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ISTITUTO NAZIONALE PER L'ANALISI DELLE POLITICHE PUBBLICHE

WORKING PAPER

INAPP WP n. 116

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ISSN 2784-8701

FEBBRAIO 2024

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Foreign markets and the nature of digital technologies: Mixed-methods evidence from Italian firms

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FEBBRAIO 2024

Il working paper è stato realizzato nell'ambito del PTA Inapp 2022-2024, con riferimento alle linee di attività afferenti alla Struttura Imprese e lavoro

This study has been developed within the research collaboration agreement "Industria 4.0, Nuove Competenze e Quarta Rivoluzione Industriale: un laboratorio per la competitività delle imprese" between Inapp and Dipartimento di Ingegneria gestionale e della Produzione, Politecnico di Torino

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ABSTRACT

Foreign markets and the nature of digital technologies: Mixed-methods evidence from Italian firms

In this study, we provide a detailed quantitative and qualitative investigation of the impact of different digital technologies' adoption on the international competitiveness of Italian firms. We take advantage of three waves of Inapp's *Relazioni Imprese e Lavoro* survey and support the econometric results with five in-depth interviews with internationalised and digitalised firms from different sectors. Through a Diff-in-Diffs approach, we find that adopting information technologies (such as big data analytics and IoT) and production technologies (robotics) increases firm performance in international markets. Furthermore, the results are driven by medium-to-large firms specialised in high-tech, knowledge intensive sectors. The qualitative investigation unravels three enabling factors prompting international performance through digital technologies' adoption: virtualisation, enhanced information processing and operational flexibility.

KEYWORDS: digital technologies, firm performance, information processing, internationalisation, mixed-methods
JEL CODES: F60, L23, O33

In questo studio si sviluppa un'analisi quantitativa e qualitativa della relazione che lega l'adozione delle tecnologie digitali e la competitività delle imprese sui mercati internazionali. A tal fine si utilizzano i dati della Rilevazione Imprese e Lavoro (RIL) – realizzata da Inapp tra il 2010 e il 2018 su un campione rappresentativo di imprese italiane – e gli esiti delle interviste in profondità condotte tra il 2022 e il 2023 a soggetti che operano sui mercati internazionali investendo in nuove tecnologie. L'elaborazione econometrica mostra che l'adozione di tecnologie dell'informazione (Big data e Internet of Things) e di tecnologie di produzione (robotica) aumenta la performance sui mercati internazionali. Tali evidenze inoltre sono trainate da imprese medio-grandi specializzate in settori ad alta tecnologia e ad alta intensità di conoscenza. L'indagine qualitativa illustra, infine, tre fattori abilitanti che stimolano la performance internazionale attraverso l'adozione delle tecnologie digitali: virtualizzazione, migliore elaborazione delle informazioni e flessibilità operativa.

PAROLE CHIAVE*: tecnologie digitali, performance delle imprese, information processing, internazionalizzazione, metodi misti*
CODICI JEL: F60, L23, O33

DOI: 10.53223/InappWP_2024-116

Cite as:
Neirotti P., Ricci A., Tubiana M. (2024), *Foreign markets and the nature of digital technologies: Mixed-methods evidence from Italian firms*, Inapp Working Paper n.116, Roma, Inapp

1. Introduction

Digitalisation affects how firms organise internal resources and fare in the marketplace (Strange and Zucchella 2017). Acknowledging such impact is all the more relevant since we are amidst a wave of diffusion of new technologies, often labelled Industry 4.0 (I4.0), being ICTs and the World Wide Web the first and second waves, respectively (Bergamaschi *et al.* 2021). Sensors embedded in production machinery, automated lines and warehouses, integrated software for data-driven decision-making, artificial intelligence, and web-based platforms offer companies new opportunities to adapt and provide higher-quality products and services, revise logistics and supply chains management and possibly diversify (Goldfarb and Tucker 2019; Teruel *et al.* 2022).

Companies internationalise to increase their market shares and sales and generally improve their performance. However, whether and how internationalisation affects firms' performance is one of the most debated questions in the international management and economics fields (Werner 2002; Ruigrok *et al.* 2007). Notwithstanding the debate, it is acknowledged that technological adoption is one of the most relevant factors shaping such a relationship.

The adoption of digital technologies (DT) influences the decision to enter foreign markets and the capacity to be competitive internationally, especially for small and medium enterprises facing harsher resource constraints (Cassetta *et al.* 2020). The adoption and use of digital technologies support the increased information processing needs associated with the complexity of managing different international markets (Dutot *et al.* 2014a; 2014b) and the necessity for increased coordination and control of the value chains (Tushman and Nadler 1978). However, the capability of firms to seize the opportunities provided by the new wave of I4.0 digital technologies has not been explored from an empirical point of view. Such a lacuna limits our capability to understand the transformative potential of I4.0 technologies. On the one hand, I4.0 technologies have, for example, the potential to prompt the reshoring of manufacturing activities, stimulate more effective practices of value co-creation with customers and clients, and pave new business opportunities with servitisation (Bettiol *et al.* 2020; Bogers *et al.* 2016). Still, the empirical evidence is scant, mainly focusing on small samples, specific instances of digitalisation, or specific sectors (Bergamaschi *et al.* 2021). On the other hand, such a transformative potential goes hand in hand with the increased managerial complexity deriving from using multiple technologies simultaneously and investing in new organisational and human capital.

The necessary data to provide an in-depth analysis of the interplay between I4.0 technological adoption and the intensity and success of internationalisation strategies is very rare. The present research sets a discontinuity with previous studies on the topic because of i) a rich firm-level survey with national representativeness across sectors and firms' sizes in Italy, namely the *Rilevazione Imprese e Lavoro* (RIL); ii) an empirical methodology capable of disentangling the role of different I4.0 DT and polishing such effect by sources of bias (Cirillo *et al.* 2023); iii) a complementary qualitative analysis consisting in five in-depth firms interviews to explore the mechanisms behind the DT-internationalisation link.

In the empirical quantitative analysis, we exploit RIL's longitudinal dimension to apply a Diff-in-Diffs regression and purge the effect of technological adoption on internationalisation from the reverse causality bias. Nonetheless, the rich information about the workforce's composition, training investments, employment dynamics, industrial relations, governance, performance and innovative activity allows us to take care of biases arising from common factors affecting international performance and technological adoption. The empirical results show that adopting information technologies (such as big data analytics and IoT) and digital production technologies (robotics) increases firms' performance in international markets. Furthermore, the results are driven by medium-to-large firms specialised in high-tech, knowledge intensive sectors.

Despite the quality of our data and the appropriateness of our empirical approach, the explanatory power of our quantitative investigation is limited. Indeed, empirical data does not allow us to explore the mechanisms underlying our relationship of interest and unravel the paths through which I4.0 DTs enable a firm's performance on foreign markets. Such incapability to open the 'black box' is familiar to most quantitative-only studies. A mixed-method approach might be the viaticum by combining quantitative and qualitative primary sources and analyses (Birkinshaw *et al.* 2011; Johnson *et al.* 2007). In our case, a mixed-method study is exceptionally proficient because it allows us to update what we know about the relationship between internationalisation and 'standard' technologies adoption to state-of-the-art contemporary DTs. Hence, we run a qualitative analysis to get more profound insights and increase the study's explanatory power (Dabić *et al.* 2020).

Taking stock of the interviews round reported by the qualitative study on digitalisation in Italian enterprises conducted by Mazali *et al.* (2023), we returned to some of the interviewed firms where the linkage between digitalisation and internationalisation was more evident, and we extended the information collected with further enquiries. Consequently, we suggest three pillars through which the adoption of emerging DTs exerts its effect on international performance: virtualisation, enhanced information processing and operational flexibility. Comprehending these three pillars sheds light on why the link between DTs and international performance is less evident in small enterprises and industry settings that are not knowledge intensive.

Such pillars determine a quicker time-to-market in a co-designing environment, the capacity to graft novel and tailored services to clients and increase the efficiency of production and logistics processes while providing more product variety. Moreover, they reinforce local market adaptation capabilities by allowing product and service customisation at economically sustainable unit costs without bargaining on quality. Consequently, DTs adopters experience benefits in terms of both competitiveness and attractiveness in global markets.

In the next section, we describe the theoretical background we rely upon to assess DT adoption's role on firms' international performance. A brief description of the data precedes the empirical methodology and results. Finally, we lay out our qualitative enquiry, provide a schema to frame our findings, and conclude.

2. Theoretical Background

2.1 What we know about digitalisation and internationalisation

Firms internationalise to achieve market growth by securing better economies of scale and scope that can improve international competitiveness through enhanced cost efficiency. However, international market growth implies multiple strategic, managerial and organisational problems that digital technologies can mitigate.

The information processing view of the organisation highlights that firms facing a context of high environmental uncertainty, such as the one produced by being present in various foreign markets, deal with high information processing needs (Galbraith 1974). Such firms must enact technological and organisational solutions to increase their capacity to process information, like local product market divisions, lateral linkages that act transversally across units, and hierarchical links of control and information documentation (Egelhoff 1982; Tushman and Nadler 1978). To the extent that a product is the same worldwide, it is efficient and economical to centralise product knowledge and management in a single point at the parent company. Product-related information processing can be standardised, and product design and engineering can be integrated to achieve global economies of scale. If product characteristics and uses vary from country to country, firms need to combine and balance the logics of standardisation with that of market adaptation in the use of materials, production methods, configurations, marketing elements related to pricing, sales and distribution strategies. Managing such a tension requires great information processing across country units and along the hierarchical chain of supervision since logics of centralisation and decentralisation in product planning and management coexist.

The primary source of uncertainty a firm faces in internationalisation is related to the need to adapt the product to local market conditions. Dealing with such uncertainty requires substantial information collection and sharing with partners (trade partners, dealers, customers) to develop the knowledge related to product requirements and specifications (changes in regulation and customer preferences, for example). Similarly, the design and manufacturing processes need joint action and integration with foreign customers or suppliers (Premkumar *et al.* 2005).

I4.0 DTs can help handle information processing needs and cope with uncertainty. Industry 4.0 is a label to describe the trajectory of development and convergence among a bundle of complementary technologies such as cloud computing, data analytics, the Internet of Things, artificial intelligence, virtual and augmented reality, and additive manufacturing (Ricci *et al.* 2021). I4.0 has prompted a structural change from isolated manufacturing activities towards more automated, optimised and fully integrated product and data flows within global value chains (GVCs) (Strange and Zucchella 2017).

