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The extra gear of business model 4.0 for exporting and the backstage role of Public institutions, University and Business schools. Empirical insights from Italy

Working Paper Series
SOG-WP4/2023
ISSN: 2282-4189
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October 2023

LUISS

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1. Abstract

The objective of the paper is to test whether and to what extent digitalization affects the likelihood of exporting by distinguishing 4.0 technology adoption from 4.0 business model innovation (i.e., the combination of 4.0 technology adoption and associated business model innovation). Using a unique micro-level database of almost 3,000 Italian manufacturing firms, our econometric analyses show that business model 4.0 innovation accelerates the propensity to export more than the adoption of 4.0 technologies alone (i.e., without the subsequent business model change), and to a greater extent for micro-small firms, mature firms, and firms located in less developed regions (Southern Italy). Testing the endogeneity of business model innovation, we find that the firm's relationship with Public institutions and the university under the Triple Helix model, as well as training through vocational and business schools, increases the likelihood of business model innovation after the adoption of Industry 4.0 technologies. Overall, our paper is one of the first empirical analyses of the relationship between digitalization and internationalization that involves business model innovation and that goes beyond the adoption of 4.0 technology. The results offer important policy implications with respect to the goals defined in Italy's National Resilience and Recovery Plan.

This paper is a scientific study of an issue investigated in the box "Gli effetti della digitalizzazione sull'export italiano" published in "Rapporto SACE Export 2023". We wish to thank Marco Cucculelli for insightful suggestions. Thanks also to Diana Marcello for helpful contributions. The views expressed in the article are those of the authors and do not necessarily reflect those of the institutions to which they belong.

Keywords: Export – Industry 4.0 – Business Model – Triple Helix – Business schools

2. Introduction

Digitalization is transforming firms' internationalization activities and providing important benefits by supporting the access to foreign markets (Etemad et al, 2010; Joensuu-Salo et al, 2018; Cassetta et al, 2020; Naglič et al, 2020; Bettiol et al, 2020; Luo & Zahra, 2023, for a recent review see Feliciano-Cestero et al, 2023). In particular, it lowers the barriers related to physical – and also cultural (Barbaresco et al., 2016) – distances as well as the entry costs, including all costs related to transaction costs (Yamin & Sinkovics, 2006), uncertainty, information asymmetries, communication, and coordination along the supply chain (Jean et al. 2010; Chen & Kamal, 2016; De Marchi et al., 2018). In a recent global survey (Allianz, 2022), half of the companies who responded stated that digitalization reduces costs and allows access to new foreign markets that would not be easily accessible with traditional physical investments. For these reasons, digitalization can be especially critical for less competitive firms, such as smaller companies (Bertello et al., 2021), as it reduces the minimum size required to sell in foreign markets (World Trade Organization, 2018).

Digitalization is revolutionizing the way of "doing business" (Ciriello et al., 2018; Brousseau & Penard, 2007; Burmeister et al., 2016; for an empirical analysis for the Italian case, see Matarazzo et al., 2020), i.e., how an organization creates, delivers, and captures value (Osterwalder & Pignuer, 2010) by changing «the way of living, creating new business models and new ways of manufacturing» (Alcácer & Cruz-Machado, 2019, p. 900). The business model innovation driven by the adoption of 4.0 technologies, called "Business Models 4.0" (Frank et al., 2019; Müller et al., 2018, 2021), enables companies to achieve maximum efficiency and competitiveness by making the most of technological change (Bashir & Verma, 2017).

Adopting 4.0 technologies alone may not be enough to be competitive, as global competition requires high efficiency, quality, and flexibility, which can only be fully achieved by transitioning to new business models (Frank et al., 2019; Müller et al., 2018, 2021). With regard to the internationalization of the company, business model innovation, on the one hand, favors access to foreign markets through greater exploitation of new business opportunities (Zhang et al., 2018) and, on the other hand, supports demand response by realigning products, services, processes, capabilities, and networks (Sainio, 2004). Competitiveness is thus enhanced through business model innovation (e.g., Verma & Bashir, 2017; for a review of the literature on business model innovation, see Bashir et al., 2020): according to a global survey by McKinsey (2021), nearly two-thirds of respondents stated that their company will need new digital business models by 2023 to be economically viable.

Although there is an extensive literature on the impact of digitalization on firm exporting (for a literature review, Castagnoli et al., 2022) on the one hand, and on the impact of business models on firm performance (e.g., Verma & Bashir, 2017: Bashir et al., 2020) on the other, to our best knowledge there is a gap in the empirical understanding of the impact of business models 4.0 on firms' export propensity. This paper aims to try to fill this gap by making three new contributions.

First, it analyzes whether and to what extent digitalization affects the likelihood of exports by distinguishing 4.0 technology adoption alone from 4.0 business model innovation (i.e., the combination of 4.0 technology adoption and associated business model innovation).

Second, these questions are deepened by examining whether and to what extent these effects change from one type of firm to another, depending on some structural characteristics that can potentially influence the degree of competitiveness: micro-small enterprises vs. medium-sized and large enterprises; young enterprises vs. mature enterprises; enterprises located in less developed regions vs. enterprises located in more developed regions.

Third, deepening the potential factors affecting the relationship between business model 4.0 innovation and propensity to export by examining – through an instrumental variables approach that aims to address the problem of potential endogeneity – the role of vocational training and business schools, on the one hand, and that of Public institutions and universities under the Triple Helix model (Etzkowitz & Leydesdorff, 2000; Etzkowitz, 2003, 2008; Ranga & Etzkowitz, 2015), on the other hand, in promoting business model 4.0 innovation.

As far as we know, this is one of the few empirical studies that examines all these issues simultaneously. To address these issues, we use a survey conducted by Centro Studi Tagliacarne-Unioncamere in 2022 on a representative sample of 3,000 Italian manufacturing companies. The dataset allows to obtain original and fresh information on digitalization and export activity collected after the Covid-19 crisis, avoiding distortions due to external shocks on firms' behaviour. Our results show that firms that implement business model 4.0 innovations are more likely to export than firms that adopt 4.0 technologies without changing their business model. This effect is more pronounced for micro-small firms, mature firms, and firms in less developed regions (e.g., Southern Italy). As robustness check, we also find that the benefits of business model innovation compared to adopting 4.0 technologies alone are also evident in terms of export growth. Finally, in addition to confirming the robustness of the main results, the instrumental variable approach highlights the key role of vocational training and business schools, as well as the simultaneous relationship of companies with Public institutions and universities under the Triple Helix model in supporting business model change.

We should point out that these results are nontrivial for at least four reasons, especially if we think to the Italian case. Firstly, Italy is a country with a low level of digitalization and a low propensity for business model innovation. This is also due to the fact that there is a large proportion of family-managed firms: these have a low propensity to change in favor of business models 4.0 (Cucculelli et al., 2022) accompanied with a low propensity to invest in management training for business model innovation (Bearzi & Pini, 2023); the same is true for small businesses (Bearzi & Petrone, 2023). Secondly, in Italy the number of exporting companies is

decreasing and the share of these companies among the small ones and in the less developed regions (i.e., the South) is very low. Thirdly, for Italy, the international organization highlights that: (i) management skills are very low and a new management paradigm is needed; (ii) SMEs are potentially efficient when embedded in networks (OECD, 2017). Fourthly, the Italian National Recovery Plan (NRRP) (Italian Government, 2021) recognizes firm's internationalization as one of the targets of the Mission "Digitalization" (Mission 1). Moreover, NRRP also pays great attention: i) to the relationship between the public and private sectors (through innovation ecosystems), which is one of the main targets of the Mission "Education and Research" (Mission 4); ii) to leadership skills, the main strategic target of training initiatives for skills development. In this regard, it is clear that a well-functioning NRRP can not only improve the level of digitalization in terms of technology adoption, but also help companies adapt their corporate culture to the new global challenges by changing their business model.

The rest of the paper is organized as follows: Section 2 presents the literature and formulates the research hypotheses; Section 3 explains the background; Section 4 describes the data and econometric methodology; Section 5 describes the variables; Section 6 presents and discusses the results; Section 7 concludes.

3. Literature review and hypotheses development

3.1 Industry 4.0 and export

Digitalization is a potential key driver of firm's internationalization (Etemad et al., 2010; Joensuu-Salo et al., 2018; Cassetta et al., 2020; Naglič et al., 2020; Bettiol et al., 2020; Luo & Zahra, 2023, for a recent review, see Feliciano-Cestero et al., 2023). The digitalization processes strengthen the international network that works as a digital eco-system: strong connections between products (primary, intermediated, final), people (B2C, employees), places (remote, physical), means of production (machines, workers), and partners (B2B, suppliers) allows firms to improve horizontal and vertical integration with positive effects on performances, including the ones on foreign markets (Dalenogare et al., 2018; Cassetta et al., 2020). In this international digital eco-system, firms can benefit from efficient supply-chains, more production services, knowledge and technologies sharing, strengthening the brand and international visibility (Haddud & Khare, 2020; Feliciano-Cestero et al., 2023; Matarazzo et al. 2020). This marks a shift from a model of "resource ownership" to a model of "resource orchestration" (Nambisan et al., 2019).

