	%	%	%
New products development	53.0	51.7	46.9	47.2
Prototyping	59.1°	37.9°	55.1	44.4
Production activity	50.0*	72.4*	55.1	69.4

Production management	28.8	44.8	34.7	41.7
Logistic & Supply Chain Management	10.6°	24.1°	7.1*	19.4*
Marketing	27.3	17.2	31.6*	13.9*
Spare parts & Post-sale services	1.5*	13.8*	3.1	8.3
Impacts of adoption [a]	*%*	*%*	*%*	*%*
Production efficiency	56.5	60.7	54.9	61.3
Productivity	46.8	57.1	48.4	61.3
Products diversification	42.9	32.1	39.1	38.7
Product customization	22.2	21.4	18.5	22.6
Customer service	55.6	53.6	53.3	45.2
New markets penetration	20.6	17.9	25.0	19.4
Reorganization of activities Italy / Abroad	4.8*	17.9*	3.3*	16.1*
International competitiveness	16.1*	35.7*	18.7	29.0
Environmental sustainability	17.7	14.3	15.4	12.9
Motivations of adoption [b]	***Mean***	***Mean***	***Mean***	***Mean***
Efficiency seeking	3.64	3.82	3.54	3.75
Increasing variety	3.31	3.08	3.20	3.14
Exploiting new marketing opportunities	3.36	2.92	3.37	2.97
Maintaining production in Italy	2.78	3.28	2.84	3.03
Reshoring of production activities	1.61°	2.05°	1.58	1.88
Facing international competition	3.53*	4.17*	3.50	3.86
Imitating competitors	2.00	1.77	1.84	1.85
Improving customer service	3.98	3.88	3.94	3.77
Environmental sustainability	2.86	2.91	2.61	2.75

*Note: *Global Sourcing: Small firms N = 71, ML firms N = 29; Global market: Small firms N = 109, ML firms N = 41; [a] Chi-square analysis; [b] Independent sample t-test analysis. ***p <0.001; **p <0.01; *p <0.05; °p <0.10; Darker gray are the higher values of the statistically significant differences. Source: our elaboration.*

4.3 Differences in I4.0 adoption between global and domestic small firms

In the third step of the analysis, we focus on the group of small firms in an attempt to understand if upstream or downstream international strategies differ in their influence the I4.0 adoption of the global small firms in comparison to the domestic small firms.. The sub-sample of small firms that have international upstream strategies is composed by 71 (48%) global-sourcing firms vs. 76 (52%) domestic-sourcing firms. As far as the downstream strategies are concerned, there are 108 (73.6%) global-market small firms vs. 39 (26.4%) domestic-market small firms. Tab. 4 reports the results of the analysis.

There are many interesting differences between domestic and global sourcing firms when it comes to adopting I4.0 technologies. Domestic-sourcing small firms have a higher rate of adoption of robotics (45.5%)

compared to the global-sourcing ones (31.0%), highlighting greater need to improve production processes and activities to become more competitive. It is interesting to note how global and domestic firms vary in their reasons for adopting I4.0 technologies. Efficiency, customer service, and the possibility of new marketing opportunities are the main motivations for both for global and domestic small firms. However, global-sourcing small firms significantly differ from domestic ones, in adopting I4.0 technologies to become more competitive internationally (3.53) and to increase product variety (3.31). Indeed, global-sourcing small firms focus I4.0 investment primarily on new product development (53.0% vs 34.5% of domestic-sourcing small firms; the difference is significant). Meanwhile, domestic-sourcing firms concentrate, in a significantly way compared to the global-sourcing ones, more on production activities (respectively 67.3% vs 50.0%). In addition, domestic-sourcing small firms report a significant impact of new technologies on productivity (64.0% vs. 46.8% of global-sourcing small firms), notwithstanding the improvements in efficiency and customer service both types of small firms achieved. Interestingly, domestic-market small firms present the highest value (3.33) in terms of the relevance of environmental sustainability in the adoption of I4.0.