DTs can ensure accessible information flows in daily routine processes. A robust digital integration of information along the value chain allows international firms to track users, identify needs to upgrade products or services and reduce the distance between the firm and customers (Kollmann and Christofor 2014). In a similar vein, transaction cost theory predicts that ICTs adoption lowers transaction costs by adding more information transparency (such as real-time tracking) in the relationships between firms and dealers or even cutting these intermediaries with customers in foreign markets (Williamson 1979; Yamin and Sinkovics 2006).

Production robotics and virtualisation tools for product design and engineering (such as CAD 3D and virtual prototyping) reduce production technologies' level of asset specificity and increase operational flexibility, essential requirements to manage the stark market diversity associated with heterogeneous market needs. The technological trajectory started in the 1970s with industrial robotics, where software applied to machinery and automation has ignited a more rapid reconfiguration of general-purpose production technologies. Such a trajectory has supported firms in the primary strategic tension of internationalisation between global cross-border integration and market responsiveness (Subramaniam 2006).

DTs can support firms in managing various dimensions of uncertainty associated with internationalisation like demand uncertainty (inability to accurately predict fluctuations in demand due to local market conditions), supplier uncertainty (related to availability, stability of suppliers and consistency of quality and prices) and product criticality (the extent of monitoring required for the product's daily operations related to logistics, manufacturing or usage). Indeed, through their information processing power, DTs can add transparency and a more accurate forecasting of demand, production asset operational conditions and bottlenecks in production flows.

Moreover, DTs, with their different attributes associated with digitisation and connectivity (Lanzolla *et al.* 2023), have facilitated the formalisation and replicability of the organisational processes on a global scale, favouring international growth of those companies that codified and digitalised their products' and processes' operational knowledge (Malone *et al.* 1993). Brynjolfsson *et al.* (2008) labelled this effect as 'scalability without mass' (a limited need for bureaucratic structures controlling the operating line) and documented how it contributes to increased market concentration on a global scale. Such a characteristic grows more evident as a sector becomes information-intensive.

An open point is whether the 'scale without mass' principle is also visible for advanced servitisation manufacturers, who are increasingly pushed towards integratedness due to developments of digital tools and platforms allowing better control, monitoring, optimisation and automation in product management. For companies applying advanced servitisation logics in their business model, digital technologies can thus improve the operational embeddedness with customers, reducing the need for onsite proximity (Shleha *et al.* 2023)[1]. The digital character of these tools often allows integratedness to be achieved remotely with scalability, further incentivising integration (Del Giudice *et al.* 2021). Thereby, firms try to pursue market growth in the international market with a physically standardised product, leaving customisation to software and data analytics that can control product features (Porter and Heppelmann 2015).

Virtualisation technologies have enabled spatial separation and more complex types of independencies between people and objects (or other people) through virtual representations (the so-called 'digital twins') of processes or products (Lanzolla *et al.* 2023). Digital twins have improved inter-firm collaboration in product development along the supply chain, increasing the number of iterations in remote collaboration. Recent studies illustrate how the Covid-19 pandemic has accelerated the use of remote collaboration tools in product development across firms and their suppliers involved in product design and engineering (George *et al.* 2020), even in situations of high geographical and cultural distance. It has been argued that once firms and workers have incurred significant fixed costs for enabling remote working due to new technologies implementation, changes in production processes, and the updating of human capital, it is likely that they will no longer go back (Bonacini *et al.* 2021; Brynjolfsson *et al.* 2020).

Robotics powered by sensors, connectivity and AI increase the operational flexibility of production processes since they reduce the production configuration cost for particular purposes thanks to their use of AI that provides self-adaptation capabilities (Li *et al.* 2021). Similarly, inventory automation and

[1] Recent evidences testify a downside of workplaces digitalisation that is still minoritarian but on the rise. Fernández-Macías *et al.* (2023) call it 'platformisation of work', meaning a tendency to increased algorithmic control and monitoring of workers, with a consequent worsening of job quality conditions.

AI applications can allow companies to manage variety (of products) and speed (in logistic flows) with increased control, a critical success factor in international markets. Likewise, additive manufacturing is a general-purpose technology that can be reconfigured for a wide range of production needs, thus increasing the operational flexibility of machines (D'Aveni and Venkatesh 2020). Finally, blockchain increases transparency in the supply chain, supporting trust and reducing transaction costs (Schmidt and Wagner 2019).
DTs, in general, can improve firms' competitiveness by reducing the cost of storage, computation, and data transmission. The contraction in five distinct economic costs can be correlated with digital economic activity: search, replication, transportation, tracking, and verification costs (Goldfarb and Tucker 2019). Saliently, search cost reduction has pushed international hiring and outsourcing. While there is long evidence of international outsourcing (Leamer 2007), the recent increasing use of digital global labour market platforms represents a new model of international hiring. However, Agrawal *et al.* (2016) show that online platforms with standardised information benefit only workers from developing countries.
Finally, a recent line of research investigates the interaction between the adoption of new DTs and the role of internationalisation strategies for high-growth enterprises (HGE), whose growing economic importance is well knowninternationalisation activity and its impact on High Growth Enterprises (HGEs. Empirical evidence shows that HGEs are more likely to participate in foreign markets (mainly through Foreign Direct Investments) than non-HGEs and that firms adopting new DTs are more likely to be internationalised, primarily via exporting (Teruel *et al.* 2022).

2.2 What we still do not know about digitalisation and internationalisation

Notwithstanding the remarkable developments in DTs and the benefits they are expected to have for firms with an international reach, their actual impact on the internationalisation of firms is still debated due to the paucity of empirical evidence (Bergamaschi *et al.* 2021; Hervé *et al.* 2020) and some DTs ambivalence that determines their effectiveness. In this vein, the main element of ambivalence regarding emergent DTs like AI, IoT, big data and cloud computing is related to their accessibility – even for small enterprises (Brynjolfsson and McAfee 2014) – and to the level of creativity, managerial capabilities, and technical governance needed to pursue their integration and capture the value of their recombinational power (Lanzolla *et al.* 2021). Due to their low IT maturity, small and medium enterprises may not exhibit these preconditions (Bergamaschi *et al.* 2021; Romano 2018).
Consequently, the relationship between DTs adoption and internationalisation may differ across the size distribution. For example, sensors, data analytics tools and cloud computing facilitate the acquisition of helpful operational information for product improvement strategies or market segmentation. However, market adaptation requires organisational knowledge, expertise, and tacit knowledge collected on the production line or through proximity with the customer (Hennart 1982; 2001). On the one hand, small enterprises can be less exposed to this trend. For them, the link between digitalisation and internationalisation might be weaker due to their constraints in managerial resources, such as the low or nihil number of managers dedicated to foreign markets and limited capabilities to adopt and use different DTs in a bundle. This type of argument echoes the studies showing that DTs can have the paradoxical effect of increasing rigidity in firms with less advanced managerial practices

(Lu and Ramamurthy 2011). It can be the case for SMEs due to their lower budgets for technological investments and lack of managerial capabilities to develop effective governance systems and initiatives to ensure data quality.
On the other hand, the internationalisation strategy is also becoming relevant for SMEs (Dabić *et al.* 2020). In an increasingly globalised world, competition increases and even for SMEs it is necessary to look beyond national borders to survive and maintain sales levels (Lee *et al.* 2012). At the same time, technological change has made internationalisation strategies more affordable to SMEs. Remote working, artificial intelligence, IoT, mobile applications, social media and cloud computing are accessible and agile tools available to SMEs to facilitate internationalisation (Caputo *et al.* 2016; Lee *et al.* 2012). Hence, the link between digitalisation and internationalisation among SMEs is still ambiguous[2].
Following similar arguments based on the importance of tacit and market (context) specific knowledge, we may expect that the link between digitalisation and internationalisation is less evident in low knowledge-intensive industries and for small and medium enterprises acting in these sectors, including sectors specialised in complex products with a robust solution-based value proposition such as industrial machinery. Indeed, such sectors require more customer intimacy and onsite presence. However, frugal applications of some digitalisation logics can help service companies or companies with a focus on a solution-based approach to improve the level of service towards their customers, for example, by assuring customer proximity and control of the actors deployed on the customer front-end (e.g. value-added resellers, dealers, firm's employee involved in technical assistance or activities like product installing and configuration).
Therefore, in what follows, we empirically test for the effect of DTs adoption on the internationalisation of Italian firms and dissect such an effect by type of DT, firm's size and sectoral belonging.

3. Data

The empirical analysis is based on data from the last three RIL waves conducted by Inapp in 2010, 2015 and 2018 on a representative sample of partnerships and limited liability firms[3].
The RIL-Inapp survey collects a rich set of information about the composition of the workforce, including the amount of investments in training, hiring and separations, the use of flexible contractual arrangements, the asset of industrial relations and other workplace characteristics. Moreover, the data contains an extensive set of firm-level controls, including management and corporate governance characteristics, productive specialisation and other variables proxying firm strategies, such as the introduction of product and process innovations.

[2] Recent evidence shows that sustainability is a competitive driver for those SMEs having an international orientation (Denicolai *et al.* 2021).
[3] Each wave of the survey covers over 25000 firms operating in non-agricultural private sector. A subsample of the included firms (around 40%) is followed over time, making the RIL dataset partially panel over the period under investigation. The RIL-Inapp survey sample is stratified by size, sector, geographical area, and the legal form of firms. For more details on RIL questionnaire, sample design and methodological issues see: <https://bitly.ws/VqSD>.

The V wave of the RIL-Inapp survey includes questions specifically designed to collect information on the introduction of digital technologies. The key question concerns investments over the period 2015-2017 ('In the period 2015-2017, did the firm invest in new technologies?'). The respondent can choose among the following answers: *internet of things (IoT), robotics, big data analytics* and *augmented reality*. Although multiple answers are allowed, we adopt a dichotomous measure of Industry 4.0 investment and code a variable equal to 1 if a firm invested in at least one specific technology, 0 otherwise.
From the longitudinal component of the RIL dataset, we keep those firms with at least five employees and with no missing information for crucial variables. After deleting observations with missing values on the key variables, we end with a longitudinal sample of about 3000 firms over the period under study.