Within the company, 4.0 technologies contribute to meet the demand more quickly, since they improve efficiency, flexibility, and the ability to produce solutions tailored and in less time (Naglič et al., 2020; Alcácer & Cruz-Machado, 2019; Queiroz et al., 2020; Dedehayir et al., 2017). Often, small technologies, being more flexible and easy to implement, are determinant in accelerating timing of business adjustment in the face of demand changes. Examples are Big data, Internet of Things and Machine learning in providing information in real time on consumers' preferences as well as on implementing the most effective marketing strategies or the most adequate product innovations to create value for customers (Porter & Heppelmann, 2014).

Moreover, digitalization is a particularly important for small and medium-sized firms' internationalization (Bertello et al., 2021) because it reduces the minimum scale to sell in foreign markets (World Trade Organization, 2018). It lowers the barriers related to physical distances (Sinkovics et al., 2011) and entry costs[1] (Yamin & Sinkovics 2006), including all those related to transaction costs, uncertainty, information asymmetries (De Marchi et al., 2018), communications and coordination along the supply-chain (Jean et al., 2010).

Indeed, thanks to 4.0 technologies – e.g., digital platform – the firms can access foreign markets even those located further away, without expensive physical investments to be - made on the place (Strange & Zucchella, 2017). According to a recent worldwide survey (Allianz, 2022), half

[1] The transaction costs theory is one the most used in explaining the benefits of the digitalization for the firms' openness to foreign markets (for a review of the theories, Feliciano-Cestero et al., 2023).

of enterprises stated that digitalization reduces costs and allows accessing foreign markets that would be inaccessible via only traditional physical investments (e.g., local store).

3.2 Business models 4.0 and firm's competitiveness

The full potential of Industry 4.0 in improving the process efficiency is encouraged not so much as from the use of Industry 4.0-related technologies, but especially from the adoption of new business models that are called "Business Model 4.0" (Frank et al., 2019; Müller et al., 2018, 2021) (Table 1). Companies are more able to face the technological shift through business model innovation (Bashir & Verma, 2017).

Business model 4.0 is particularly important for firm's competitiveness since it increases: i) *value creation* through digitization of the processes that favor data availability and speed of decision making; ii) *value offer* through customer-tailored products with higher quality accompanied with additional services; iii) and *value capture* through more comprehensive interaction between suppliers and customers (Müller et al., 2018).

Foss and Saebi (2017, p. 201) defined business model innovation as «designed, novel, nontrivial changes to the key elements of a firm's business model and/or the architecture linking these elements», where the key elements are value creation, value offer and value capture. According to Osterwalder and Pignuer (2010) and Teece (2010), business model refers to the rational of how an organization creates, delivers, and captures value.

Firm's competitiveness comes by a complete transition to new business models 4.0 (Frank et al., 2019; Müller et al., 2018, 2021) since global competition requires high efficiency, quality and flexibility, fully reached only through new organizational methods. Indeed, business models 4.0 favor the decision-making process, increase data availability, provide additional services, and products with higher quality, as well as a more efficient interactions between suppliers and customers (Müller et al., 2018, 2020).

Specifically, the competition among firms – both at the national and international level – increasingly relies on innovative business models rather than traditional forms of innovation (Chesbrough, 2010; Gassmann et al., 2013; Teece, 2010; Zott & Amit, 2010; Schiavi & Behr, 2018;). Companies combining change technology and new business models outperform the others (Economist Intelligence Unit, 2012). According to a survey carried out by the Economist Intelligence Unit (2005, p.9) «55% of executives indicates that business model innovation will be a greater source of competitive advantage than new products».

The new emerging business models produce stronger effects on market and competitors (Teece, 2010; Zhang et al., 2018), producing competitive advantages (Teece, 2010; Amit & Zott, 2012; Bashir et al., 2016) and making the existing business models obsolete (Johnson et al., 2008; Yovanof & Hazapis, 2008; Gassmann et al., 2014; Osiyevskyy & Dewald, 2015). Several scholars pointed out that firms need to innovate their business models following the adoption of technologies to obtain new business opportunities and to gain competitive advantage (Chesbrough, 2010; Amit & Zott, 2001; Teece, 2010), going beyond the traditional innovation. Business model innovation allows to obtain sustained benefits over time – they are more

valuable also in recession and time of instability – than product innovation that are more easily imitated (Bashir & Verma, 2017; Boston Consulting Group, 2009).

Table 1: the effect of Industry 4.0 on the business model elements of manufacturing firms.

Value creation	Value offer	Value capture
Production equipment - Productivity increases - Energy savings - Load balancing - Higher fault resistance of production equipment - Fast access to manufacturing data - Machine-health monitoring - Self-controlled production - Increased in-house production - Lower stocks - Easier production maintenance - Retrofitting of older machinery and new equipment required	**Products** - Larger product spectrum - Less maintenance required - Versatile, flexible products (particularly machines) - Higher quality and output of the produced machines - Incorporation of manufacturing data in products and in production management systems - Products tailored to customer demands - Human-machine-interfaces	**Customer groups** - New customer groups addressed within the B2B customer base - Both the risks and the opportunities for customer retention are intensified
Workforce - Attenuation of job shortages in manufacturing, yet likely shortages in Industry 4.0-qualified personnel - Better integration of lower qualified and elderly personnel - New job profiles - New workplaces - Higher technical expertise and employee trainings required - Technology-based trainings - Support in failure recognition - Decreasing number of manufacturing jobs	**Service** - Machine retrofitting services - Condition monitoring - Remote maintenance - Digitization services for customers - Data analytics services - Manufacturing and product simulations - Virtual product development - Engineering and product configuration services	**Customer interaction** - Customer contact via digital platforms - Eased interaction through digital communication - Co-design and co-engineering - Higher cost transparency - Joint decision-making - Value chain integration of customers - Suppliers become more transparent to customers - Decreases in customer loyalty due to higher anonymity
Partners and suppliers - Higher inter-company connectivity - Co-design of the value offers - Joint data analysis - Higher information transparency - Higher delivery reliability - Innovative partnerships - Increased virtual contact - Higher standardization required		**Payment methods** - Digital accounting and automated invoices - Increased payment reliability - Streamlined payment documentation - Increase in subscription models, pay-per-use and pay-per-feature

Source: Müller et al. (2018 p. 7).

Compared with other traditional innovations, business models 4.0 influence firm's competitiveness by lowering transactions costs (Bashir & Verma, 2017) and, more specifically, by changing the revenue model and cost structure raising the profitability (Wu et al., 2013). The Boston Consulting Group (2009) found that business models innovators earn an average premium (in terms of total shareholder return) four times higher than product innovators; and this arises also over time, because after ten years business model innovators continue to outperform product innovators. In the same vein, IBM (2006) estimated that companies focusing more on business model innovation show an operating margin growth higher (+5% in terms of compound annual growth rate over 5 years) than other companies.

Furthermore, some studies (Christensen, 1997; Gilbert, 2005; Chesbrough, 2010) show that the existing business models limit the innovation potentials – so hindering firm performance – because often they ignore the use of new technologies since these last are more difficult to incorporate into current business models.

In the market competitiveness, through business models 4.0 innovation, firms can react to demand by realigning its products, services, processes, skills, networking (Sainio, 2004) and, due to their high flexibility, they also get more customized products and data driven technologies. Also, business model 4.0 innovation provides access to new resources and create flexible and efficient facilities to deliver value to customers (Magretta, 2002; Matarrazzo et al., 2020), including a greater exploitation of new business opportunities (Zhang et al., 2018). According to a study of IBM (2006), more than 50% of the executives surveyed stated that business model innovation contributes to reducing costs and increasing flexibility, as well as more than 40% highlighted that new business models helped them in exploiting new market opportunities.

According to the recent literature, Bouwman et al. (2019) highlighted the key role of business model innovation for internationalization, while Reim et al. (2022) investigated the business model challenges that SMEs face when trying to operate in foreign markets. For Italy, Matarazzo et al. (2020), using a multiple case study, found that business model change driven by the adoption of digital technologies impacts on internationalization by increasing the international markets and the foreign sales.