Tab. 4: I4.0 differences between global and domestic small firms

Variables	**Global sourcing**	**Domestic sourcing**	**Global market**	**Domestic market**
I4.0 technologies adoption [a]	%	%	%	%
Robotics	31.0°	45.5°	41.3	30.8
Additive manufacturing (3D-P)	36.6	29.9	31.2	38.5
Laser cutting	46.5	48.1	46.8	48.7
Big Data/Cloud	38.0	31.2	37.6	25.6
3D scanner	15.5	16.9	17.4	12.8
Augmented reality	14.1	14.3	14.7	12.8
IoT & Intelligent products	22.5	18.2	19.3	23.1
Avg num. of I4.0 techs adopted [b]	2.04	2.04	2.08	1.92
Value chain activities and I 4.0 investment [a]	%	%	%	%
New products development	53.0*	34.5*	46.9	34.8
Prototyping	59.1	49.1	55.1	52.2
Production activity	50.0°	67.3°	55.1	69.6
Production management	28.8	38.2	34.7	26.1
Logistic & Supply Chain Management	10.6	5.5	7.1	13.0
Marketing	27.3	29.1	31.6°	13.0°
Spare parts & Post-sale services	1.5	3.6	3.1	0.0
Impacts of adoption [a]	%	%	%	%

Production efficiency	56.5	66.0	54.9**	85.7**
Productivity	46.8°	64.0°	48.4*	81.0*
Products diversification	42.9	30.0	39.1	28.6
Product customization	22.2	14.0	18.5	19.0
Customer service	55.6	54.0	53.3	61.9
New markets penetration	20.6	28.0	25.0	19.0
Reorganization of activities Italy / Aborad	4.8	4.0	3.3	9.5
International competitiveness	16.1	18.0	18.7	9.5
Environmental sustainability	17.7	18.0	15.4	28.6
Motivations of adoption [b]	***Mean***	***Mean***	***Mean***	***Mean***
Efficiency seeking	3.64	3.54	3.54	3.85
Increasing variety	3.31*	2.87*	3.20	2.74
Exploiting new marketing opportunities	3.36	3.32	3.37	3.21
Maintaining production in Italy	2.78	2.68	2.84	2.32
Reshoring of production activities	1.61	1.53	1.58	1.53
Facing international competition	3.53*	3.00*	3.50	2.42
Imitating competitors	2.00	1.71	1.84	2.00
Improving customer service	3.98	3.95	3.94	4.11
Environmental sustainability	2.86	2.62	2.61*	3.33*

** Global sourcing N = 71, Domestic sourcing N = 76; Global market N = 108, Domestic market N = 39*

*[a] Chi-square analysis, [b] Independent sample t-test analysis; **p <0.01; *p <0.05; °p <0.10; Darker gray are the higher values of the statistically significant differences. Source: our elaboration.*

In terms of downstream strategies, international small firms differ from domestic ones in that they have a higher propensity to focus investment on marketing activities (31.6% vs. 13.0% of domestic-market small firms), confirming their market-based competitive feature. The domestic-market small firms show significantly higher outcomes compared to global market small firms in terms of production efficiency (85.7% vs. 54.9%) and productivity (81.0% vs. 48.4%), highlighting in this case the focus on production competitive strategies.

5. Discussion and conclusion

Using an original dataset, our research provides empirical evidence on how firms of different sizes and with different internationalization strategies, pertaining to both upstream and downstream activities, adopt I4.0 technologies. Currently, global sourcing and its relationship to a firm's adoption of I4.0 technologies is a popular research topic given the value I4.0 technologies adds to reshoring strategies (Ancarani *et al*., 2019; Dachs

et al., 2019; Müller *et al.*, 2017) and its potential to improve relationships along the value chain (Alcácer *et al.*, 2016). Similarly, I4.0 technologies are described as having the capacity to enable global-market firms to achieve higher export propensity, thanks to its ability to increase production efficiency and flexibility and provide a deeper understanding of customers (Kagermann, 2015).

ML firms compared to the small ones are more likely to adopt specific technologies such as robotics and big data/cloud, and to adopt more technologies than one at once. Same differences emerge considering the international strategy of small and ML firms. The relatively higher investments in production and data management technologies may be explained because larger firms face more complex activities when doing business on a global scale. The higher predisposition of ML firms toward production activities is confirmed by examining the business areas where firms invested in I4.0 technologies that refer to the management of production processes.

Firm size is an important factor that affects the adoption path of I4.0, but it is not the only relevant variable, as the study emphasizes the role of international strategies in shaping the manner in which a firm invest in I4.0 technologies. This is evident when comparing international small and ML firms and even more noticeable when viewing the data on global and domestic small firms. Both groups of small firms (global and domestic) exhibit a similar adoption rate for the seven technologies investigated. Only the domestic-sourcing small firms have a significantly higher adoption rate for robotics, highlighting the key role of production activities in local sourcing strategies. If small domestic firms want to stay competitive, all other factors being equal, they must increase their production efficiency and productivity, which may explain why they are keener to invest in robotics, interpreted as a proxy for production automation. However, it is interesting to notice that this does not eliminate (although reduce) the firms capabilities in personalizing the product. Automation is not embraced at the expenses of flexibility. On the contrary, small domestic firms demonstrate the original trait of mixing automation with variety of production.

