POLITECNICO DI TORINO
Repository ISTITUZIONALE

ICT-based innovation and its competitive outcome: the role of information intensity

Original
ICT-based innovation and its competitive outcome: the role of information intensity / Neirotti, P., Pesce, D.. - In: EUROPEAN JOURNAL OF INNOVATION MANAGEMENT. - ISSN 1460-1060. - 22:2(2019), pp. 383-404. [10.1108/EJIM-02-2018-0039]

Availability:
This version is available at: 11583/2717957 since: 2020-12-05T22:06:36Z

Publisher:
Emerald Group Publishing Ltd.

Published
DOI:10.1108/EJIM-02-2018-0039

Terms of use:

This article is made available under terms and conditions as specified in the corresponding bibliographic description in the repository

Publisher copyright
Emerald postprint/Author's Accepted Manuscript (articoli e capitoli libri)

© 2019 Emerald Publishing Limited. This AAM is provided for your own personal use only. It may not be used for resale, reprinting, systematic distribution, emailing, or for any other commercial purpose without the permission of the publisher'

(Article begins on next page)

27 November 2026

ICT-based innovation and its competitive outcome: the role of information intensity

Paolo Neirotti [a] and Danilo Pesce [a]*

[a]*Department, of Management and Production Engineering, Turin, Italy*

**Danilo Pesce, Corresponding Author*
Politecnico di Torino - Department of Management and Production Engineering
Corso Duca degli Abruzzi, 24
10129 Turin, Italy
email: danilo.pesce@polito.it
phone: +39 011 090 7280

ACCEPTED ARTICLE

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record.

Please cite this article as:

Paolo Neirotti, Danilo Pesce, (2018) "ICT-based innovation and its competitive outcome: the role of information intensity", European Journal of Innovation Management, https://doi.org/10.1108/EJIM-02-2018-0039

Permanent link to this document: https://doi.org/10.1108/EJIM-02-2018-0039

ICT-based innovation and its competitive outcome: the role of information intensity

Research Paper

Purpose

Prior research highlights the vital role of Information and Communication Technologies (ICT) for innovation in response to environmental conditions. However, there is a lack of studies that analyse the determinants of ICT investments on the innovation activities of firms in relation with their impacts on the industrial and competitive dynamics using large datasets.

Design/methodology/approach

In this paper, we investigate the effects of ICT investments on the industrial and competitive dynamics for a large and representative panel dataset. All the industries are included, and lagged effects of ICT investments are studied. Our model is tested on a seven-year panel (2008-2014) of 231 Italian industries using two-stage least squares instrumental-variables (IV) estimators with industry time and fixed effects.

Findings

The results indicate that munificent industries and higher ICT spending are interrelated facts, showing that in sectors with more growth opportunities firms invest more in ICT and this leads to higher industry concentration, greater profit dispersion and higher competitive turbulence in the sector. Also, the paper shows that SMEs can rarely take advantage of their ICT-based innovation to start high-growth phenomena.

Practical implications

The results suggest that ICT-based innovation may create competitive advantages that are hard to sustain over the long-term raising important implications for managers involved in ICT-enabled innovations and policy-makers involved in building programs to foster innovation.

Originality/value

Against the backdrop of today's digital transformation, the paper enriches our understanding on the disruptive effects exerted by the digitalization of the innovation process and provides a base to continue the investigation of industrial changes and competitive dynamics.

Keywords*: Information and communication technologies, Competitive dynamics, Digitalization, ICT-based innovation, Industry effects*

1 Introduction

Information and Communication Technologies (ICT) enable a variety of innovation types, due to their long-term evolution trend from being an asset supporting information processing and automation of administrative activities to ubiquitous technologies that today can make products capable of processing and communicating information over the Internet (Nolan, 1979; Porter and Heppelmann, 2014).

In Information Systems literature, the multipurpose nature of ICT has led to the distinction between two types of innovation that can be enabled by these technologies (Stoel and Muhanna, 2009; Neirotti and Raguseo, 2017).