3.3 Research hypotheses

In line with all arguments explained above, we posit the following hypotheses:

- *Hp.1: business model 4.0 innovation supports export propensity more than the adoption of 4.0 technologies alone*;
- *Hp.2: business model 4.0 innovation supports export growth more than the adoption of 4.0 technologies alone*.

Focusing on firm's size, 4.0 technologies play a key role in the internationalization process in particular for smaller firms (e.g., Strange & Zucchella, 2017) because they reduce the minimum scale for selling abroad (World Trade Organization, 2018) by reducing physical distances, uncertainty and information asymmetries (De Marchi et al., 2018); they allow a better optimization of the value through a change of the new business model (Denicolai et al., 2020; Strange & Zucchella, 2017; Borges et al., 2009).

From the geographical point of view, firms generally perform better when they face a benign domestic environment since the location advantages (Camagni & Capello, 2013) – which include knowledge-based assets, infrastructure and technology – shapes the firms' competitiveness. In particular, in Italy there are wide geographical differences in terms of endowment and quality of infrastructures and economic development levels. Specifically, this evidence is confirmed by the literature on Industry 4.0 (Pini, 2019) and export (Menghini, 2015), according to which the geographical area can negatively connote both openness to Industry 4.0 and openness to

export. In this regard, we can argue that the adoption of 4.0 technologies aimed at changing the business model may fill the gap also from the geographical point of view.

Finally, according to the firm's age, young firms tend to be born with an innovative business model, thanks to the fact that for them implementing innovative business is easier also due to quick decision-making processes (Santos et al., 2009; Ries, 2011).

In light of the above arguments, we posit the following three additional hypotheses:

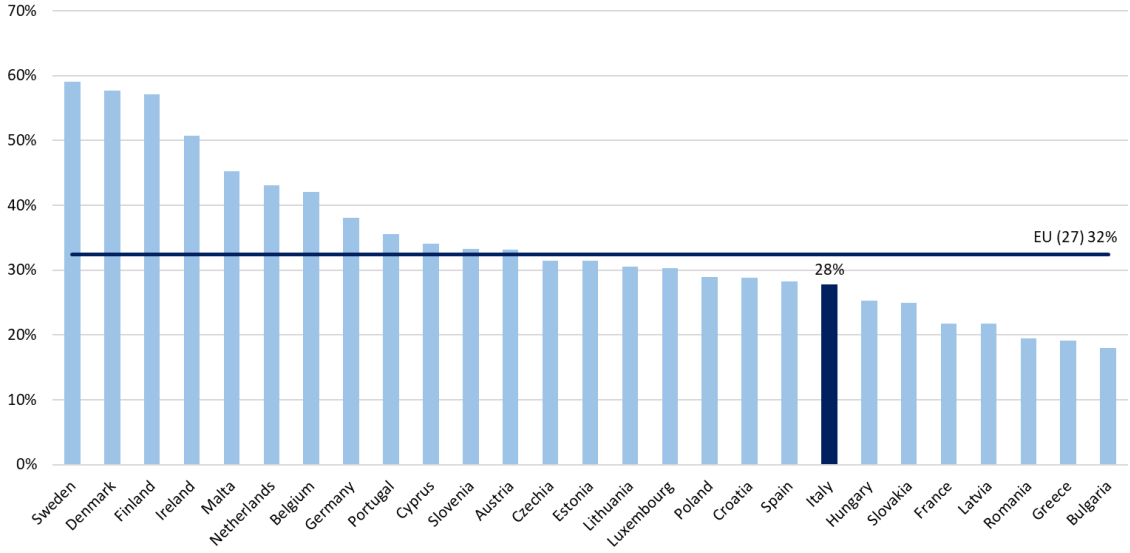
- *Hp.3a: business model 4.0 innovation supports the export propensity to a greater extent in micro-small firms*;
- *Hp.3b: business model 4.0 innovation supports the export propensity to a greater extent in mature firms*;
- *Hp.3c: business model 4.0 innovation supports the export propensity to a greater extent in Southern firms*.

4. Background

3.1 Industry 4.0 and export

Italy is an interesting case to study since it presents wide margins of improvement by looking its positioning in the European Union. Firstly, Italy shows a low level of firms' digitalization: it is the 20th EU country for firms' digitalization according to the share of firms with a high/very high digital intensity: 28% vs EU average 32% (Figure 1).

Figure 1: share of firms with high/very high digital intensity, % on total firms.



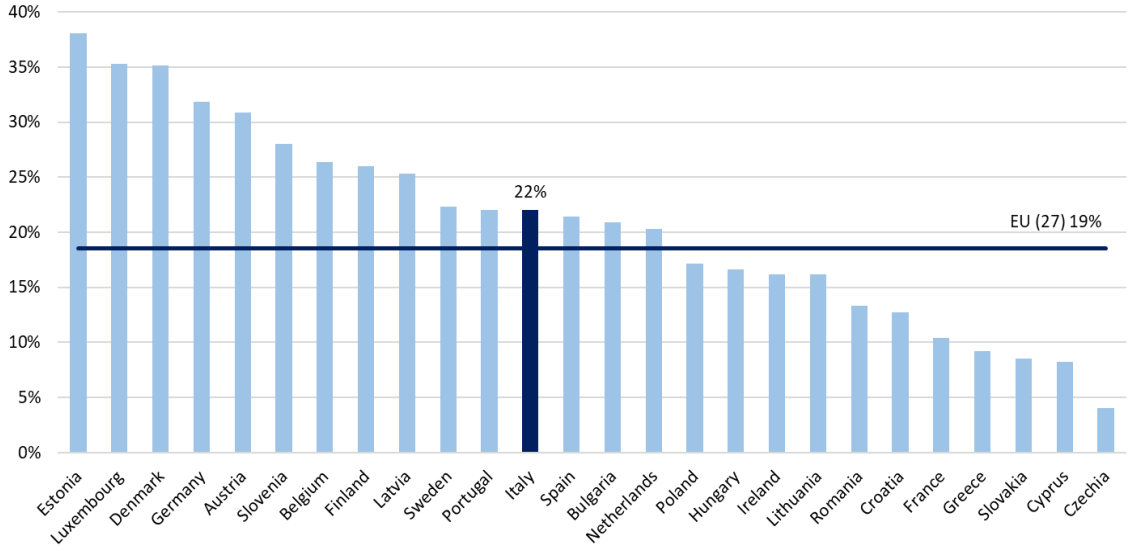
Source: elaboration on EUROSTAT data.

Secondly, Italy is the 12th country for share of exporting firms within the manufacturing sector (year 2020, source: Eurostat) (Figure 2). Moreover, in Italy the number of exporting firms is reducing (with reference to the total economy and for the pre-Covid period 2017-2019: -3.3% exporting firm, corresponding to around -4,000 in absolute terms, source: Istat); and the share of exporting firms among the small ones is very low in comparison to the medium-large ones (14% vs 87%, manufacturing sector, source: Istat) as well as for the ones located in less developed regions (i.e., in the South: 8% vs 20% in the Center-North, manufacturing sector, source: Istat).

Focusing on the aim of this paper, we study the relation between 4.0 technologies and export propensity by splitting 4.0 technologies adoption between "without business model innovation"

and “with business model innovation”. We built a variable (that is the main independent variable in the econometric analyses) taking the following values: 0 if the firm did not invest in 4.0 technologies; 1 if the firm invested in 4.0 technologies without changing the business model; 2 if the firm invested in 4.0 technologies also changing the business model (more details in the Section Variables description). According to the survey carried out by Centro Studi Tagliacarne-Unioncamere in 2022 on 3,000 Italian manufacturing firms (5-499 employees), 23% has invested 4.0 technologies without innovating the business model, while 26% has also invested the business model. The other half of the sample did not adopt 4.0 technologies (Figure 3).

Figure 2: share of exporting firms, % on total manufacturing firms, 2020



N.B. Form Malta data not available.
Source: elaboration on EUROSTAT data.

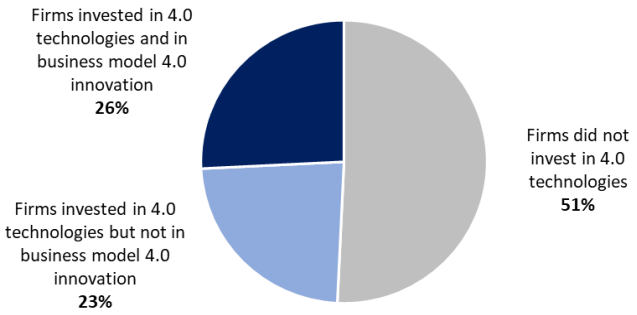
Regarding the export propensity, data shows that digitalization supports the capacity of selling abroad and the business model innovation further enhances this potential. Exporting firms are 41% among those that have not invested in 4.0 technologies, while among the firms that invested in 4.0 technologies this share rises to 60% and further increases to 73% among the firms that invested in 4.0 technologies and changed the business model (Figure 4).