3.1 Desciptive statistics

Table 1 provides the descriptive statistics for the main variables.
As for the outcomes, we observe that, on average, 29% of firms operate on international markets, and 9% is the percentage of sales obtained from selling products and/or services on international markets. It amounts to an average of 2.6 if we consider the (log of) total sales per employee. Further, table 1 shows that, on average, 38% of firms invested in at least one DT in between 2015 and 2017. This incidence reduces to 14% once investments in cybersecurity are excluded, while the percentage of firms that adopted information technologies and robotics is 11% and 5%, respectively.
Data on management and corporate governance indicate that 23% (53%) of firms are run by managers/entrepreneurs with tertiary education (upper secondary education) and only 14% by a female. This evidence is consistent with the predominant role of firms small in size and family-owned, a well-known feature of the Italian economy that also mirrors the substantial prevalence of dynastic management (90%) – that is selected throughout informal ties by the family owners – as compared to external/professional management recruited on the outside markets (see Damiani *et al.* 2019).
It is worth noticing that the low average human capital endowments of those who run Italian firms and the predominance of dynastic objectives may induce risk aversion and present biases in financing innovative investments (Basiglio *et al.* 2023). We will argue below that controlling for these management and corporate governance characteristics helps to minimize the omitted variable biases in the econometric analysis.
Among workforce composition, we find that the proportion of tertiary educated workers is limited (10%) while the share of aged workers (24%) and of blue collars is relatively high (54%) – a feature coherent with the productive specialisation of the Italian economy.
Concerning firms' characteristics, RIL data highlight that about 2% are multinationals, 61% was a member of an employer's association, 38% (32%) invested in product (process) innovation, and, on average, 2.4% benefited from the Irap tax cuts in term of investment plans. The mean value associated with the (log of) number of employees reflects that more than 90% employed less than 50 workers, while statistics on geographical localisation and sector of activities are not reported. Of course, the descriptive statistics on the total sample hide substantial heterogeneities by size, business sector, and geographic location. We do not show them to save space, but they are available upon request.

Table 1. Descriptive statistics

	N of Obs	Mean	Std dev	Min	Max
	Foreing markets and digital technologies				
Foreign markets (0/1)	8,562	0.289	0.453	0	1
% sales from Foreign markets	8,562	9.009	2.136	0	100
ln (sales foreign mkt per employee)	8,562	2.941	4.719	0	13.090
At least one DT	8,562	0.385	0.487	0	1
At least one DT (no cyber)	8,562	0.139	0.346	0	1
Information tech	8,562	0.110	0.312	0	1
Robotics	8,562	0.051	0.221	0	1
	Management and corporate governance				
Tertiary education	8,562	0.231	0.421	0	1
Upper secondary ed	8,562	0.543	0.498	0	1
Female	8,562	0.142	0.349	0	1
Dynastic management	8,562	0.905	0.294	0	1
Internal management	8,562	0.063	0.243	0	1
External management	8,562	0.032	0.177	0	1
	Workforce characteristics				
Share of tertiary ed	8,562	0.097	0.187	0	1
Share of upper secondary	8,562	0.483	0.305	0	1
Share of lower secondary	8,562	0.420	0.330	0	1
Share of aged workers	8,534	0.236	0.211	0	1
Share of middle aged	8,534	0.477	0.229	0	1
Share of executives	8,562	0.038	0.091	0	1
Share of white collars	8,562	0.380	0.313	0	1
Share of blue collars	8,562	0.582	0.330	0	1
	Firms characteristics				
Multinational ownership	8,562	0.018	0.134	0	1
Employers' association	8,562	0.612	0.487	0	1
Firms age (in years)	8,562	26.927	14.828	0	338
Irap tax cut	8,562	0.024	0.154	0	1
Product innovation	8,562	0.381	0.486	0	1
Process innovation	8,562	0.325	0.468	0	1
Ln(number of employees)	8,562	2.501	0.834	1.609	9.227

Note: pooled 2010-2015-2018 data. Sampling weights applied.
Source: Authors' calculations on RIL longitudinal sample

What is worth discussing briefly are the main differences between firms that invest in digital technologies and those that do not. In this regard, table A1 in the appendix illustrates how digitised firms have higher international performance (in both the intensive and extensive margins) than firms that have not invested. Similarly, the first group of firms is characterised by a relatively higher incidence of highly educated managers, a higher share of workers with a college degree, and a stronger innovative propensity in productive processes and products.

4. Econometric strategy

To assess the quantitative effect of various DTs on international performance, we estimate the following equation:

$$Y_{i,t} = \alpha_1 DT_i + \alpha_2 (DT_i \cdot 2018) + \alpha_3 (DT_i \cdot 2014) + \beta_1 MWF_{i,t} + \vartheta_1 (s_{i,t} * r_{i,t}) + \vartheta_2 (s_{i,t} * d_{i,t}) + \mu_i + \lambda_t + \varepsilon_{i,t} \quad [1]$$

Where $Y_{i,t}$ indicates the (log of) sales per employee from selling products and services on foreign markets for each firm *i* in years *t*=2010, 2015, 2018. Our key explanatory variable, DT_i, is a dummy taking the value of 1 whether the firm invested in at least one DT – Internet of Things, robotics, big data analytics, and augmented reality – over 2015-2017, and 0 otherwise. Then, the treatment group comprises firms declaring to have invested in new technologies over 2015-2017 ($DT_i=1$), while the control group comprises firms that did not invest at the same timespan ($DT_i=0$). Further, we disentangle the nature of DTs by defining two dummy measures of DT investments: the first identifies the subset of information technologies (IoT, big data analytics and augmented reality), and the second one measures the adoption of digital production technologies (robotics).

The time variable 2018 – the year of the survey wave collecting information about the 2015-2017 investments – is an indicator for the post-treatment period, and remarks the pre-treatment period. The interaction term $DT_i \cdot 2018$ identifies the Diff-in-Diffs effect of DTs adoption while $DT_i \cdot 2014$ allows to verify the Common Trends Assumption (CTA) with respect to the initial omitted year, 2010. The CTA implies that we should observe parallel trends in the outcome variable for treated and control groups without treatment. If CTA holds, the Diff-in-Diffs estimator removes any time-varying effect influencing the treatment and control groups.

Notwithstanding the Diff-in-Diffs with fixed effects (FE) approach, the vector $MWF_{i,t}$ includes a comprehensive set of control variables capturing organisational and economic firms' characteristics, further shielding our estimates from omitted variable bias. In particular, we include controls for managerial and corporate governance, workforce composition and firms' productive features, geographical location and sectoral specialisation. All these covariates have been discussed in the descriptive section. Concerning the time-invariant and unobserved forces that may influence our relation of interest, the parameter μ_i captures firms' time-invariant unobserved heterogeneity, λ_t are year dummies, the interaction terms $(s_{i,t} * r_{i,t})$ and $(s_{i,t} * d_{i,t})$ formalise 2-digit sector-by-firms' size and 2-digit sector-by-regions FEs, respectively. They account for the heterogeneous patterns across sector-specific technologies that vary between geographical regions and firm size. Finally, $\varepsilon_{i,}$ is the idiosyncratic error term.

Moreover, we combine the Diff-in-Diffs FEs regression model with Propensity Score Matching (PSM) methods to mitigate potential self-selection biases further. The idea is to run regressions on a restricted sample of 'treated' and control firms with similar probabilities (propensity scores) of investing in digital technologies.
Note that this strategy is suitable to deal with the issue of 'first adopters', even though we have no explicit information about the use of DTs before 2015-2017. Indeed, DTs diffusion in Italy was limited and scarce before 2015, whereas it peaked in the following period also because of the introduction of the Italian National Plan Industry 4.0. Further, the PSM balances the treatment and control groups on a comprehensive variety of firm features that strongly correlate with the probability of investing in technological advancements. Hence, even though we do not observe pre-treatment adoption, we can figure it as a latent variable that, thanks to the PSM, is evenly distributed across our groups[4].
We are confident that our quantitative framework is well-suited for accounting for the potential reverse causality issues[5]. Diff-in-Diffs fixed effect model compares 'treated' firms that invested in DTs over 2015-2017 with the 'control' firms that did not. The model takes care of a comprehensive set of observables and unobservable characteristics, minimising concerns associated with self-selection in technological choices. In this regard, the timing of the Italian National Plan Industry 4.0 helps our identification: the policy introduced (mostly after 2016) a set of horizontal fiscal incentives to lower financial constraints on technological investments and sustain the digital transition. In the short run, such an external shock may be considered a sort of exogenous variation in the treatment with respect to international performance.

5. Results

5.1 Main estimates

Table 2 shows the Diff-in-Diffs FE estimates of equation [1] when different DTs sets are examined[6]. In particular, column [1] estimates that the adoption of at least one digital technology – over the period 2015-17 – increases by 42% the amount of sales from international markets per employee, that is an average increase of 14.3% on annual basis.
Investments in information and digital production technologies increase the performance on international markets, even standalone. That is, we observe that having invested in the Internet of Things, big data analytics or augmented reality increases by 39% the (log of) foreign sales per capita while (see column [2]) and similarly (+36%) we find for robotics (column [3]).

[4] In section 5 we tackle the issue of 'first adopters' also by exploiting the RIL data on past investments in information technologies, that is selecting the subsample of firms that did not invest in information/hardware devices in the initial period of the analysis.
[5] In this regard one may argue that competitive firms in international markets might be more resourceful and thus more capable of investing in new technologies implementation. As well, they might have access to broader human and financial capital markets, enabling them to pursue digital technologies development effectively (Cirillo *et al.* 2023; Gal *et al.* 2019).
[6] We do not present pooled OLS estimates. These results are available upon request.

The not-statistically significant coefficient associated with the interaction terms between DTs adoption and the pre-treatment year 2014 supports the validity of the CTA. In other words, we find parallel trends in (log of) international sales per employee between firms in the treated and control groups up until the adoption of information technologies (column [2]) and robotics (column [3]) over the period 2015-2017.

Table 2. Estimates of Diff-in-Diffs with FE. Dep var: (log of) sales per capita from international market

	[1]	[2]	[3]
DT*years2018	0.424**		
	[0.110]		
DT*years2014	0.168		
	[0.201]		
Information tech*year 2018		0.391**	
		[0.185]	
Information tech *year 2014		0.161	
		[0.184]	
Robotics*year 2018			0.364*
			[0.119]
Robotics*year 2014			0.245
			[0.202]
Year 2018	0.116	0.141	0.171
	[0.127]	[0.090]	[0.096]
Year 2014	0.130	0.138*	0.143
	[0.098]	[0.078]	[0.069]
Management characteristics	Yes	Yes	Yes
Workforce characteristics	Yes	Yes	Yes
Firms characteristics	Yes	Yes	Yes
Constant	3.793***	3.786***	3.780***
	[0.138]	[0.328]	[0.137]
Obs	8562	8562	8562
R2	0.773	0.777	0.773

Note: management characteristics include education, age and gender of those who run the firm, dynastic and internal managers; workforce characteristics include the composition of the employees in terms of education, professional status, contractual arrangement and age; firm characteristics include the presence of employers' association, multinational, past product and process innovation, firms' age in years. All regressions include full interactions between 2-digit sectors and NUTS2 region and firm size classes FE. Robust standard errors in parentheses are clustered at the firm level. Statistical significance: *** at 1%, ** at 5%, * at 10%.