Innovations falling in the first type placed cost reduction, efficiency, operational results and business process improvement among the main goals for ICT investments. This first type of technologies is relatively mature and is triggered by the adoption of enterprise systems that support production planning and control, inventory management, invoicing, asset maintenance, collaboration and data sharing and integration with supply chain partners to manage demand and material flows. Being related to technologies like Enterprise Resource Planning (ERP) systems that are today well established, this type of innovation may not affect competitive dynamics in an industry to a larger extent, despite the fact that the diffusion of such innovations has reached only in recent years the late majority and SMEs (Eurostat, 2014). The second type of innovations supports firms in "doing new things" rather than "doing the same things with less". In doing so, they are aimed at improving external orientation towards customers and services through improvements in new product development, Customer Relationship Management (CRM), and the development of new business logics like servitization (i.e., selling an integrated combination of products and services) and e-commerce. Whereas innovations consisting in "doing the same things with less" are aimed at reducing operational expenses and at protecting a firm's profit margin from competitive pressure on prices, the type of innovations consisting in leveraging ICT to "do new things" can be aimed at a firm's revenue growth, at finding more munificent and high-growth market segments, or at increasing a customer's willingness to pay thanks to additional products or services jointly provided. Not all the firms in an industry can have the capability to realize such type of innovation and this can contribute to explain the evidence of intra-industry heterogeneity in the accumulation of intangible assets and capabilities (Arrighetti *et al.*, 2014). Hence, this second type of innovation can have a more profound impact on industry dynamics compared to relatively mature innovations that are aimed at improving a firm's internal efficiency.

At the same time, these two innovation typologies can have different rates of diffusion in industries and profound implications for industrial and competitive dynamics. Industry-level studies can contribute to the understanding of the differences in the economic impact of ICT-based innovation, especially when studies can compare such effects across industries. This topic has been marginally investigated so far in

both innovation studies and in Information Systems research due to the complexity of building large datasets of industries with a time series dimension that can capture the economic impact of ICT in a comprehensive manner.

Information Systems studies show that ICT enhances innovation by increasing a firm's strategic agility, yielding more options for competitive actions (Sambamurthy *et al*., 2003). Notably, the existing literature on ICT and innovation has tended to focus on product innovation (Pavlou and El Sawy, 2006) or on ICT as a form of process innovation (Benner and Tushman, 2003). However, the extensive research on the linkages between these two streams of literature, and specifically on the connection between ICT and innovation (Roberts *et al*., 2012) has not explored the ICT effects and implications for industrial and competitive dynamics. Among the few exceptions, on US industry-level data Brynjolfsson and colleagues (2008) have provided a first contribution to the effects of ICT-based innovation on industrial dynamics showing that information intensive sectors exhibit more concentration dynamics and greater profit dispersion. While this has been an important theoretical contribution on the strategic value of ICT-based innovation, there is still need for further understanding in the form of both theoretical and empirical contribution. For example, there is no evidence whether few firms (rather than many) are capable of seizing the opportunities in "doing new things" by investing in new ICT features. This is especially worth of investigation in countries where products and processes are less digitalized compared to the US, where most of the research on the business value of ICT-based innovation has taken place. In this regard, past innovation studies (Bell and Pavitt, 1993) show that there are considerable differences in technological regime, technological accumulation, path and rate of capability building between countries. These differences may, to some extent, change or even challenge those existing conclusions mostly based on the experiences from digitalized economies such as the US, particularly when discussing the process of technological development in a country with a very diversified industrial composition like Italy.

Here we investigate this phenomenon by combining the implications at the industry-level of the Resource Based View (Barney, 1991) and of institutional theory (Scott, 1987; Powell and DiMaggio, 2012) to analyse how industry structures and competitive dynamics have been evolving in Italy using a seven-year panel (2008-2014). We draw on Resource Based View to understand how the heterogeneity in capabilities "between" and "within" sectors can influence the outcome of ICT investments on industrial dynamics. The period under analysis is adequate to this purpose since it includes the deep economic recession between 2008 and 2013. Recent studies show that countries like Italy that have been particularly hit by such economic recession have seen an increase in the industry heterogeneity of performance (Landini, 2016).

Using instrumental variables and taking into account unobserved heterogeneity of industries and endogeneity of ICT investments, our findings suggest a bi-directional causality between the digital options enabled by ICT investments and the industry competitive environment. Specifically, the results suggest that munificent industries and higher ICT spending are interrelated facts, showing that in sectors with more growth opportunities firms invest more in ICT. Higher spending in ICT also leads to higher industry concentration, greater profit dispersion and higher competitive turbulence in the sector. Also, the paper shows that in industries with more spending in ICT, SMEs and start-ups can rarely take advantage of their ICT-based innovation to start high-growth phenomena.