These findings are confirmed by the first preliminary and partial results coming from the wave 2023 of the survey (Centro Studi Tagliacarne-Unioncamere) on a reduced sample of 600 Italian manufacturing firms (5-499 employees). The share of exporting firms passes from 46% with reference to those not investing in 4.0 technologies to the maximum of 68% among the firms investing in 4.0 technologies and that also innovate the business model, while for the firms only investing 4.0 technologies the share stands at 58% (Figure 5) (these results are also published in SACE, 2023).

This positive effect of business model change arises also concerning the export performance. Indeed, focusing on exporting firms, the share of those expecting an export increase in 2023 passes from 30% among the firms that have not invested in 4.0 technologies to 41% among the

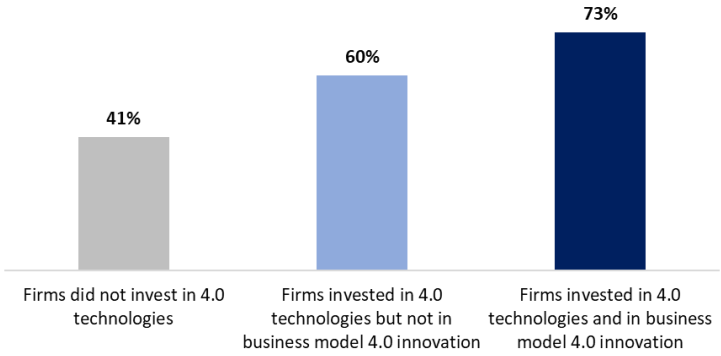
firms that have invested only in 4.0 technologies, peaking at 47% among the firms that also changed the business model following the 4.0 technologies adoption (Figure 6) (these results are also published in SACE, 2023).

Figure 3: firms by investment in 4.0 technologies and related business model 4.0 innovation, % on total firms.



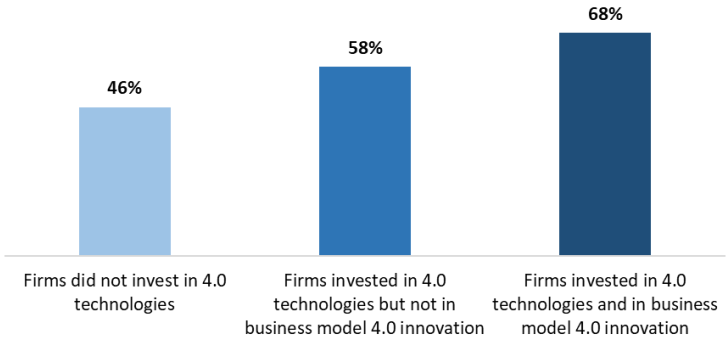
Source: elaboration on Centro Studi Tagliacarne-Unioncamere survey, 2022.

Figure 4: exporting firms by the investment in 4.0 technologies and related business model 4.0 innovation, % on total firms.



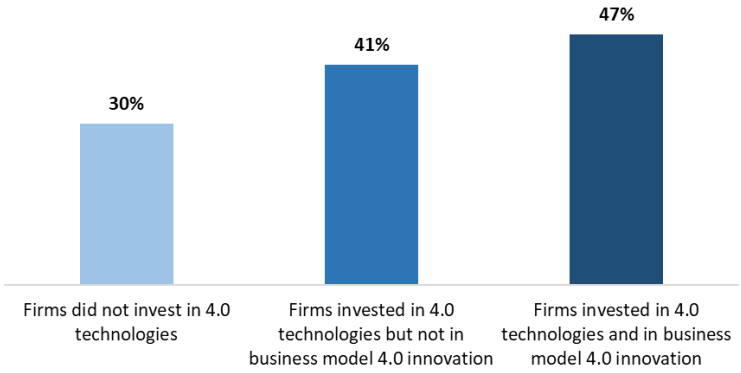
Source: elaboration on Centro Studi Tagliacarne-Unioncamere survey, 2022.

Figure 5: exporting firms by the investment in 4.0 technologies and related business model 4.0 innovation, % on total firms.



Source: elaboration on Centro Studi Tagliacarne-Unioncamere survey on 600 manufacturing firms, 2023.

Figure 6: firms expecting an export growth in 2023, by the investment in 4.0 technologies and related business model 4.0 innovation, % on total exporting firms.



Source: elaboration on Centro Studi Tagliacarne-Unioncamere survey on 600 manufacturing firms, 2023.

5. Data and method

5.1 Data

The data used in the econometric analyses come from the survey carried out by Centro Studi Tagliacarne-Unioncamere (Italian Union of Chambers of Commerce) in 2022. These data allow us to study firm's capacity to sell in foreign markets after the Covid-19 crisis. The sample has been selected by a stratified simple random sampling design with strata given by size class in terms of employees (5-9, 10-49, 50-249, 250-499), industry (four sectors of the section C manufacturing sector of the Nace Rev.2 classification) and geographical location (North-West, North-East, Center, South). The number of respondents has been of about 3,000 enterprises with a response rate of 16.2%. The survey adopted a calibration estimator such that the estimates of the number of enterprises in each stratum is equal to the known population total. The estimator deals with the selection bias for unit non-response, assuming the missing responses depend on the enterprises size.

The survey was conducted via CATI method (Computer-Assisted Telephone Interviewing) by a professional contractor with the aim of gathering both qualitative and quantitative information on firm; several preliminary briefings have been held with the contractor aiming at explaining to interviewers the exact meaning of the issues of the questions (for more details, see the Appendix). The quality of the data was subsequently validated. Furthermore, according to Dorling and Simpson (1999), the quality of the data was also ensured by the fact that they came from a public agency confirming a response rate and the representativeness of the population. The information gathered with the survey are enriched with those coming from administrative archive, concerning: i) firm characteristics (e.g., age, economic sector); ii) firm's exporter status (exporter/non exporter) in the years prior to 2022 by constructing a panel exploring if the firm exports or not in each year for the period 2017-2022.

5.2 Method

As our dependent variable is binary, we use probit model that is the suitable econometric model for this case (Wooldridge, 2010, pp. 453-459). Thus, through probit regression we model the conditional probability of exporting according to the different choice of investing in 4.0 technologies and in business model innovation. Specifically, our probit model is as follows:

$$\mathbf{Prob}(\boldsymbol{Export} = \mathbf{1})_i = \boldsymbol{\Phi}(\boldsymbol{\beta_0} + \boldsymbol{\beta_1} \mathbf{4.0} \boldsymbol{tech\ BM} \mathbf{4.0}_i + \boldsymbol{\beta_2} \boldsymbol{C_i} + \boldsymbol{\varepsilon_i}) \quad \textbf{(1)}$$

where *Prob(Export=1)* represents the probability that the firm exports. The variable *4.0techBM4.0* measures the choice of investing in 4.0 technologies and in business models

innovation, taking the following values: 0 = if the firm did not invest in 4.0 technologies; 1 = if the firm invested in 4.0 technologies but not in business models 4.0 innovation; 2 = if the firm invested in 4.0 technologies and in business models 4.0 innovation. C is a vector of control variables concerning firm's age (Age), firm's size (Micro as reference category, Small, Medium-large), family ownership (Family), foreign-invested (Foreign), sector (Food sector as reference category, P&H sector, Mechanical sector, Other sectors), and geographical location (North-West as reference category, North-East, Center, South). All control variables are binary except for Age that is continuous (Table A2 A1). Collinearity problems does not emerge since all values of Variance Inflation Factor (Table A3) are below of the critical value of 10 (Yoo et al., 2014). Φ is a standard normal cumulative distribution function. Finally, ε_i is the normally distributed random error with zero mean and constant variance $\mathrm{N}(0, \sigma^2)$ that captures any other unknown factors. To know the effects of any explanatory variable on the response probability $\mathrm{P}(Y = 1|\mathbf{x})$ we calculated the marginal effects (average marginal effects). Marginal effect indicates «the effect on conditional mean of Y of a change in one regressor, say, x_j» (Cameron & Trivedi, 2010, p. 343).

Furthermore, we address the potential endogeneity problem because although our estimations control for several factors, it might be possible that there are some unobserved factors directly affecting business model 4.0 innovation, and so also the export activity through its influence on business model 4.0 innovation. Thus, we control for potential endogeneity of investing in business models 4.0 innovation by using instrumental variables approach and considering a dummy variable taking value 1 if the firm invested in 4.0 technologies and business models 4.0 innovation (*4.0tech&BM4.0dum*). As known, instrumental variables approach is one of the most widely used econometric method (e.g., Wooldridge, 2010; Marra & Radice, 2011): it allows to control for a possible existence of one or more instruments that may influence the endogenous variable, are independent of unmeasured confounders, and do not directly affect the outcome (e.g., Angrist et al., 1996).