Source: Author's elaborations on RIL-ORBIS data

It is worth noticing that digitalisation also positively impacts the 'extensive' margin of international performance. In particular, table A2 displays the estimates of the equation [1] when the outcome represents the propensity of selling products and/or services in foreign markets. Here, we observe that investing in at least one DT and adopting information technologies or robotics separately increases the probability of operating in foreign markets.

5.2 Heterogeneity across sectors

To test whether the industry environments shape the link between digitalisation and internationalisation, we replicate previous regressions by distinguishing between firms operating in high-tech sectors and those working in low-tech ones, construction, and utilities[7].

Table 3. Estimates of Diff-in-Diff with FE. Sectors by technology and knowledge intensity. Dep var:(log of) sales from international markets per capita

	High tech and KIS sectors			Low tech and no KIS sectors		
	[1]	**[2]**	**[3]**	**[4]**	**[5]**	**[6]**
DT*year 2018	0.438**			0.483**		
	[0.189]			[0.219]		
DT*year 2014	-0.009			0.323*		
	[0.235]			[0.188]		
Information tech*year 2018		0.479**			0.418	
		[0.230]			[0.261]	
Information tech *year 2014		-0.148			0.368	
		[0.221]			[0.252]	
Robotics*year 2018			0.679***			0.269
			[0.242]			[0.325]
Robotics*year 2014			0.453			0.233
			[0.271]			[0.172]
Year 2018	-0.046	-0.027	-0.005	0.126	0.156	0.202
	[0.139]	[0.132]	[0.133]	[0.146]	[0.149]	[0.139]
Year 2014	0.076	0.103	0.024	0.106	0.112	0.151
	[0.128]	[0.113]	[0.113]	[0.111]	[0.108]	[0.107]
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Constant	3.444***	3.451***	3.345***	3.875***	3.869***	3.549***
	[0.766]	[0.764]	[0.685]	[0.419]	[0.422]	[0.319]
Obs	2257	2257	2257	6057	6057	6057
R2	0.796	0.796	0.796	0.759	0.759	0.759

Note: other controls include management characteristics such as education, age and gender of those who run the firm, dynastic and internal managers; workforce characteristics such as the composition of the employees in terms of education, professional status, contractual arrangement and age; firm characteristics such as the presence of employers' association, multinational, past product and process innovation, firms' age in years. All regressions include full interactions between 2-digit sectors and NUTS2 region and firm size classes FE. Robust standard errors in parentheses are clustered at the firm level. Statistical significance: *** at 1%, ** at 5%, * at 10%.

Source: Author's elaborations on RIL-ORBIS data

[7] We rely on the OCSE nomenclature, according to which the 2-digit NACE sectors classify as follows: 1 'High-Tech' 2 'Med-High-Tech' 3 'Med-Low-Tech' 4 'Low-Tech' 5 'KIS-Market' 6 'KIS-High-Tech' 7 'KIS-Finance' 8 'KIS-Other' 9 'LKIS-Market' 10 'LKIS-Other' 11 'Mining & Quarrying' 12 'Construction' 13 'Utilities'.

The first three columns of table 3 report the Diff-in-Diffs estimates for the subsample of firms operating in high-tech and medium-high-tech manufacturing, KIS-market, KIS-high-tech, KIS-finance and other KIS service sectors.
In particular, estimates in column [1] indicate that, within the high-tech sectors, DTs adoption exerts a significant effect on foreign markets sales per capita, with a coefficient estimate equal to +44%. Further, the coefficient associated with is not significantly different from zero, suggesting that, in high-tech sectors, the changes in our outcome variable before treatment were not dissimilar between treated and control firms. Focusing on columns [2] and [3], we also find that information technologies and robotics increase the dependent variable equal to +48% and +68%, respectively. Again, the test of parallel trend assumption is overcome for information technology and robotics.
The picture changes if we consider the last three columns of table 3, where we report the results for low-tech manufacturing, LKIS-market, LKIS-other, mining & quarrying, construction and utilities. In column [4], we observe that the overall DTs significantly increase the (log of) sales per employee (+48%), while if we distinguish information technologies and robotics, no significant effect is found within the low-tech and LKIS sectors. As drafted in the theoretical section, firms active in such sectors rely intensively on customer proximity and onsite presence, and their business hardly follows paths of servitisation.
Once we acquired that the positive relationship between DTs adoption and international performance is driven mainly by firms operating in high-tech sectors, we now test whether such an effect within high-tech sectors varies across firms' size, as small and large firms face different opportunities and challenges in adopting and extracting gains from digital investments. Cirillo *et al.* (2021) and Romano (2018) point out that the adoption rate of new enabling technologies more than doubles among large companies compared to small firms[8].
The first three columns of table 4 report the results regarding small firms with less than 50 employees in the high-tech and KIS sectors, whereas the last three columns deal with the medium-large firms with more than 49 employees. As expected, none of the former three columns retrieves statistically significant coefficients for DTs adoption, whereas columns [4]-[5]-[6] corroborate the idea that a firm's size matters the most, even within sectoral classes.

[8] We also run regressions separately for small and medium-large firms without restricting to the subsample of high-tech sectors. As expected, we find that the medium-large companies drives the positive relationship between DTs adoption and international performance. In particular, the adoption of digital technologies leads to an increase of +72% in the (log of) sales per employee; this figure rises to + 82% if we focus on the subset of information technologies.

Table 4. Estimates of Diff-in-Diffs with FE. Subsample of high-tech, KIS sectors. Heterogeneity by size. Dep var: (log of) sales from international markets per capita

	N of employee<50			N of employee >=50		
	[1]	[2]	[3]	[4]	[5]	[6]
DT*year 2018	0.165			1.123*		
	[0.264]			[0.580]		
DT*year 2014	0.417			-0.330		
	[0.351]			[0.500]		
Information tech*year 2018		0.082			1.289**	
		[0.265]			[0.515]	
Information tech *year 2014		0.200			-0.317	
		[0.350]			[0.589]	
Robotics*year 2018			0.608			1.089*
			[0.398]			[0.573]
Robotics*year 2014			0.876*			0.272
			[0.483]			[0.329]
Year 2018	0.155	0.171	0.145	-0.559	-0.504	-0.359
	[0.121]	[0.110]	[0.118]	[0.466]	[0.390]	[0.359]
Year 2014	-0.021	0.031	0.007	0.272	0.232	0.093
	[0.105]	[0.103]	[0.104]	[0.394]	[0.332]	[0.291]
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Constant	3.007***	3.002***	2.785***	4.102**	4.016**	4.003***
	[0.858]	[0.861]	[0.857]	[1.527]	[1.520	[1.410]
N of Obs	1537	1537	1537	651	651	651
R2	0.784	0.783	0.784	0.717	0.717	0.714

Note: other controls include management characteristics such as education, age and gender of those who run the firm, dynastic and internal managers; workforce characteristics such as the composition of the employees in terms of education, professional status, contractual arrangement and age; firm characteristics such as the presence of employers' association, multinational, past product and process innovation, firms' age in years. All regressions include full interactions between 2-digit sectors and NUTS2 region and firm size classes FE. Robust standard errors in parentheses are clustered at the firm level. Statistical significance: *** at 1%, ** at 5%, * at 10%.

Source: Author's elaborations on RIL-ORBIS data

5.3 Further results

The Diff-in-Diffs estimates may not be enough to infer an impact of DTs on firm performance in international markets. It would be the case if some productive characteristics were systematically different between the firms belonging to the treated and control groups. We try to restore randomness in selection by conditioning the Diff-in-Diffs regressions on the common support condition. Then, treated and control firms are singled out through a PSM approach according to their likelihood of investment in digital technologies[9]. No difference seems to be statistically significant: the matching is successful both for labour productivity and average wages, and the trimming mechanism leads us to restrict the sample to comply with the common support condition notably.

[9] To assess the quality of the matching, we calculate the differences between the mean values of a large subset of the variables we used to match the treatment and control groups for the sales per employees. Overall, the figures confirm that the two groups, although initially different, appear to be rather similar after matching.

To assess the matching quality, table B1 (see the appendix) presents the differences between the mean value of a subset of the variables (sectoral dummies are not reported to save space) that are used to match the treatment and control groups. Overall, the figures in table A2 confirm that the treated and control firms, though initially different, appear to be similar after the matching.

Finally, table 5 displays the Diff-in-Diffs estimates of equation [1] after imposing the common support condition, i.e., restricting the sample and applying the weights obtained by the PSM matching procedure. The estimates found in the matched sample are consistent with those presented in table 2 regarding the direction and statistical significance of the impact of DT on international performance. In particular, the estimates in column [1] show that the DT adoption is associated with a rise in sales from foreign markets +72%. That is, an average increase of 24% on an annual basis. In column [2], we observe that the effect of information technologies is lower in magnitude (+46%), while no significant estimates are found for robotics.

Table 5. Estimates of Diff-in-Diffs with FE. Matched sample. Dep var: (log of) sales from international markets per capita

	[1]	[2]	[3]
DT*years 018	0.723***		
	[0.256]		
DT*year 2014	0.395		
	[0.253]		
DT infor tech*years 2018		0.467**	
		[0.222]	
DT infor tech *years 2018		0.254	
		[0.223]	
Robotics*year 2018			0.330
			[0.236]
Robotics*year 2014			0.242
			[0.232]
Year 2018	-0.281	-0.015	0.168
	[0.228]	[0.180]	[0.151]
Year 2014	-0.130	0.014	0.050
	[0.221]	[0.172]	[0.140]
Other controls	Yes	Yes	Yes
Constant	5.225***	5.171***	5.129***
	[0.512]	[0.512]	[0.512]
Obs	3041	3041	3041
R2	0.868	0.867	0.867

Note: other controls include management characteristics such as education, age and gender of those who run the firm, dynastic and internal managers; workforce characteristics such as the composition of the employees in terms of education, professional status, contractual arrangement and age; firm characteristics such as the presence of employers' association, multinational, past product and process innovation, firms' age in years. All regressions include full interactions between 2-digit sectors and NUTS2 region and firm size classes FE. Robust standard errors in parentheses are clustered at the firm level. Statistical significance: *** at 1%, ** at 5%, * at 10%.

Source: Author's elaborations on RIL-ORBIS data

As before, the test for the CTA is not significantly different from zero, confirming that digital investment leads and does not simply correlate with performance.