Taken together, these findings contribute to the literature on ICT and innovation (Roberts at al., 2012) underscoring the role of industrial competitive dynamics for the successful use of ICT and the realization of economic gains from innovation and enriching our understanding on the disruptive effects exerted by the digitalization of the innovation process. The results raise implications for managers involved in ICT-enabled innovations and policy-makers involved in building programs to foster innovation.

2 Theoretical Background

2.1 ICT-based innovation: implications of ICT spending on competitive dynamics

It is widely acknowledged that industry is the factor that mostly influences the firm's accumulation of intangible assets such as ICT resources (Arrighetti *et al*., 2014). Since within a sector firms tend to face similar conditions in the competitive and institutional environment (Scott, 1987; Powell and DiMaggio, 2012), they face the same market supply of technologies and deal with the same operational problems. Also, managers tend to use their industry peers as frames of reference when determining choices of ICT strategy whose returns are affected by a high degree of uncertainty (Neirotti and Paolucci, 2014). Such phenomena may lead to industry-level commonalities, particularly in terms of observable aspects such as the heuristics driving ICT spending and the timing in the adoption of certain technologies (Mauri and Michaels, 1998). Higher spending in ICT can capture more complex usage patterns of ICT and more sophisticated industry-specific capabilities that are built on ICT (Neirotti and Paolucci, 2014). As such, ICT spending can be used as a condensed variable that explains "between" sector differences in the extent of ICT adoption and of ICT-related capabilities. In other words, there might be a great deal of "between-sectors-heterogeneity" in ICT spending, which is associated with different outcome in industrial and competitive dynamics.

Our stylized analysis has discriminated three types of possible situations associated with different level of ICT spending existing at the industry-level. First, a "normal" average situation involving several

industries can be represented by a wide industry-level diffusion of technologically mature ICT solutions that require limited ICT spending due to low implementation and running costs due to the standardized features that characterize such systems. Today, simple standard applications of ERP systems supporting inventory management, sales and administrative activities can be an example of such technologies. As Figure 1A depicts, the diffusion of such technologies may have involved a large number of firms at the industry-level, even among SMEs (Raymond and Uwizeyemungu, 2007; Dibrell *et al*., 2008), for which investments in ICT is limited due to the maturity of the technologies. Under these conditions, such industries may thus exhibit a relatively "medium" spending in ICT by all the companies in the industry.

The second situation in our stylized analysis can be associated with traditional low-tech sectors with a very limited capability of absorbing and deploying ICT. In such circumstances, within the industry just a restricted tier of relatively more technologically savvy (and larger) enterprises - compared to the industry average - may have made investments in relatively mature technologies like ERP. Compared to the first circumstances, these sectors can exhibit a limited spending in ICT at the industry-level, which depicts that even more mature ICT resources have not been institutionalized in the industry recipe. This situation is depicted in Figure 1B and may be categorized as a situation of "low" spending in ICT at the industry-level.

Finally, the third possible stylized scenario is of "high" ICT spending at the industry-level. Such scenario can be associated with situations in which the most technologically savvy firms have a more complex portfolio of ICT solutions and information systems that support a broad array of functions. Such portfolios require relatively higher operational expenses and capital expenditures compared to the situations depicted above. This may be the case of ICT systems supporting more complex organizational processes like new product development, supply chain collaboration, Customer Relationship Management (CRM) and e-commerce initiatives. Most of these technologies can support firms in new initiatives aimed at revenue generation, responding to market changes and broadening the repertoire of competitive actions (Sambamurthy *et al.*, 2003). This situation - where in the industry mature technologies have been institutionalized and some firms have invested in a more complex array of non-mature technologies - can be associated with higher spending at the industry-level, and also with greater industry heterogeneity in resource deployment and capabilities. In fact, in the situation depicted in Figure 1C, a vast array of firms is characterized by a more limited spending in ICT due to the deployment of a less rich portfolio of ICT systems. This situation can be accompanied by a greater level of "within-industry" heterogeneity in the extent of ICT adoption and in the firm-level spending in ICT. This is due to the fact that for the restricted tier of savvy and better managed firms the broader implementation of non-mature information systems involves a high level of social complexity (Mata *et al.*, 1995, p.497) and path dependency (Dierickx and Cool, 1989) – due to the fact that emerging ICT usually requires the

previous successful adoption of more mature ICT, and complementary investments in human capital and managerial practices (Brynjolfsson and Hitt, 1996; Bresnahan *et al*., 2002).