Since we are in presence of an endogenous variable with a binary outcome, we use a bivariate probit model (Heckman, 1978; Maddala, 1983): as well known, from both a theoretical and empirical point of view, simultaneous likelihood estimation methods are superior to conventional two-stage instrumental variable procedures (e.g., Wooldridge 2010; Bhattacharya et al., 2006; Freedman & Sekhon 2010).

Considering *4.0tech&BM4.0dum* endogenous, we can argue that the probability of investing in business model 4.0 innovation is likely to be determined by other factors. The first instrument variable concerns the possibility that the firm carries out training activities through external Professional training and Business schools, in this last case specifically involving management training (*ProfessTraining&BS*). This because the in-depth change of the business models requires a disruptive improvement of skills of employees: according to the World Economic Forum (2020), 50% of workers will need re-skilling training by 2025, and if we consider also up-skilling training, the share rises to 73%; moreover, 44% of employees will change their core skills in the next five years (World Economic Forum, 2022). Secondly, the management plays a key role in designing new business models innovation (Müller et al., 2018, 2020) since Industry 4.0 requires a high level of expertise (e.g., Schneider, 2018) to deploy the knowledge asset in innovation

outcomes. More specifically, in the Industry 4.0 era an adequate corporate culture is required to reach exploratory innovation strategies leading to new business models. This relies on the development of flexibility, openness, willingness to learn, adaptability, diversity, autonomy in decision-making, that are driven in large part by the top management (Müller et al., 2020).

The second instrument variable (Triple Helix) is used in the case that the firm has a strong and enduring simultaneous relationships with territorial institutions (Government agencies, Chambers of commerce, etc.) and University under the Triple Helix Model. This can be argued considering that the Triple Helix (Industry-Government-University) (Etzkowitz & Leydesdorf, 2000; Etzkowitz, 2003; 2008) enhances the transition from a low-risk and low-development model to a higher-risk and higher-gain development model, fostering radical innovation, new growth opportunities and skills (Ranga & Etzkowitz, 2015), contributing to shape a broader perspective of innovation (Qian, 2017). More specifically, the simultaneous firm's interaction with government and academia represents a source of knowledge – also favoring the optimal use of external knowledge – and funding, supporting organizational change, technical improvements, networking and information exchanges (Ranga et al., 2008). The advantage of this relationship is due to the fact that each actor, besides fulfilling their core function, may also "take the role of the other" so playing non-core roles, which make them a stronger source of innovation (Etzkowitz, 2006).

We consider the follow bivariate probit model:

$$\mathbf{Prob}(\boldsymbol{Export} = \mathbf{1})_i = \boldsymbol{\Phi}(\boldsymbol{\beta_0} + \boldsymbol{\beta_{21}}\mathbf{4.0}\boldsymbol{tech}\&\boldsymbol{BM4.0dum} + \boldsymbol{\beta_{22}}\boldsymbol{C_i} + \boldsymbol{\varepsilon_i}) \quad (2)$$

$$\mathbf{Prob}(\mathbf{4.0}\boldsymbol{tech}\&\boldsymbol{BM4.0dum} = \mathbf{1})_i = \boldsymbol{\Phi}(\boldsymbol{\beta_0} + \boldsymbol{\beta_{21}}\boldsymbol{I_i} + \boldsymbol{\beta_{22}}\boldsymbol{C_i} + \boldsymbol{\mu_i}) \quad (3)$$

where I_i is the vector of the instrumental variables corresponding to *ProfessTraining&BS* and *Triple Helix*. C_i is a vector of the control exogenous variables, and ε_i and μ_i are the normally distributed random errors with zero mean and constant variance $\mathrm{N}(0, \sigma^2)$.

Equations (2) and (3) constitute the bivariate probit model aimed at estimating the effect of the investment in business model 4.0 innovation (*4.0tech&BM4.0dum*) on the probability of exporting (*Export*) controlling for the endogeneity of the *4.0tech&BM4.0dum*.

The correlation between the unobserved determinants of exporting (subsumed in ε_i in Eq. 2) and the unobserved determinants of *4.0tech&BM4.0dum* (subsumed in μ_i in Eq. 3) $\rho = Corr(\varepsilon_i, \mu_i)$ indicates the endogeneity degree of the variable *4.0tech&BM4.0dum*. If we reject the Hypothesis $\rho = 0$ the Eq. (1) is inconsistent, and we have to estimate the two-equation system (Bivariate Eq. 2 and Eq. 3)[2]. If we do not reject the Hypothesis $\rho = 0$ we can just estimate Eq. (1).

[2] We tested the endogeneity of *4.0tech&BM4.0dum* by calculating the test of endogeneity Robust score chi2 in the linear regression (IV-2SLS): the test is significant at 1%.

6. Variables description

6.1 Dependent variables

Table A1 describes all variables. Our dependent variable is a dummy variable measuring the export propensity (*Export*): it takes value 1 if the firm exports and 0 if the firm does not export, in line with previous studies (e.g., Hagsten & Kotnik, 2017; for the Italian case, Minetti et al., 2015; Cassetta et al., 2020). Moreover, in investigating the causality, we use other two dependent variables: i) the first one (*Export start*) taking value 1 if the firm did not export in the period 2017-2020 but it started to export in 2021 (and continuing also in 2022); ii) the second one (*Export stop*) taking value 1 if the firm stopped the export activity in 2021 (and also in 2022) after having exported in the period 2017-2020. In this regard, we expect that the adoption of business model 4.0 positively affects only the Export start. Finally, we used also a variable measuring the export performance through a binary variable (*Export growth*) taking value 1 if the firm with an export increase in 2021 and 2022.

6.2 Main independent variable

Concerning the main independent variables, we construct a variable taking: 0 = if the firm did not invest in 4.0 technologies (*no4.0tech*); 1 = if the firm invested in 4.0 technologies but not in business models 4.0 innovation (*4.0tech noBM4.0*); 2 = if the firm invested in 4.0 technologies and in business models 4.0 innovation (*4.0tech&BM4.0*). This approach is aimed to simultaneously considering the adoption of 4.0 technologies in line with previous studies (e.g., for the Italian case, Bettiol et al., 2020; Büchi et al 2020; Cugno et al., 2022), on one hand, and the business model 4.0 innovation (Müller et al., 2018; for empirical analysis for the Italian case, Cucculelli et al., 2022), on the other. Concerning business model change, we refer to "innovation" as the changes made in the business logic for value creation, value capture (Bouwman et al., 2019), also including the value offer under the concept of Business model 4.0 (Müller et al., 2018), to distinguish from the concept of business model development.

6.3 Control variables

We included a set of variables to control for potentially confounding effects of various firm's characteristics that may influence the likelihood of exporting. Size is one of the factors potentially affecting firm's export activity (Majocchi, Bacchiocchi, & Mayrhofer, 2005). In this regard, the most extended literature highlights that size positively influences export behavior (e.g., Wagner, 2015; Williams, 2011) because a large size allows important economies of scale; while other views support a greater internationalization of small firms because they are more flexible and faster in recognizing opportunities and in adapting to changes in the external

environment (Lee et al., 2012). Thus, we included a variable capturing the size class (*Micro* as reference category; *Small*; *Medium-large*).

Moreover, since firm's age may affect the internationalization (Majocchi, Bacchiocchi, & Mayrhofer, 2005; Wagner, 2015), we included a continuous variable (*Age*) indicating the number of years since inception.

To consider that the foreign-ownership may boost economic performance also through the possibility to access new and distant markets (for the Italian case, e.g., Ascani et al. 2020 on the effects of the presence of multinational enterprises on the economic performance), we included a binary variable (*Foreign*) equals to 1 if the firm is a foreign-invested enterprise.

Concerning the governance, given that family firms behave differently compared to the non-family ones (Chua et al., 1999; Miller et al., 2010), also in the internationalization field (for a recent review, Casprini et al., 2020), we included a dummy variable (*Family*) taking value 1 if the firm is family-owned.

We control also for the sector through a variable that categorizes the firms in four economic sectors: Food sector (as reference category); Mechanical sector; Personal and household goods (*P&H_sector*); Other manufacturing activities (*Other_sectors*).