For the sake of robustness, we conclude our quantitative analysis by running the Diff-in-Diffs FE regressions on the sub-sample of 'first adopters'. The first adopters are identified in the RIL data as those firms that did not invest in information technologies (hardware and software) in 2010, the initial period in which we test the parallel trend assumption.

Table A3 in the appendix supports the empirical picture that emerged in previous sections, confirming the positive effects of investing in at least one DT on the international market performance (column [1]). The positive link also holds if we consider information technologies and robotics separately.

6. Evidence from an in-depth qualitative study

Despite the evident quality of the RIL data and the appropriateness of our empirical approach to identify our relationship of interest, the presented quantitative evidence has limited explanatory power (Dabić *et al.* 2020). Expressly, we have limited arguments to explain why the effects of digitalisation on internationalisation do not occur in some settings, such as small enterprises or low-tech and LKIS sectors. Because of the limited scope and depth of information provided by quantitative data, econometric studies cannot often open the 'black box' and delve into the underlying mechanisms governing the apparent effect. In this respect, mixed-methods studies that combine quantitative and qualitative primary sources and analyses represent a valuable and promising opportunity (Johnson *et al.* 2007). It is particularly true in our case since the relationship between 'standard' technology adoption and internationalisation has been documented quantitatively; still, by adding a qualitative study to our econometrics, we provide a double-fold contribution: a detailed account of the phenomena taking place in the 'black box' and an updated treatise of contemporary digital technologies.

We present results collected during five in-depth interviews with as many firms regarding the channels through which the adoption of DTs fosters internationalisation. Such firms were already involved in a study on the interplay between technology and competencies during the era of digitalisation (Mazali *et al.* 2023), and each of them represents a "revealing context" in which the phenomena of interest could be "transparently observed" (Yin 1994, 40). These five internationalised firms are located between Piedmont (Northern Italy) and Apulia (Southern Italy), with a marked entrepreneurial orientation towards technology adoption (Hervé *et al.* 2020). Since we already know most of the enterprises' history and business characteristics through the work of Mazali *et al.* (2023), we focused the round of interviews on I4.0 technologies adoption, their impact on the internationalisation performance and strategy, and the interplay with productivity (the draft questionnaire that served as a guideline for the interviews is available in the appendix). The cases analysed allowed us to reach theoretical saturation (Yin 1994; Eisenhardt 1989) and individuate the presence of three pillars qualifying the relationship between DTs and internationalisation. Hence, we stopped the interview process (Corbin and Strauss 1990).

Herein we briefly describe each interviewed firm's history and characteristics. We highlight what kind of technological investment was made and how it affects the firm's management and internasionalisation, with careful reference to the specificities of the sector the firm is active in.

Firm A. Firm A is a company founded in 2000, active in a niche of the fashion market and dealing with the design, engineering, development, prototyping and production of luxury clothing lines. Firm A supplies the world's leading fashion players, and 95% of its final production goes to international customers. Indeed, internationalisation is a prerequisite for an Italian firm engaged in a market such as luxury fashion, whose leaders are clustered in Milan, London, Paris and New York.
Still, Firm A's internationalisation position and strategy are worth studying because they descend from the uniqueness of its technological solutions. Indeed, Firm A represents a remarkable example of the evolution and transformation of inherently traditional work, such as tailoring, due to digitalisation. In the last ten years, Firm A started a technological trajectory that led the designing, developing, prototyping and production processes to be highly supported and embedded into digitalised systems.
New clothes' templates come in 2D or 3D, and clients give feedback on these digital twins of the actual garments. The production line has been empowered with the implementation of 3D laser printers. A new and highly mechanised warehouse, endowed with radio-frequency identifications to manage the crafting of multiple collections contemporaneously, has been built. The effective use of these technologies required the parallel implementation of a management information system to handle the workflow's complexity. Moreover, the workforce underwent specific training in the appropriate digital skills.
During our interview, it clearly emerged that implementing digital technologies sustained and promoted Firm A's internationalisation strategy. Specifically, DTs had three distinct effects on the firm's ability to collaborate with international customers.
First, DTs help decrease the costs related to communication, coordination and management of the designing and engineering stages. Hence, DTs supported Firm A in the co-design approach with the client with direct and positive consequences on the final product's quality.
Second, the uniqueness of Firm A's technological solutions represents a strategic and rather unique resource that facilitates the clients' attraction and retention. Thus, mastering emerging digital technologies (like the recent use of blockchain to track production flows in a supply chain characterised by high levels of vertical de-integration) enhances the company's reputation as an innovator. DTs have increased their strategic importance during the pandemic since virtualisation and product digital twin have allowed remote collaboration with the client where social distancing and international travel blockades have impeded physical meetings between stylists and Firm A's makers. Product virtualisation has also been exploited by Firm A to achieve a higher level of environmental sustainability since it has eliminated the use of express and airline couriers for sending physical prototypes to the client's site during the product validation stages. Similarly, digital twins have optimised the use of material, reducing waste to a minimum.
Third, mastering virtualisation technologies has eventually allowed Firm A to apply these competencies to a more extensive product portfolio: the company started with man outwear and has progressively entered other product lines like knitwear. Such an expansion allowed the company to increase the linkages with its current customer base and augment the extent of scope economies in coordination with suppliers.
Firm B. Firm B is a technologically innovative and entrepreneurial family business founded in 1957 that transitioned, from 1985 on, from a furniture manufacturer to a supplier of automated warehouses for the manufacturing and retail sectors, nowadays its primary business activity.

Even though Firm B's internationalisation process started in the early 2000s and involves about 50 countries, the exports-to-sales ratio is about 35%: Firm B's primary market is domestic, which, in the interviewee's opinion, might come from the inherent requirement of proximity with the customer sites in the sales and after-sales processes, the latter one related to the implementation and maintenance of automated warehouse solutions.

Concerning the production side, in 2019, Firm B acquired smart and connected machines for its production process, making production capacity more flexible and efficient thanks to superior planning and control capabilities of production flows. Parallelly, it updated its IT structure (MRP, MES, CRM and other software to support mechanical design, product and commercial management) and hired experienced managers to empower its organisational capabilities and effectively seize the opportunities generated by such technological investments. These changes improved Firm B's productivity, which, in turn, is a necessary condition for international competition.

The company is also exploring different trajectories of product and service innovation, including servitisation, enabled by digital technologies. One is about the use of augmented reality to support dealers in the activities related to installing and maintaining warehouses located in foreign countries. Indeed, training personnel in loco or sending expatriates to the customer site for installation and maintenance is a disproportionate and unjustified cost compared with the warehouse's economic value. Technological solutions are needed to administrate remote assistance. Firm B developed a digital platform that monitors all the managed warehouses in the globe from the Firm B operations centre in real-time to collect data and make diagnostics (digital twin). Data collection is possible thanks to a pervasive distribution of sensors applied to warehouses' robotics.

Since a few years, the company has already grasped part of the organisational benefits that augmented reality can provide through simpler technologies. Specifically, web conferencing tools, such as Zoom or Skype, and mobile devices, such as tablets and smartphones, favour more coordination between field workers and the company's engineering department, thus helping bi-directional knowledge flows. Such technological upgrades empower field workers with the technical knowledge available in Italy's centralised engineering department. Still, it also allows such a department to access localised knowledge and better control of dealers and their field workers in foreign countries.

A second technological trajectory entails using more advanced technologies and deploying the Internet of Things and artificial intelligence in a new generation of diffused, automated self-warehouses. Such connectivity and automation approach can find application in ensuring remote control of the asset, more prompt assistance and maintenance to international customers (use of prescriptive or predictive logic); responding to quick-commerce needs of city logistics; and amplifying its after-sales services that tackle the streamlining of warehouses' life cycle costs. Indeed, Firm B aims at refining its consultancy services offer for its warehouse management optimisation by, on the one hand, endowing warehouses with interconnected sensors that monitor storage efficiency and, on the other hand, applying AI algorithms that individuate viable solutions remotely.

Firm C. Firm C is a company founded in 1891 whose primary business is hot moulding and mechanical machining for commercial and heavy-duty vehicles. Firm C's exports-to-sales ratio is about 65%. Indeed, most of its principal clients are multinationals in the vehicle production industry.

In the last decade, Firm C went through a series of essential investments in DTs that led to the implementation of a fully automated lean production machine with laser tools to weld and harden steel. The increased production volume and complexity required the parallel implementation of a hardware and software monitoring and traceability system (MES) necessary to safeguard the firm from errors and product malfunctioning. Adopting new technological and procedural solutions goes hand in hand with an organisational restructuring of Firm C. In particular, the firm invested in ameliorating its organisational practices, hired and trained dedicated managerial roles, and devoted substantial efforts to implementing a new lean corporate program to reduce errors on the shopfloor, increasing efficiency and quality.

Implementing and integrating such innovative technological and organisational solutions have allowed Firm C to offer novel services and products with higher value added to its international clients. Indeed, Firm C today provides its clients with assembled products that otherwise require coordinating a variety of suppliers scattered globally but at a lower price and coordination costs for the client. In other words, Firm C reshored production activities and offers a competitive deal and a high-quality standard thanks to its technologically and organizationally empowered production efficiency.

On the other hand, the company's growth and internationalisation process is driven by the demand exerted by its multinational customers. Customers' requests are the stimulus to invest and the platform to enlarge the presence abroad. Following the clients' lead is an explicit firm's entrepreneurial strategy.

Firm D. Firm D is a family firm founded in 1966, specialised in printing labels for wines, spirits and, recently, cosmesis. It is a multinational company with production plants in five countries (Italy, France, Scotland, United States and Mexico) and a markedly international orientation: in 2021, around 45% of its sales occurred abroad.

Firm D's keen propension to invest in technologically advanced solutions makes it an outlier within its sector. In 2016, Firm D started investing in augmented and virtual reality to produce 3D renderings of its clients' and competitors' products on the shelf, support the development of customers' packaging (label) and reduce the time-to-market. It made a significant investment to automatise the production facility with Autonomous Mobile Robots and improve the printing process' security and efficiency. Firm D even patented a photocell system technology to foster reels traceability and avoid the risk of mixing between printing and packaging. All these production-related investments come with IoT technologies for real-time data collection and implementation and the updating of ERP and CRM systems.

Firm D technological orientation derives from its entrepreneurial strategy: build a competitive advantage through the capacity to supply clients with high-quality, premium products at a reasonable cost and a large scale. At the same time, high productivity, excellent quality and repeatability of production performance are sine-qua-non conditions for Firm D to compete globally. New DTs have made it possible to meet three needs: offer quality products in line with global customers' expectations, optimise production processes by reducing production costs, and increase operational flexibility by using efficiently the same machines to cope with the expanded product variety of international markets.