Figure 1 about here

In a nutshell, our idea is that higher spending in ICT at the industry-level can capture higher heterogeneity within sectors in ICT-related innovations and capabilities and this can explain differences in the industrial and competitive dynamics compared to sectors where ICT is object of lower spending at the industry-level. There is vast empirical evidence in supporting this assumption. On firm-level data, Faggio *et al*. (2010) found evidence that more intensive ICT investments lead to higher dispersion in productivity and wage at the industry-level. Arrighetti and colleagues (2014) found that in sectors with more investments in intangible assets some firms with superior human capital and historical intangible asset base persist in accumulate intangible assets, while others tend to diverge towards less knowledge intensive types of production.

The idea is that intensive ICT investments can provide growth opportunities that just a limited tier of more savvy and better managed firms can capture. The consequences of such dispersion on industrial and competitive dynamics have not been studied yet and calls for exploring a range of outcomes at the industry-level, which is presented in the next section.

2.2 ICT-based innovation and consequences for industrial dynamics: the quest for dependent variables

The idea that higher spending in ICT at the industry-level can imply for a certain number of firms more opportunities of business growth calls for an interest in exploring the effect of ICT spending on industry munificence, which depicts the availability of opportunities and resources for growth and which is traditionally analysed as the revenue growth rate in an industry. Two elements lead to an interest over exploring the effects of ICT-based innovation on this variable. First, ICT can improve a firm's strategic agility, yielding more options for competitive actions (Sambamurthy *et al*., 2003) and for growth in revenues. This is well expressed in the multi-side and multi-layered nature of ICT-based innovation, for which innovation in a sector can be monetized in another one (Lucas *et al*. 2013). The second element is due to the fact that business processes, once they are codified and standardized in an information system, can be easily replicated throughout an organization. This implies that organizations can extend their operational effectiveness in various geographical areas and "add scale without mass" (Brynjolfsson *et al*., 2008).

The "scale without mass" principle raises interest in analysing whether, due to ICT-based innovations, sectors associated with high ICT spending are subject to more significant market concentration and profit dispersion and are thus "dominated" by a restricted tier of large and more effective enterprises. At the same time, the evolving nature of ICT and its ongoing development may destroy the dominant market position of ICT leaders in favour of rivals or new entrants, thereby putting an industry in conditions of hypercompetition (D'Aveni, 1994) and high-growth opportunities for entrepreneurial firms. Another driver of hypercompetition can lie in the effect that ICT and the Internet have in increasing market transparency and contestability and in reducing barriers to entry (Porter, 2001). In this vein, hypercompetition may go along with a process of growth for small enterprises and start-ups that can reflect their ability to use the Internet as an effective distribution channel. Hence, we considered as dependent variables also industry dynamism and the revenue share of high-growth enterprises.

2.3 Industry-level effects of ICT-based innovation and relevant country-level factors: the case of Italy

For innovation studies on ICT and their competitive impact, Italy represents a European context that is profoundly different from the US, where the majority of studies on the business value of ICT have been taken place.

Several comparative statistics depict for Italy a less favourable terrain for ICT penetration. Italy has a low percentage of ICT investment – 11.3% of total non-residential gross fixed capital formation – as opposed to 32.14% of the US and 25% of the UK and Sweden (OECD, 2017). This is due to the fact

that Italy has an economic structure based primarily on manufacturing industries and small and medium enterprises, which explains its difficulties in accessing international markets: in fact, Italy is the fifth-largest manufacturer in the world, but it is "only" the seventh exporting economy (OECD, 2013a). Hence, for many sectors ICT might be hardly leveraged to address opportunities of business growth existing in foreign markets. The international research on management practices made by Bloom and Van Reenen (2007) reveal for Italy a low level of management practices, especially among SMEs. In addition, the educational conditions are not favourable to rapid ICT penetration since the number of graduates and investments in education and continuous training are fairly below the OECD average (OECD, 2013b). Finally, Italy has been more severely hit by the economic recession between 2008 and 2013 and this has been shown to have increased "within" industry heterogeneity in performance (Landini, 2016)