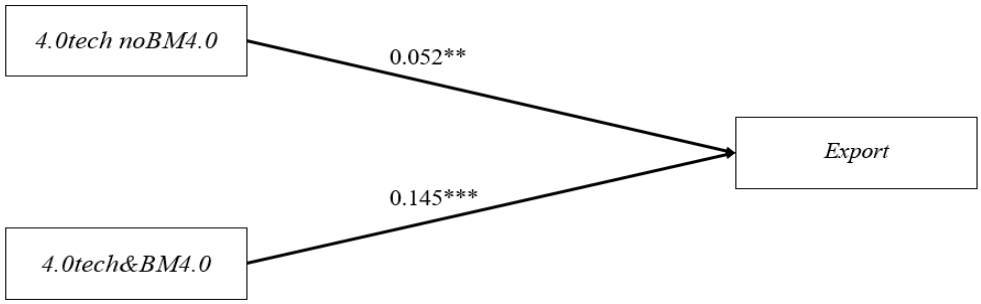
Finally, to account for the fact that the location is a factor potentially affecting firm's competitiveness (Camagni & Capello, 2013) – and this is particularly relevant in Italy where socio-economic geographical differences are relevant (e.g., Svimez, 2021) –, we control for the area in which the firm is located including three dummies: *North-East, Centre, South* (*North-West* as reference category).

7. Results and discussion

7.1 Baseline results

Table A4 reports the baseline results. We find that the adoption of 4.0 technologies, even in absence of business model change (*4.0tech noBM4.0*) increases the likelihood of exporting; but when this is combined with business model 4.0 innovation (*4.0tech&BM4.0*) the likelihood rises further: the average marginal effects (AMEs) are positive and statistically significant, respectively at 5% and at 1%, but the magnitude related to the second case is almost triple than the first (0.145 vs 0.052, column A; Figure 7) (these results have been anticipated in SACE, 2023). Thus, the Hypothesis 1 (*Hp.1 Business model 4.0 innovation supports the export activity more than the adoption of 4.0 technologies alone*) is confirmed.

Figure 7: the different effects between adopting 4.0 technologies "without" and "with" business model 4.0 innovation on export propensity.



The figure reports the marginal effects of probit regression including control variables (see Table A4).
*** p<0.01; ** p<0.05; * p<0.1

Despite working on cross-section analysis, we address the potential problem of causality by comparing the effect of business model 4.0 innovation on starting export with the effect on stopping export. The results show that with respect to the probability of becoming a new exporter (*Export start*), business model 4.0 innovation has a positive and significant influence (ME: 0.032, p<0.05, column B); while with respect to the probability of stopping the status of exporter (*Export stop*) there isn't any relation (ME is not significant and by the way negative; column C). More specifically, it is interesting to underline that only when there is business model 4.0 innovation (*4.0tech&BM4.0*) the probability of becoming exporter increases, because the adoption of 4.0 technologies without changing business model (*4.0tech noBM4.0*) does not have any significant effect (ME: 0.007, p>0.1, column B).

This results empirically support the idea that new business models provide a strong exploitation of business opportunities (Zhang et al., 2018) by allowing firms to capture new customers, to increase virtual contacts, to benefit from eased interaction through digital communication that facilitates also co-design, co-engineering etc.

The importance of the business model change combined with the 4.0 technologies adoption emerges also in terms of export performance. Despite that only adoption positively affects the probability of registering an export growth, the combination with business model innovation increases further this likelihood: the marginal effect for the second case (*4.0tech&BM4.0*) is higher than the first one (*4.0tech noBM4.0*) (0.079 vs 0.042, column D), and with a stronger significance level (1% vs no significance). Thus, the Hypothesis 2 (*Hp.2 Business model 4.0 innovation supports the export growth more than the adoption of 4.0 technologies alone*) is confirmed.

These findings are in line with those of the Economist Intelligence Unit (2012) about the importance of joining technologies and business model innovation, so confirming the strand of literature underlining that business models innovation is a key driver for the firm's competitiveness (e.g., Frank et al., 2019; Müller et al., 2018, 2021; Bashir & Verma, 2017), including in foreign markets as is here empirically demonstrated.

In Table A5 (and in Figure 8) we differentiate the estimates according to the diverse typologies of firms. Firstly, the results show that the effect of business model 4.0 innovation on export propensity is higher for micro-small firms than for medium-large ones (ME: 0.187 vs 0.127, $p<0.01$ in both cases, Columns A-B), so confirming Hypothesis 3a (*Hp.3a Business model 4.0 innovation supports the export propensity to a greater extent in micro-small firms*).

Moreover, we also find another difference: the only adoption of 4.0 technologies has a positive and significant impact on the probability of exporting only for micro-small firms (ME: 0.089, $p<0.01$, column A), while for medium-large ones only business model change plays a key role (ME: 0.058, $p>0.1$, columns B).

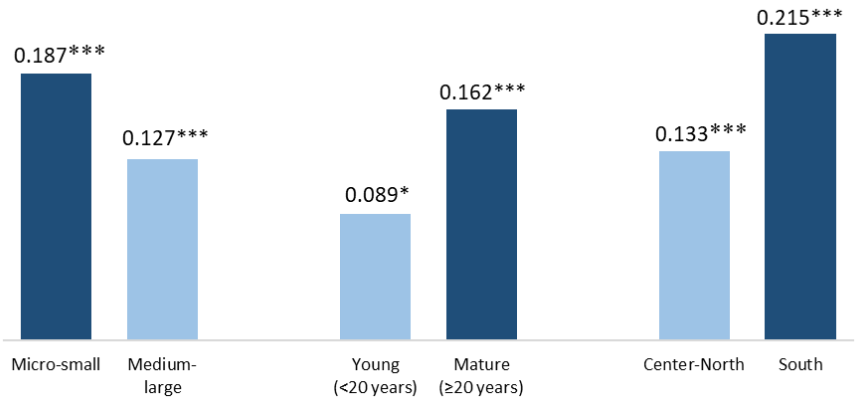
Secondly, if we disentangle the estimates by the firm's age, we find that business model 4.0 innovation has a stronger effect on the likelihood of exporting for mature firms[3]: the marginal effect of *4.0tech&BM4.0* is quadruple than those referred to young firms, with a higher statistically significant level (ME: 0.162 $p<0.01$ vs 0.089 $p<0.10$, columns D-C). Thus, the Hypothesis 3b (*Hp.3b Business model 4.0 innovation supports the export propensity to a greater extent in mature firms*) is confirmed.

Thirdly, from a geographical perspective, the benefit of business 4.0 innovation on export propensity is higher for the firms located in Southern Italy than for those located in North-Central Italy (ME: 0.215 vs 0.133, $p<0.01$ in both cases, columns F-E). Thus, the Hypothesis 3c (*Hp.3c Business model 4.0 innovation supports the export propensity to a greater extent in Southern firms*) is confirmed.

[3] In line with other previous studies on firm age (Cucculelli et al., 2014), we consider mature firms those with twenty and more years of age (in terms of years since inception) and young firms with less than 20 years of age.

All these results, according to different firm's characteristics, confirm as underlined in literature on the role of 4.0 technologies in reducing the barriers to export for smaller enterprises (Bertello et al., 2021) on one side, and enrich the reasoning to other types of enterprises, such as the ones mature as well as the ones located in less developed regions, on the other side.

Figure 8: the effects of business models 4.0 innovation on export propensity.



The figure reports the marginal effects (probability of exporting with respect to not adopting 4.0 technologies) of probit regression including control variables (see Table A5).
*** p<0.01; ** p<0.05; * p<0.1

7.2 Robustness check: IV estimates

We control for a possible endogeneity of business model 4.0 innovation by applying the instrumental variables (IV) approach (Table A6 and Figure 9). Thus, we consider business model 4.0 innovation endogenous, and we instrument it with two instruments, as just above argued: i) the investments on training activities through external Professional training and Business schools; ii) the strong and enduring simultaneous relationships with territorial institutions (Government agencies, Chambers of commerce, etc.) and University under the Triple Helix model.