Firm E. Firm E is a family firm founded in 1963. Born as a technical support centre, it is now a leading worldwide distributor of spare parts for home appliances. Building on a solid and intrinsic orientation to export high-quality Italian products abroad and taking advantage of the favourable conditions of the home appliances sector starting from the '90s, Firm E has been experiencing constant overall growth and an even more marked increase in its sales abroad, 65% of its total sales in 2020 and 75% in 2022.

Firm E constant growth and expansion made it a multi-product, multi-client, high-quality, fast-delivery company. In this context, Firm E made a series of technological and organisational advancements: an automatic warehouse; a reorganisation of the orders' preparation management areas to diminish mistakes in the consolidation phase; two digital channels in the form of proprietary digital platforms for e-commerce to reduce distances with customers and improve the products' distribution; a software to support a data-driven decision-making process and demand prediction to move away from an experiential approach; a reorganisation of internal practices to pursue a lean philosophy.
Given its efficient storage and fast-release capacities, such enhancements allow Firm E to widen the product range without investing in net working capital. Moreover, Firm E can ensure maximum flexibility in the type of order (size and timing). Consequently, Firm E's international competitiveness builds on price leverage.

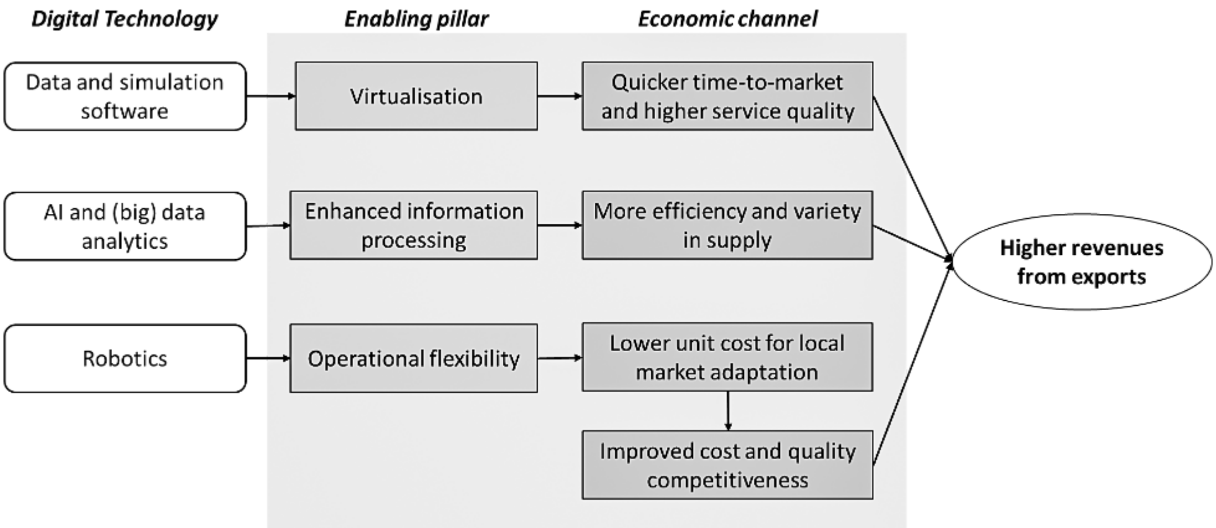
6.1 Results

Table 6 summarises our findings. Synthesising the interviews' content, we unravel three enabling factors prompting international performance through DTs adoption: these are the pillars the firms' internationalisation strategy rests on. Each pillar builds on a set of DTs and answers to a firm's specific need emerging when expanding in new, foreign markets. Together with the pillars, we evidence the mechanisms through which the technology enables firms to face each need successfully. Furthermore, Figure 1 depicts the consequential link between adopting some set of DTs and international performance, with particular attention to the economic channel through which the technological effect deploys. Namely, the pillars are virtualisation, enhanced information processing and operational flexibility.

Table 6. Summary of results from the qualitative study

Enabling pillars	Firm's need	Enabling mechanisms
Virtualisation	Knowledge transfer along GVCs	Augmented reality allows transferring of product-related knowledge on a global scale in a virtual way (for example, to dealers and installers) Virtual reality allows producing digital twins in the product engineering phase and supporting more frequent and cheaper feedback loops with international clients remotely Smart and connected machines allow providing new customised consulting services to foreign customers remotely
Enhanced information processing	Deal with increased demand uncertainty and complexity	More granular information assures an increased capability to manage rising product variety and lower unit costs for small and less frequent orders simultaneously in a centralised unit
Operational flexibility	Manage local market adaptation	Capability to manage local markets and consequently increase product variety in one central operational unit Low unit cost in case of customisation on small orders (such as special editions of global products)

Figure 1. Graphical representation of the consequential link between DTs adoption and international performance



Source: Authors' elaboration

Virtualisation. When expanding into foreign markets, firms face the challenge of distance, whether it increases communication costs, inhibits the ability to observe and recognise issues and timely react to them, or impedes direct maintenance of a firm's products and services. The enhanced opportunities of virtualisation offered by recent digital technologies reduce the need for onsite proximity with a client or a distribution partner. Implementing augmented reality tools allows firms to exchange knowledge with collaborators abroad in real time and with excellent specificity. Although onsite collaborators must come with a minimum degree of embedded competence and tacit knowledge, being able to apply home-country technicians' highly specific, competent knowledge remotely through augmented reality is an excellent opportunity to increase the reach and quality of the service provided.

Furthermore, when smart and connected machines enhance maintenance, firms can envisage new opportunities and provide clients with advanced servitisation logics to ameliorate their products' efficiency and efficacy through monitoring, control and tailored problem-solving. For example, Firm B pursues such a trajectory. The capacity to offer tailored, customised services steps into a superior level with virtual reality and the possibility it opens up to get through product engineering with systematic co-designing. Indeed, digital twins allow for shortening feedback loops with clients without harming communication's effectiveness. As a result, co-developed products reach the final stages of production more rapidly and with higher client involvement and satisfaction, thereby increasing the revenue from exports.

Enhanced information processing. The theoretical background anticipated that internationalisation leads firms to face unprecedented uncertainties and complexity, mainly related to demand. Indeed, dealing with multiple markets means facing heterogeneous sources of demand fluctuations (each market asks for its appropriate product or service adaptation in terms of quality and quantity) and suppliers' value chain-related issues. Moreover, DTs applied to co-design and production allow to manage simultaneously multiple products, multiple selling channels and various degrees of customisation of orders (the case of Firm E and Firm D are particularly evident in this regard). All such phenomena generate an impressive amount of information that the firm can – should – collect, fetch into data, digest and transmute into knowledge to inform its decision-making process. Amidst such a challenge, AI algorithms and advanced data analytics are powerful tools. They help firms predict demand based on past transactions and external data, relieve part of the burden of streamlining warehouses and dispatches, and support strategic decisions regarding how to organise the supply chain. Consequently, firms' management of transactions, delivery, stocks and communications become more efficient and less erroneous, leaving room for investments to increase the variety of supply. Nonetheless, enhanced products' traceability is increasingly a requirement for mass-scale production, and DTs make the task affordable.

Similarly, the increased engineering complexity in the product and production process (due to competition on a higher level of quality) requires more capacity to collect, process and manage information about the traceability of each product along global value chains. Indeed, companies like Firm C invested in sensorised and connected machinery and information systems for tracing manufacturing activities (MES) to give international clients transparent access to certified data about the production process and the costs of each item in an order.

Operational flexibility. As anticipated concerning informational management, going abroad (successfully) entails a great deal of local market adaptation for the production side, too. Local markets' variety translates into product variety because a firm's offer must meet local tastes and contingent factors, such as customised special editions to celebrate particular recurrences. A side effect of customisation is that it may generate quantitatively small orders. With standard production methods, product variety would require dedicated machinery at work in different lines or plants and entail high costs for small-scale production (if economically sustainable at all). On the contrary, the deployment of automated robots enhanced with AI, capable of executing the output of the co-design phase smoothly, decreases machines' asset specificity radically. Therefore, the investments in net working capital per unit produced fall since flexibility rises.

Similarly, the amount of idle capacity in manufacturing decreases due to the more rapid configuration times of production machinery. Such a change in the production facility boosts firms' competitiveness in terms of unit cost and demand matching at the local market level, paving the way for centralised design, engineering and production activities (and thus increased revenues from export) and eventually enabling the reshoring of clients' activities.

6.2 Final considerations

Quality is a keyword throughout all interviews. DTs adoption allows firms to increase market competitiveness, but, most importantly, it builds up attractiveness and market leadership because of the uniqueness and advancements of the solutions offered without bargaining on quality. The competitive advantage spurred by DTs adoption stems from the capacity to handle complex productive tasks (multiple product lines, numerous and contemporary clients with a variety of customisable orders, possibly various sales channels and a tight schedule) effectively.

A fourth factor is worth mentioning, even though it is not of a technological nature: a marked entrepreneurial orientation. Indeed, it is common for all five firms interviewed that technological adoption is grafted into an entrepreneurial approach of managers willing to bear the risks and uncertainties of innovation investments. It emerged clearly from most interviewees that even though supportive public policies such as the Italian Industry 4.0 Plan did provide incentives to adopt, the orientation towards the enhancements of production and management was pre-existing and essential and was seen as a precondition for market growth.

7. Discussion

Our study has theoretically and empirically documented the link between adopting Industry 4.0 technologies and increased revenue from exports. It shows that such a link exists and finds its explanation in the pillars of virtualisation, operational flexibility and increased information processing through which the I4.0 DTs deploy their impact. In so doing, we have isolated the effects of the more recent wave of DTs in enhancing firms' internationalisation presence and performance. Even though the three pillars pre-dated the current I4.0 wave, DTs like augmented and virtual reality, robotics, IoT, AI, and solutions for big data management allow the extension of the pillars' reach and power in a production or product design setting.

A novel contribution provided by the paper is that the effects of such technology adoption on internationalisation decrease the smaller the enterprise and the lower the technological orientation and knowledge intensity of the industry the firm belongs to. We can offer a composite interpretation of these results based on previous literature and the specific nature of the pillars documented in the case studies.

First, the objectives of virtualisation and increased operational flexibility that firms pursue through adopting I4.0 technologies require firms to invest in a bundle of complementary technologies and organisational practices. Adopting this bundle results from a gradual and incremental investment process in digital technologies and the development of new organisational practices in design, engineering and production methods. Several studies, such as Neirotti and Paolucci (2007), underline how compressing time to catch up with a delay in the adoption of DTs is inefficient and ineffective, especially for firms that have not created and formalised a system for governing investments in Information Technologies (IT) (Weill and Ross 2005). Small and medium-sized enterprises are often in this condition due to their limited IT budgets.