Internationalization strategies play a key role when considering why firms adopt I4.0 technologies. If we focus on small firms, both global and domestic, we can see that the main motivations of adoption are: firstly improving customer service and then efficiency. This confirms that small firms are more reactive than proactive in the use of I4.0 technologies (Prause, 2019). Small firms tend to respond to a need originating in the market than to anticipate it. Efficiency is also important as it could be expected. All firms declared the need to improve efficiency, especially in a competitive market as the one Italian small firms are specialized in: traditional, medium-tech or low-tech products. In addition to efficiency and customer purposes, for global-sourcing small firms, increased global competition and the need to

improve product variety are two of the most compelling reasons to invest in new technologies. Meanwhile, domestic-market small firms are more likely to adopt new technology to increase their environmental sustainability, which is a means by which domestic firms can differentiate themselves and attract the interest of the market (Chiarvesio *et al.*, 2015). These strategies are clearer when examining where they invest in I4.0 technologies. Global-sourcing small firms apply the technology to new product development. The choice aligns with their need to increase product variety to be able to compete globally. On the other hand, domestic-sourcing small firms focus their investment on production activities. Again, this choice appears rational for specialized manufacturing firms in a high-cost country (like Italy). This result confirms previous findings about the role technology plays in supporting the management of customers at the international level (Leeflang *et al.*, 2014). Overall, the findings highlight the fact that small firms, like larger firms, take different trajectories when implementing the I4.0 paradigm, but the results are consistently favorable and show that the implementation of I4.0 is related to the firm strategy (Agrawal *et al.*, 2018) that affects also the internationalization strategies (Phillips and Moutinho, 2018). Our findings reveal several interesting theoretical, managerial and policy implications. From a theoretical perspective, the relationship between I4.0 and international firms is shaped by firm size, but more significantly, by international firm strategy. Rather than new technology altering a firm's international strategy, firms are more likely to view I4.0 technologies as tools to help them achieve that strategy. There is an alignment between l4.0 adopted and firm's international strategy. It is not so much the type of technology adopted as the motivation to do so that distinguishes the approaches of small and ML firms to I4.0. In particular, ML firms focus their I4.0 goals on becoming more competitive and on improvements to the production processes, whereas small international firms concentrate on market-driven activities. When comparing global and domestic small firms the business areas where firms implement the new technology represent the main difference between the two groups. This means that technology *per se* does not improve competition if it is not guided by a coherent strategy. On the contrary, is the fit between technology and the international strategy of the firms that pays off.

It is vital for managers to consider I4.0 as part of the firm's strategy in terms of international positioning. Managers should evaluate areas where they may need to implement new technology in relation to their overall and international strategies. Managers of small global firms should focus on marketing and innovation activities because certains I4.0 technologies enhance their ability to meet demand and make changes as the market shifts.

From a policy making point of view, in relation to the need of fit between technology and international strategy of the firm, the policy should

take into account two main objectives. The first one is to lower the cost of adoption of I4.0 in order to foster experimentation and the learning curve of the firm. The alignment between I4.0 and the international strategy of the firms needs constant maintenance and exploration. The second one is to increase the internal competences of the firms in terms of I4.0 technologies. From this perspective, supporting training initiatives could help firms closing the gap between I4.0 and international strategy.

The limitations of this study create opportunities for future research. First, our results could be influenced by the specific structure and organization of Italian firms and their manufacturing activities. Moreover, the use of different industries within a small sample prevents a more detailed analysis on the role of sector in the I4.0 adoption path related to the internationalization strategies. In this sense, future studies should consider other countries and consider also different manufacturing sectors, focusing on few or only one sector. Second, because our study is cross-sectional, we are not able to determine the timing of internationalization strategies and I4.0 adoption in order to define the direction of the relationship between the implementation of I4.0 technologies and the international outcome. Future studies should use a panel-based methodology in order to take into account how technologies influences strategies over time. Finally, the last limitation involves the use of different types of new technologies at the same time. Future research should consider groups of technologies (operations vs. data management) in order to specifying the analysis on how the different group of I4.0 technologies affects the firm's international activities and strategies.

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