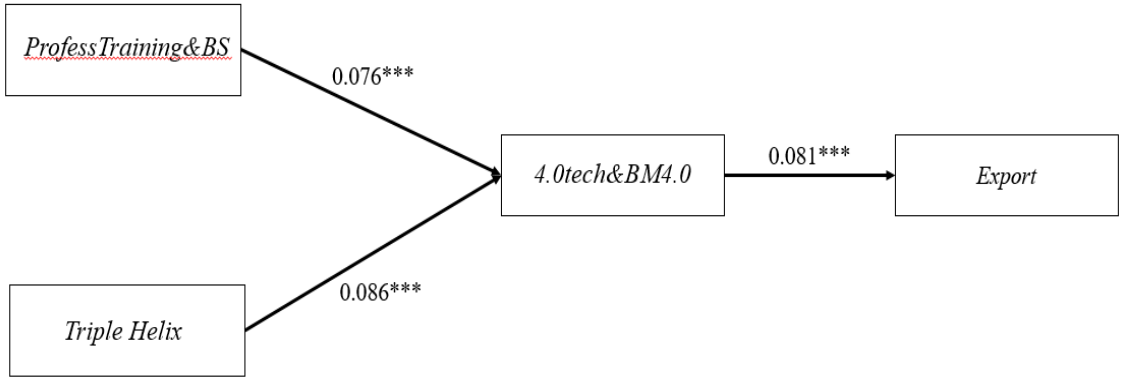
Since the aim is to investigate the business model 4.0 innovation, in this case we construct a dummy variable (*4.0tech&BM4.0dum*) capturing if the firm combined 4.0 technologies adoption and the change of the business model. The results confirm the positive and statistically significant impact of business model 4.0 innovation on the export propensity (ME: 0.081, p<0.01, column D). Concerning the endogeneity of business model 4.0 innovation, since the Wald test $\rho = 0$ (correlation between the unobserved determinants of exporting, i.e., ε_i in Eq. 1, and the unobserved determinants of *4.0tech&BM4.0dum,* i.e., μ_i in Eq. 2) is rejected at the 1%, the variable *4.0tech&BM4.0dum* is endogenous.

Concerning the validity of the instruments, F statistics (on OLS regression) for the instruments' relevance is over 10 (58.465, p<0.01), hence the instruments are not weak. More specifically, based on Stock and Yogo's (2005) tabulation of the critical values for the weak instruments test, we reject the null of a relative bias greater than 5%. Overall, looking the coefficient of each instrument, all are statistically significant at 1%. Thus, investing in training activities through

external Professional training and Business schools rises the likelihood of combining 4.0 technologies adoption and business model innovation; as well as having a strong and enduring simultaneous relationship with Public institutions and University under the Triple Helix model.

Finally, concerning the exogeneity of the instruments, the Wooldridge robust score test is not significant (0.018, p>0.1), so we can consider the instruments to be exogenous.

Figure 9: the effects of business models 4.0 innovation on export propensity considering the backstage role of Triple Helix, and external Professional training and Business schools.



The figure reports the marginal effects of probit regression including control variables (see Table A6).
*** p<0.01; ** p<0.05; * p<0.1

8. Conclusion

Digitalization is changing the process of firms' internationalization favoring the access to foreign markets and potentially revolutionizing doing business by changing the business model. Many authors recognized that the full exploitation of 4.0 technologies arises with the innovation of business models, through the implementation of the so-called business model 4.0. In the current global scenario, the business model innovation allows firms to be more competitive than other traditional forms of innovation.

There is a vast literature on the impact of digitalization on firms' internationalization as well of on business model innovation, but there is a gap in combining these two strands of literature, especially through empirical analyses.

Exploiting a survey conducted by Centro Studi Tagliacarne-Unioncamere in 2022 on a representative sample of 3,000 Italian manufacturing firms, this paper tries to fill this gap by investigating whether and to what extent the digitalization impacts on the likelihood of exporting by differentiating only 4.0 technologies adoption from business model 4.0 innovation (namely the combination of 4.0 technologies adoption and the following business model innovation). We analyzed also whether and to what extent the effect of business model 4.0 innovation on export propensity changes when passing from micro-small to medium-large firms, from young to mature firms, from firms located in more developed regions (Center-North Italy) to those located in less developed regions (South Italy). The main results show that: i) business model 4.0 innovation has a stronger effect in increasing the likelihood of exporting than the only 4.0 technologies adoption: ii) the effect of business model 4.0 innovation is higher for micro-small firms, for mature ones, and for those located in less developed regions.

Finally, by applying an instrumental variables approach, we deepen the relationship between business model 4.0 innovation and export propensity by studying the potential factors affecting business model 4.0 innovation: training activities through professional training and Business schools, on one side, and the simultaneous firm's relationship with Public institutions and University under the Triple Helix model, on the other side. We found that both these factors positively affect business model 4.0 innovation, that in turn – controlled for endogeneity – continues to support export propensity.

Several policy implications can be drawn by our results. Firstly, it is determinant to design policy interventions aimed not only at technologies adoption, but also at changing business models to obtain the most benefit from the digitalization (usually, policy measures are more concentrated on technology adoption than on business model change). Indeed, the European Commission underlined that «EU innovation policy must be based on a definition of innovation that

acknowledges and values all forms of new knowledge – technological, but also business models» (European Commission, 2022, p. 164).

Secondly, in doing so it is critical by leveraging on Public institutions and University as actors that favor, through coordination mechanism, accessibility of valuable resources, uncertainty reduction, increase of trust, networking, knowledge transfer, so enforcing internal capabilities and gaining incremental competitive benefits. These effects are determinant in a period in which strong disruptive changes are needed to face the new economic paradigm driven by the Fourth industrial revolution. In this regard, Italian businesses may often suffer of several limitations: i) scarce awareness of the benefits of the Fourth industrial revolution; ii) information asymmetries; iii) scarce knowledge for the full exploitation of 4.0 technologies; iv) rigid mental models; v) risk aversion.

Thirdly, since the complete digital transition requires a new corporate culture and entrepreneurial mindset to positively react to paradigm changes, catching-up the benefits of the Fourth industrial revolution, it is determinant to accompany (with coordinated mechanism) the investments in digitalization with a strong program of advanced training. In this regard, Professional training and Business schools play a key role in changing the corporate culture to address the current global challenges, including the preparation of managers to change the business model. This is critical in Italy where there are many mature firms that may need to change their business model, on one side; and, on the other, many family firms are managed by family members who often lack the necessary knowledge, show close-mindedness and higher risk aversion.

These supporting actions provided by Public Institutions, Universities and Business schools should be aimed at favoring the “competitive convergence” of the entrepreneurial system. In doing so, it is paramount to focus on firms that most require a business model change, which – not by chance – are also those where a business model 4.0 innovation have a stronger effect on export propensity.

In the light of all explained above, the Italian experience of Digital Business Points (PID - Punto Impresa Digitale) of the Italian Ministry of Economic Development in collaboration with Unioncamere (Italian Union of Chambers of Commerce) represents a best practice recognized also at the European level (European Union, 2022). This is because this initiative is aimed at spreading information, supporting, and training businesses on digital innovation issues, encouraging the adoption and implementation of new digital industrial technologies, by leveraging on the collaboration between enterprises and academia.

Overall, supporting the transition of the entire economic system towards the digitalization requires a broad and coordinated effort by all actors comprising entrepreneurs, Public institutions, academia, professional trainers, business schools, at national and local level, to define and effectively implement the right policies ensuring a fair and resilient economy. This is the current, and the greatest challenge of the Italy’s Recovery and Resilience Plan. In this regard, first empirical analyses demonstrates that a firm’s activation of NRRP projects has a positive effect on the choice of investing in managerial training aimed at the business model innovation (Pini, 2023).

This paper presents some limitations that can be tackled by future research. Firstly, the cross-sectional analysis impedes more in depth investigation of the cause-effect mechanism. Secondly, we did not consider the intensity and the typologies of 4.0 technologies. Thirdly, similarly, we did not deepen the typologies of business model innovation by differentiating value offer, value creation, and value capture in relation to the export propensity. Fourthly, we analyzed the relationship with external actors with a dummy variable without considering the intensity and the typology of the relationship. Furthermore, future research may make use of more surveys to study if the estimated effects are stable over time and cross-country analysis would allow to better highlight the specificities of the Italian entrepreneurial system.

9. Appendix

Table A1: variables description.

Variables	Type	Description
Dependent variable		
Export	Dummy	1 = if the firm exports in the two-year period 2021-2022; 0 = otherwise
Export start	Dummy	1 = if the firm did not export in the period 2017-2020 and it started exporting in 2021-2022
Export stop	Dummy	1 = if the firm exported in the period 2017-2020 and it stopped exporting in 2021-2022
Export growth	Dummy	1 = if the firm states an export increase in 2021 and 2022
Main independent variables		
4.0tech BM4.0	Categorical	0 = if the firm did not invest in 4.0 technologies (no4.0tech); 1 = if the firm invested in 4.0 technologies but not in business models 4.0 innovation (4.0tech noBM4.0); 2 = if the firm invested in 4.0 technologies and in business models 4.0 innovation (4.0tech&BM4.0)
Control variables		
Age	Continuous	Number of years since inception
Family	Dummy	1 = if the firm is family-owned; 0 = otherwise
Foreign	Dummy	1 = if the firm is foreign-invested; 0 = otherwise
Sector	Dummies	1 = if the firm belongs to a n -sector; 0 = otherwise. The sectors are the following: Food sector; Mechanical sector; P&H sector (Personal and household goods); Other sectors (Other manufacturing activities)
Size	Dummies	1 = if the firm belongs to a n -size class; 0 = otherwise. The size class are the following: Micro (5-9 employees); Small (10-49 employees); Medium-large (50-499 employees)
Geographical location	Dummies	1 = if the firm belongs to a n -geographical area; 0 = otherwise. The geographical areas are the following: North-West; North-East; Center; South
Instruments		
ProfessTraining&BS	Dummy	1 = if the firm carries out training activities through external Professional training and Business school; 0 = otherwise
Triple Helix	Dummy	1 = if the firm has strong and enduring simultaneous relationships with territorial institutions (Government agencies, Chambers of commerce, etc.) and University; 0 = otherwise

Table A2: summary statistics.