Many examples of complementarities exist between investment in DTs and organisational practices. In recent years, some studies have illustrated how implementing lean production methods and principles is an essential organisational precondition for adopting AI in some processes, like predictive or prescriptive maintenance of machinery or the optimisation of internal logistic flows (Buer *et al.* 2018; Cagnetti *et al.* 2021; Rossini *et al.* 2019). In this vein, by introducing more rules and formalisation in different production management processes, lean production can positively affect the quality and the amount of data used for operational data-driven decision-making (Neirotti and Colombari 2023).

A second reason can be that in low or medium-tech industries, the virtualisation of product-related services can be less applicable because a substantial part of the competence on products' behaviour can be hardly and ineffectively codified in virtual product prototypes and digital workflows, given the importance that tacit and experiential knowledge has in the design and engineering phase (Lanzolla *et al.* 2021; Pesce *et al.* 2023).

A third reason is that due to their business and strategic orientation, primarily related to engineering a solution for customers, small enterprises often apply operational flexibility sequentially, working exclusively for one or very few customers at a time and cooperatively. Such customer intimacy (Hax and Wilde II 2001) reduces product variety during part of the product life cycle, thus demeaning the need for a high information processing capacity (Galbraith 1974) and the adoption of an extended bundle of modern DTs. Similarly, small firms seldom increase their level of centralisation in managing product diversification and adaptation to different market needs. Indeed, centralisation requires a degree of organisational slacks, like managerial attention, that small enterprises often do not possess. By contrast, the need for DTs in these enterprises should be more driven by the search for interoperability in data and information processing with a limited number of strategic customers from which the company is dependent from a relational standpoint.

8. Conclusions

The role of digitalisation in firms' internationalisation belongs to a relatively young research domain whose conclusions are far from clear. More specifically, the literature investigating the relative importance of the most recent digital technologies of the Industry 4.0 era is still scant.

To shed light on the link between digitalisation and internationalisation in the Industry 4.0 era, we used a mixed-methods approach that is becoming quite popular in the economics literature and is valued as promising in international business studies. Using quantitative methods, we show that adopting information-related digital technologies (such as big data analytics and IoT) and production-related digital technologies (robotics) improves firm performance in international markets. As expected these results are mainly driven by medium-to-large firms specialised in high-tech, knowledge intensive sectors.

The qualitative investigation increases our explanatory power by bringing out the three pillars that stimulate international performance through digital technologies' adoption (virtualisation, enhanced information processing and operational flexibility) and evidencing the respective economic channels.

In operationalising these pillars, we shed light on the reasons why the effect of digital technologies on international performance can be more evident in large and medium companies in high-tech and KIS sectors than in other settings. In particular, in these settings, the use of DTs can provide substantial benefits by allowing more remote coordination and collaboration with international clients and more centralisation in managing a diversified product mix.

Our analysis builds on Italian evidence and mirrors the Italian industrial and technological context but can and should be replicated in other countries. We encourage further research to collect further empirical evidence to perform comparative studies. Indeed, the distribution of digital technologies (with a great variety within the bundle) and the international exposure of industrial sectors are very country-specific, as well as other factors that may affect firms' internationalization strategy decisions and modes, such as the distribution of human capital investments and digital skills shortages.

Appendix

Appendix A

Table A1. Descriptive statistics by DT investments (except cyber security)

	Investing DT			Not investing in DT		
	N of Obs	Mean	Std dev	N of Obs	Mean	Std dev
	Foreign markets and digital technologies					
Foreign markets (0/1)	1,817	0.434	0.496	6,745	0.265	0.442
% sales form foreign markets	1,817	13.783	24.594	6,745	8.236	20.696
ln (sales foreign mkt pc)	1,817	4.422	5.183	6,745	2.702	4.595
Information tech	1,817	0.786	0.410	6,745	0	0
Robotics	1,817	0.368	0.482	6,745	0	0
	Management and corporate governance					
Tertiary education	1,817	0.277	0.448	6,745	0.223	0.416
Upper secondary ed	1,817	0.541	0.498	6,745	0.543	0.498
Female	1,817	0.129	0.336	6,745	0.144	0.351
Dynastic management	1,817	0.042	0.202	6,745	0.031	0.173
Internal management	1,817	0.878	0.327	6,745	0.909	0.288
External management	1,817	0.080	0.271	6,745	0.060	0.238
	Workforce characteristics					
Share of tertiary ed	1,817	0.117	0.184	6,745	0.094	0.187
Share of upper secondary	1,817	0.482	0.282	6,745	0.483	0.309
Share of lower secondary	1,817	0.401	0.313	6,745	0.422	0.333
Share of aged workers	1,813	0.217	0.192	6,721	0.239	0.214
Share of middle aged	1,813	0.477	0.205	6,721	0.477	0.233
Share of executives	1,817	0.034	0.076	6,745	0.039	0.093
Share of white collars	1,817	0.412	0.312	6,745	0.374	0.313
Share of blue collars	1,817	0.553	0.322	6,745	0.587	0.331
	Firms characteristics					
Multinational ownership	1,817	0.017	0.129	6,745	0.018	0.135
Employers' association	1,817	0.655	0.476	6,745	0.605	0.489
Firms age (in years)	1,817	27.779	14.362	w6,745	26.789	14.898
Irap tax cut	1,817	0.042	0.200	6,745	0.021	0.145
Product innovation	1,817	0.596	0.491	6,745	0.346	0.476
Process innovation	1,817	0.577	0.494	6,745	0.284	0.451
Ln(number of employees)	1,817	2.930	1.055	6,745	2.432	0.770

Note: pooled 2010-2015-2018 data. Sampling weights applied.

Source: Authors' calculations on RIL longitudinal sample

Table A2. Estimates Diff-in-Diffs with FE. Dep var: probability of internationalisation

	[1]	[2]	[3]
DT*years2018	0.027**		
	[0.009]		
DT*years2014	0.003		
	[0.019]		
Information tech*year 2018		0.032*	
		[0.019]	
Information tech *year 2014		0.005	
		[0.019]	
Robotics*year 2018			0.004
			[0.014]
Robotics*year 2014			0.002
			[0.022]
Year 2018	0.006	0.006	0.011
	[0.009]	[0.009]	[0.006]
Year 2014	0.009	0.008	0.009
	[0.006]	[0.008]	[0.004]
Management characteristics	Yes	Yes	Yes
Workforce characteristics	Yes	Yes	Yes
Firms characteristics	Yes	Yes	Yes
Constant	0.363***	0.363***	0.362***
	[0.013]	[0.033]	[0.013]
Obs	8562	8562	8562
R2	0.736	0.74	0.735

Note: management characteristics include education, age and gender of those who run the firm, dynastic and internal managers; workforce characteristics include the composition of the employees in terms of education, professional status, contractual arrangement and age; firm characteristics include the presence of employers' association, multinational, past product and process innovation, firms' age in years. All regressions include full interactions between 2-digit sectors and NUTS2 region and firm size classes FE. Robust standard errors in parentheses are clustered at the firm level. Statistical significance: *** at 1%, ** at 5%, * at 10%.

Source: Author's elaborations on RIL-ORBIS data

Table A3. Estimates Diff-in-Diffs with fixed effect. Dep var: ln(sales from international mkt per capita)

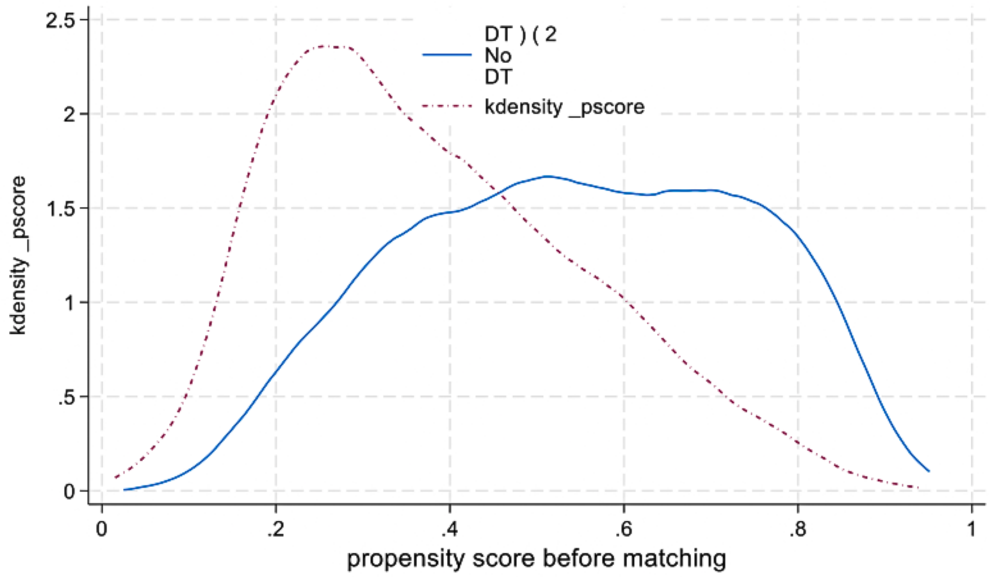
	[1]	[2]	[3]
DT*year 2018	0.538**		
	[0.175]		
DT*year 2014	0.502		
	[0.276]		
Information tech*year 2018		0.534*	
		[0.286]	
Information tech *year 2018		0.351	
		[0.276]	
Robotics*year 2018			0.483*
			[0.211]
Robotics*year 2014			0.686
			[0.503]
Year 2018	0.144	0.163	0.197
	[0.143]	[0.117]	[0.120]
Year 2014	0.166	0.201**	0.200**
	[0.091]	[0.102]	[0.045]
Management characteristics	Yes	Yes	Yes
Workforce characteristics	Yes	Yes	Yes
Firms characteristics	Yes	Yes	Yes
Constant	2.626***	2.639***	2.605***
	[0.252]	[0.433]	[0.227]
Obs	4949	4949	4949
R2	0.724	0.733	0.724

Note: management characteristics include education, age and gender of those who run the firm, dynastic and internal managers; workforce characteristics include the composition of the employees in terms of education, professional status, contractual arrangement and age; firm characteristics include the presence of employers' association, multinational, past product and process innovation, firms' age in years. All regressions include full interactions between 2-digit sectors and NUTS2 region and firm size classes FE. Robust standard errors in parentheses are clustered at the firm level. Statistical significance: *** at 1%, ** at 5%, * at 10%.