Despite this average unfavourable situation for the diffusion of ICT-based innovation, Italy has a number of highly innovative firms on the efficient "frontier" of productivity, an international business scope, and a wide domestic base of revenue and employment. This happens in industries like car-making (e.g., FCA), aerospace (e.g., Leonardo), food (e.g., Barilla and Ferrero), gas and electrical utilities (e.g., Eni and ENEL), luxury goods in textile, apparel and leather products (with plenty of firms with world-class capabilities in product design and international marketing). OECD studies (e.g., Andrews *et al*., 2015) show that in any developed country for such "frontier firms" technological innovations and advanced management practices are spreading more rapidly across countries than they are within them. Thus, the gap between an elite US firm and an elite Italian firm is narrowing even as the gap between an elite Italian firm and its haggardly compatriot is expanding. Frontier firms may also push their domestic suppliers towards more investments in ICT integrating their supply chain. The spillover of knowledge and new operational practices from frontier firms to their suppliers may be slow. This fact can reinforce industry heterogeneity, especially when sectors increase their investments and spending in ICT.

The existence of highly innovative frontier firms and of less innovative and worse managed firms within the same sector implies a situation of high heterogeneity, which may also involve ICT-based innovation and ICT-related capabilities. In such context, the effects related to ICT spending on industrial and competitive dynamics can be puzzling and are worth of investigation. Specifically, high spending at the industry-level in ICT may imply for the sector a high effort in ICT-based innovation and in doing new things. Given the high heterogeneity existing at the industry-level, not all the firms – in countries like Italy – may cope with this challenge.

3 Hypotheses

The fact that in industries characterized by a higher spending in ICT are expected to have a higher strategic dependence on ICT implies that in these settings firms may more likely use ICT-based innovations for broadening their repertoire of competitive actions (Sambamurthy *et al.*, 2003). Specifically, in industries where products, services and processes can be powered by digital technologies have increased possibility to rapidly scale up operations and revenue – due to the low marginal costs in replicating information – (Brynjolfsson *et al.*, 2008), to expand their operations in foreign countries (Malhotra and Temponi, 2010) and to support product innovation and collaboration with partners (David *et al.*, 2003) – even in sectors that have been traditionally unrelated to the one of the focal firm. At the international level, evidence of this trend can be observed in how digital platforms such as Google and Amazon reapplied their core competences by entering a multitude of markets (e.g., publishing, advertising, media, smart appliances). In countries like Italy, this can be the case of the utilities industries that in the last years have intensified their ICT spending to seize the opportunities of enlarging their bundle of services towards new markets like Internet provisioning, electric mobility solutions and smart home services (Porter and Heppelmann, 2014; Iansiti and Lakhani, 2014). The same could be applied in sectors like luxury goods (with wearable applications), car making and appliances (connecting them through IoT architectures).

These mechanisms imply that sectors with more intensive spending in ICT are more likely to be munificent environments that present opportunities for business expansion in existing and new markets and in markets that are rich in slack resources through which firms – even the less efficient ones – can pursue growth (Keats and Hitt, 1988). Therefore, a condition of high spending in ICT in an industry can be associated with higher levels of munificence in the industry.

Thus, we posit what follows:

> *H1. A condition of high spending in ICT in an industry is associated with a higher munificence (i.e., growth in industry revenue).*

Higher extent of spending in ICT at the industry-level may be associated with higher market concentration within the industry, since some firms cannot easily replicate the ICT-based initiatives introduced by leaders in ICT use (McAfee and Brynjolfsson, 2008). There are asset stock accumulation dynamics (Dierickx and Cool, 1989; Eisenhardt and Martin, 2000) and time compression diseconomies (Rumelt, 1984) that hinder followers from bridging the gap in ICT use separating them from leaders by simply accelerating the pace of annual expenditures on ICT. This can be particularly evident in a country like Italy where the majority of firms in many sectors are characterizing by low management practices and human capital (Arrighetti *et al.*, 2014). In other words, the ICT adoption process is cumulative and the opportunities for innovation enabled by ICT are path-dependent and firm-specific (Franklin *et al.*,

2013): the foundation of resources and capabilities already accumulated by a firm influences the marginal costs and the returns of adopting an additional ICT resource (Knott *et al.*, 2003). Thus, although many technologies are readily available to firms on the open market, the need to predicate new ICT purchases on existing resources explains the response lag of competitors in replicating the resource portfolio of leaders in ICT use (Neirotti and Paolucci, 2007).