	Obs.	Mean	Std. Dev.	Min	Max
Export	2,402	0.537	0.499	0	1
Export start	2,402	0.070	0.255	0	1

Export stop	2,402	0.119	0.324	0	1
Export growth (a)	1,724	0.218	0.413	0	1
no4.0tech	2,402	0.507	0.500	0	1
4.0tech noBM4.0	2,402	0.235	0.424	0	1
4.0tech&BM4.0	2,402	0.258	0.437	0	1
Age	2,402	32.467	16.294	3	98
Family	2,402	0.805	0.396	0	1
Foreign	2,402	0.056	0.230	0	1
Food sector	2,402	0.213	0.409	0	1
Mechanical sector	2,402	0.224	0.417	0	1
P&H sector	2,402	0.307	0.461	0	1
Other sectors	2,402	0.257	0.437	0	1
Micro	2,402	0.311	0.463	0	1
Small	2,402	0.430	0.495	0	1
Medium-large	2,402	0.259	0.438	0	1
North-West	2,402	0.322	0.467	0	1
North-East	2,402	0.316	0.465	0	1
Center	2,402	0.205	0.404	0	1
South	2,402	0.157	0.363	0	1
ProfessTraining&BS	2,402	0.505	0.500	0	1
Triple Helix	2,402	0.060	0.237	0	1

(a) The statistics of *Export growth* is calculated on total exporting firms.

Table A3: Variance Inflation Factor.

	VIF
4.0tech noBM4.0	1.27
4.0tech&BM4.0	1.38
Age	1.10
Family	1.04
Foreign	1.11
Mechanical sector	1.64
P&H sector	1.79
Other sectors	1.67
Small	1.43
Medium-large	1.81
North-East	1.37
Center	1.36
South	1.34

Table A4: baseline results.

	Export	Export start	Export stop	Export growth
	(A)	(B)	(C)	(D)
4.0tech noBM4.0	0.052**	0.007	-0.005	0.042
	(0.025)	(0.013)	(0.017)	(0.031)
4.0tech&BM4.0	0.145***	0.032**	-0.014	0.079***
	(0.025)	(0.015)	(0.018)	(0.030)
Age	0.000	-0.000	0.001*	0.000
	(0.001)	(0.000)	(0.000)	(0.000)
Family	0.017	0.025*	-0.019	0.033
	(0.024)	(0.014)	(0.017)	(0.029)
Foreign	0.377***	-0.009	-0.133***	0.068*
	(0.073)	(0.030)	(0.045)	(0.038)
Mechanical sector	0.011	-0.049***	0.079***	0.017
	(0.028)	(0.015)	(0.019)	(0.038)
P&H sector	-0.025	-0.035**	0.049***	-0.026
	(0.026)	(0.016)	(0.017)	(0.034)
Other sectors	-0.006	-0.018	0.071***	-0.005
	(0.027)	(0.017)	(0.018)	(0.035)
Small	0.150***	-0.056***	0.017	-0.003
	(0.023)	(0.015)	(0.016)	(0.032)
Medium-large	0.460***	-0.104***	-0.018	0.080**
	(0.026)	(0.015)	(0.019)	(0.037)
North-East	-0.043*	-0.009	0.008	0.027
	(0.023)	(0.012)	(0.016)	(0.028)
Center	-0.059**	0.001	-0.004	0.050
	(0.027)	(0.015)	(0.018)	(0.034)
South	-0.090***	0.033*	0.015	0.013
	(0.028)	(0.018)	(0.021)	(0.037)
Obs.	2,402	2,402	2,402	1,291
Wald chi2	408.54***	80.82***	35.53***	37.93***
Pseudo R2	0.166	0.070	0.024	0.027

Dependent variable at the top of the column. Table displays average marginal effects. Robust standard errors in parentheses. Wald test of the model specification is reported.
*** p < 0.01, ** p < 0.05, * p < 0.1.

Table A5: disentangling by size, age and geographical area.

	Size		Age		Geographical area	
	Micro-small	Medium-large	Young <20 years	Mature ≥20 years	Center-North	South
	(A)	(B)	(C)	(D)	(E)	(F)
4.0tech noBM4.0	0.089***	0.058	0.054	0.049*	0.045*	0.051
	(0.030)	(0.045)	(0.049)	(0.028)	(0.026)	(0.070)
4.0tech&BM4.0	0.187***	0.127***	0.089*	0.162***	0.133***	0.215***
	(0.031)	(0.042)	(0.052)	(0.029)	(0.028)	(0.062)
+ controls						
Obs.	1,781	621	587	1,815	2,026	366
Wald chi2	80.68***	28.72***	71.62***	356.58***	334.48***	68.75***
Pseudo R2	0.038	0.075	0.104	0.188	0.165	0.154

Dependent variable: *Export.* Table displays average marginal effects. Robust standard errors in parentheses. Wald test of the model specification is reported. *** p < 0.01, ** p < 0.05, * p < 0.1.

Table A6: IV estimates.

	Bivariate probit coeff.		Marginal effects	
	4.0tech&BM4.0[(a)]	Export	4.0tech&BM4.0[(a)]	Export
	(A)	(B)	(C)	(D)
4.0tech&BM4.0dum[(a)]		1.185***		0.081***
		(0.213)		(0.010)
+ controls				
# ProfessTraining&BS	0.581***		0.076***	
	(0.063)		(0.010)	
# Triple Helix	0.662***		0.086***	
	(0.112)		(0.015)	
$\rho = corr(\varepsilon_i, \mu_i)$		-0.512		
		(0.133)		
Obs.		2,402		
Wald Chi2		1066.43***		
Exogeneity of instrumented variable: Wald-test $\rho = 0$ (Chi2)		9.796***		
Instruments relevance: F-test		58.465***		
Instruments exogeneity: Overidentification test Wooldridge's Robust score test Chi2		0.018		

[(a)]Dummy variable (*4.0tech&BM4.0dum*) taking value 1 if the firm invested in 4.0 technologies and business model 4.0 innovation; 0 = otherwise. The dependent variable is reported at the top of the column. The table displays coefficients and marginal effects of the bivariate probit. Robust standard errors in parentheses. Wald chi-square test of joint significance for all the explanatory variables is reported. The symbol # indicates the instrumental variable. Exogeneity of instrumented variable: if we reject the Hypotesis the variable *4.0tech&BM4.0dum* is exogenous. Instruments relevance: F-test on IV-2SLS, significance, with a F-value > 10, means to reject the hypothesis of irrelevance of the instrumental variables. Wooldridge's Robust score test Chi2 for the overidentification restriction on IV-2SLS, no significance means to not reject the hypothesis of exogeneity of the instrumental variables.
*** p < 0.01, ** p < 0.05, * p < 0.1.

The description of the survey

The target population of Centro Studi Tagliacarne-Unioncamere survey refers to Italian manufacturing firms with a number of employees between 5 and 499. The frame population is the Italian Business Register with 126,000 units.

The sample has been selected by a stratified simple random sampling design with strata given by size class in terms of employees (5-9, 10-49, 50-249, 250-499), industry (four sectors of the section C manufacturing sector of the Nace Rev.2 classification: Food; Personal and Households goods; Mechanical; other manufacturing activities) and geographical location (North-West, North-East, Center, South).

The data collection has been based on the CATI (Computer-Assisted Telephone Interviewing) technique. The interviewers had three training days to avoid response bias for please-the-interviewer concern. The sampled enterprises received a presentation letter highlighting the scope of the survey and the privacy disclaimer. Finally, the survey supervisor randomly assigned the sampled enterprises to the interviewers.

The number of respondents (the anonymity is guaranteed) has been of about 3,000 enterprises with a response rate of 16.2%. The survey adopted a calibration estimator such that the estimates of the number of enterprises in each stratum is equal to the known population total. The estimator deals with the selection bias for unit non-response, assuming the missing responses depend on the enterprises size.

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11. Additional information

Marco Pini, Marco Gentile, Damiano Angotzi – Paper: The extra gear of business model 4.0 for exporting and the backstage role of Public institutions, University and Business schools. Empirical insights from Italy

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