Source: Author's elaborations on RIL-ORBIS data

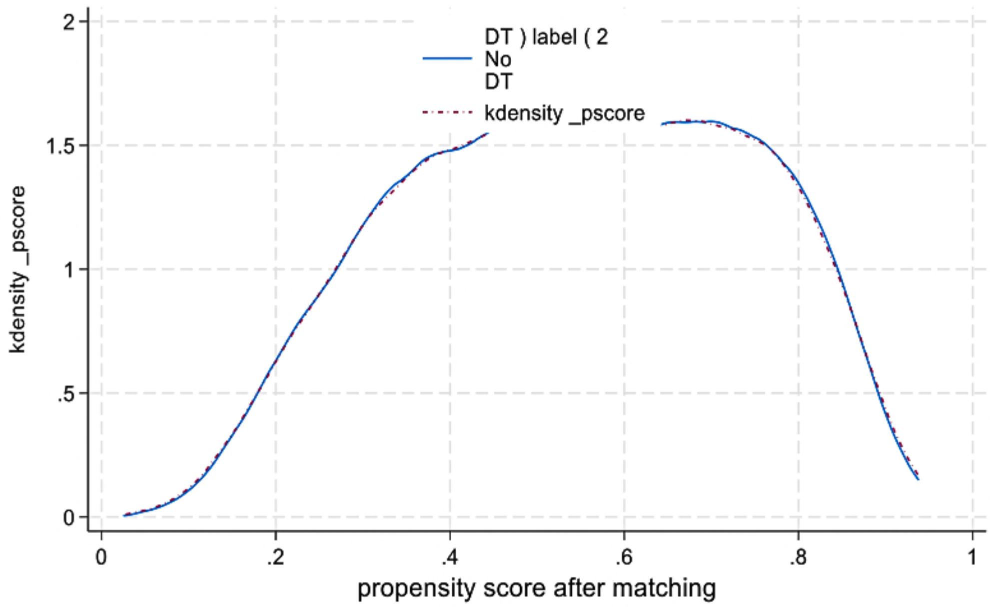
Appendix B

Figure B1.



Source: Author's elaborations on RIL-ORBIS data

Figure B2.



Source: Author's elaborations on RIL-ORBIS data

Table B1. Quality of the matching procedure. Balance property

	Matched / unmatched	Mean		% bias	% reduct bias	t-test	
		Treated	Control			t	p>t
			Management characteristics				
Tertiary education	U	0.397	0.291	22.5		8.66	0.000
	M		0.410	-2.81	87.5	-0.81	0.417
Upper secondary ed	U	0.455	0.503	-9.6		-3.61	0.000
	M		0.444	2.2	76.9	0.67	0.505
Age in years>55	U	0.334	0.347	-2.7		-1.01	0.312
	M		0.339	-1.0	61.1	-0.32	0.752
Female	U	0.094	0.124	-9.7		-3.54	0.000
	M		0.089	1.6	83.6	0.52	0.604
Dynastic manag	U	0.791	0.851	-15.7		-6.16	0.000
	M		0.783	2.2	86.3	0.61	0.544
Internal manag	U	0.133	0.091	13.3		5.28	0.000
	M		0.143	-3.3	75.0	-0.91	0.361
			Workforce characteristics				
Share of graduate	U	0.145	0.105	21.8		8.36	0.000
	M		0.147	-0.8	96.3	-0.23	0.815
Share of upper secondary	U	0.457	0.447	4.0		1.45	0.146
	M		0.453	1.8	55.4	0.58	0.564
Share of executives	U	0.051	0.041	11.0		4.22	0.000
	M		0.052	-1.1	90.5	-0.33	0.745
Share of white collars	U	0.384	0.354	10.7		4.01	0.000
	M		0.391	-2.3	78.5	-0.71	0.48
			Firms characteristics				
Multinational	U	0.068	0.026	19.7		8.55	0.000
	M		0.086	-8.9	55.0	-2.12	0.034
Employers' membership	U	0.764	0.683	18.3		6.72	0.000
	M		0.770	-1.2	93.2	-0.39	0.695
Firms age (in years)	U	32,05	29,932	12.5		4.71	0.000
	M		32,647	-3.5	72.1	-0.98	0.329
Irap tax cut	U	0.051	0.031	9.7		3.91	0.000
	M		0.056	-2.5	74.2	-0.67	0.506
Product innovation	U	0.663	0.362	63.2		23.76	0.000
	M		0.649	2.9	95.4	0.87	0.383
Process innovation	U	0,650	0.333	67		25.35	0.000
	M		0.638	2.6	96.2	0.76	0.446

Note: tests for each sector, firms' size in classes and NUTS2 regions are omitted for brevity. They are available upon request.
Source: Author's elaborations on RIL-ORBIS data

Table B2. Summary of the interviews

	Firm A	Firm B	Firm C	Firm D	Firm E
Tecnologie digitali	Cad 3D. Digital twin di prodotto (simulazione per co-progettazione). Sistemi di gestione del processo produttivo (ERP modificato, WMS, PDM).	Esplorazione su realtà aumentata (digital twin). Piattaforma informatica per la gestione dei magazzini world-wide. IoT (sensoristica applicata alla robotica). Rifacimento della struttura informatica (MRP, MES, CRM e altri programmi di supporto). AI per analisi predittiva come servizio post-vendita (servitization).	Sistema di monitoraggio e tracciamento della produzione. MES.	Rendering 3D tramite realtà aumentata e virtuale. IoT per raccolta dati produzione. Aggiornamento sistemi ERP e CRM.	Piattaforma digitale per l'e-commerce. Svolta data-driven del modello decisionale (software).
Tecnologie fisiche	Stampanti laser e infrarossi 3D (taglio e cucitura). Magazzino automatico (RFID).	Macchinari I4.0.	Catena di produzione automatizzata con laser (tempraggio e saldatura).	Nuove macchine di stampa digitali (più flessibilità, meno produttività). AMR per uno stabilimento forklift-free.	Magazzino automatico.
Ambito di applicazione	Ingegnerizzazione/ progettazione del prodotto.	Servizio di installazione, manutenzione e assistenza post-vendita al cliente.	Ingegnerizzazione del processo produttivo.	Ingegnerizzazione del processo produttivo. Ingegnerizzazione/ progettazione del prodotto.	Gestione ordini e logistica e automazione processi.
Visione imprenditoriale/ strategica	Minori costi di coordinamento senza rinunciare alla qualità della co-progettazione. Attrazione clienti e reinforzo della posizione in qualità di leader tecnologico (early adopter). Differenziazione di prodotto e gestione della diversità. Efficienza del processo produttivo (minori costi).	Maggiore produttività per essere più competitivi. Produrre a maggior valor aggiunto. Continuità del servizio. Esplorazione city logistics	Evoluzione da contoterzista 'semplice' a contoterzista capace di produrre prodotti ingegneristicamente complessi (reshoring). Necessità strategica di competere sulla trasparenza informativa (tracciabilità) nei confronti del cliente.	Alta qualità a costo competitivo (ambidexterity); in tre parole: produttività, qualità, ripetibilità.	Leva di prezzo. Crescita della quota di mercato tramite l'ampliamento del magazzino, la diminuzione del delivery time e l'approccio multicanale.

Segue

segue **Table B2.**

	Firm A	Firm B	Firm C	Firm D	Firm E
Information processing needs	Gestire maggiore varietà prodotto negli accessori, legati a cicli di prodotto molto corti (obsolescenza rapida). Gestire a distanza il processo di ingegnerizzazione, soprattutto su nuovi materiali o su specifiche di qualità molto elevate imposte dal cliente (feedback loop).	Sapere come il cliente usa il magazzino (per manutenzione e analisi predittiva). Maggiore assistenza da remoto ai tecnici in loco (installazione e manutenzione).	La produzione su larga scala in un settore formalizzato come l'automotive richiede alta tracciabilità di prodotto. Maggiore consapevolezza del processo produttivo per elaborare nuove soluzioni da offrire ai clienti in base alle loro necessità.	Ottimizzare i processi produttivi riducendo i costi tramite il monitoraggio. Customizzazione per commesse specifiche o locali ('etichette speciali per la festa spagnola').	Creazione e gestione di un servizio offerto che è multiprodotto, multi-cliente, multicanale e fast-time. Sfruttare le informazioni di vendita e da fonti terze (analisi di mercato) per sviluppare modelli predittivi della domanda.
Esposizione internazionale	95% della produzione per clienti internazionali.	35% del fatturato (deficitarie competenze commerciali). Magazzini installati in circa 50 Paesi.	65% del fatturato. Una sede produttiva estera (Argentina). Clienti multinazionali.	44.5% del fatturato. Sei stabilimenti produttivi nel mondo (Italia, Francia, Scozia, Stati Uniti e Messico). Società collegate di diritto locale. Accordi commerciali con Svizzera e Spagna.	75% del fatturato.
Clienti esteri	Maison del lusso internazionali.	Tiffany, Zecca Città del Messico, Zara.	Stellantis, Daimler, ZF.	Principali brand mondiali di spirits e vino (cosmetica in parte minoritaria).	Principali brand mondiali di pezzi per elettrodomestici bianchi.

Draft questionnaire

We are conducting an empirical academic investigation that aims to quantify the impact of the adoption of cutting-edge technologies belonging to the Industry 4.0 paradigm on the company's internationalisation level. Your experience and your opinion on this matter are of immense help to us in clearly identifying how the two phenomena (adoption and internationalisation) are related and the organisational and productive mechanisms involved.

- In which of these Industry 4.0 technologies have you invested and when?
  - IOT, Robotics, Big Data Analytics, Augmented Reality, Artificial Intelligence;
  - Have you used tax incentives linked to the National Industry 4.0 Plans?
  - What objectives did you set yourself when deciding to adopt these technologies, or with what expectations of impact on your products and/or processes (e.g. production, product development)?
- Could you describe the type and level of your presence in international markets? In particular:
  1. Presence on foreign markets (which geographical areas?);
  2. Have you made direct investments abroad? When? What activities are overseen by your foreign units?
  3. What are the relevance and trend of the share of turnover generated by exports in total sales in 2021 (trend compared to 2018);
  4. Do you have commercial agreements with foreign companies?
- Let us now come to the heart of our interview. Can you describe if and how the use of state-of-the-art technologies of Industry 4.0 has enabled you to improve your level of internationalisation? In particular:
  - Did it allow you to increase your export quota more easily?
  - Has it allowed you to get a better edge? If so, how?
    - Reducing production costs and chain coordination?
    - Increasing benefit and level of service to foreign customers?
    - Other?
- To what extent is (high) productivity and growth a prerequisite for adoption and internationalisation or a consequence of it?
- Is there anything you want to tell us about the relationship between technological adoption, internationalisation and productivity that we haven't discussed?

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