A second element favouring market concentration is due to the ambivalent impact that ICT can have a on a firm's strategic agility. ICT can hinder agility in firms that are poor in ICT management capabilities or in human capital (Lu and Ramamurthy, 2011), since ICT can ossify business processes rather than making them more agile and easy to reconfigure. Past studies (Sambamurthy *et al.*, 2003; Overby *et al.*, 2006; Lu and Ramamurthy, 2011) have also shown that high ICT spending in the face of change and uncertainty reinforces the current underlying patterns and logic in managerial and organizational routines when firms lack the competences to manage ICT-based innovations. This leads to unintended firm rigidity in responding to radical environmental changes (Lu and Ramamurthy, 2011). At the industry-level, the consequence of the fact that ICT can be a driver of strategic agility for some ICT-savvy companies and a driver of rigidity for other firms can be reflected in increasing market concentration, as ICT-savvy companies are able to take advantage of ICT to enter new businesses and serve new unexplored customer needs. As such, sectors where more ICT spending is needed are more likely to be dominated by a restricted tier of firms that have sustained high fixed costs for developing their platforms and brands online and can now leverage their data, brand and competencies to enter a multitude of new businesses and to exploit network economies in information exchange.

Another reason for market concentration lies in the ability of larger firms to encode operational best practices in information systems such as Enterprise Resource Planning (ERP) or Customer Relationship Management (CRM), and to replicate them across their operational units. This allows firms to achieve an operational predominance due to superior efficiency or organizational effectiveness in many market segments at the same time (Brynjolfsson *et al.*, 2008).

Thus, we expect the following:

> *H2. A condition of high spending in ICT in an industry is associated with a higher concentration of sales revenue.*

The increased market concentration favored by high spending in ICT may be accompanied by a process of increasing dispersion in profitability at the industry-level. Specifically, asset stock accumulation dynamics (Dierickx and Cool, 1989; Eisenhardt and Martin, 2000) and time compression diseconomies (Rumelt, 1984) may hinder followers from bridging the gap in ICT use separating them from leaders by simply accelerating the pace of annual expenditures on ICT. This is more likely when in a sector, institutional pressures toward investments in specific fields (ICT, in our case), increase. Under such

circumstances, institutional theories explain that mimetic, coercive and normative mechanisms are likely and may leave firms to accelerate the rate of investments in technologies even when they do not rely on pre-existing complementary capabilities. Therefore, divides in profitability may increase.

Also, the technical and organizational complexity of ICT-initiatives requiring higher ICT spending and the ambivalent nature of ICT as a resource that enhances agility in some firms and hinders it in others implies that sectors approaching higher investments in ICT may become more amenable to seeing profitability divides with the increasing spending in ICT.

Thus, we may expect the following:

> *H3. A condition of high spending in ICT at the industry level is associated with greater profit dispersion within the industry.*

Despite an expected high level of market concentration and profit dispersion, a high level of turbulence can characterize industries with higher spending in ICT. Specifically, dominant positions cannot be maintained over the long term due to the low sustainability of competitive advantages based on ICT. This occurs for a variety of reasons. First, sectors with a high penetration of the Internet exhibit high price competition, lower barriers to entry and more competition from substitute products (Porter, 2001). Second, the evolving nature of ICT implies a higher level of turbulence in technology and then in market conditions, since firms can always deploy the "next big thing". As we mentioned above, in the last decade, technology evolution in ICT has included new enabling technologies such as IoT, Big Data, artificial intelligence, cloud computing, additive manufacturing and distributed ledgers. It is unlikely that all the firms that have dominated an era of ICT can still maintain their dominant position in the following one. At the international level, this has been, for example, the case of Yahoo!, which has been displaced by Google in the industry of content distribution and advertising, by Apple in music distribution, which now risks being displaced by other players whose value proposition lies in online streaming (e.g., Spotify), by television networks that have been first disrupted by on-demand satellite television channels (e.g., Sky) and then by over-the-top platforms like Netflix and Amazon. In a country like Italy where the "average firm" exhibits limited capabilities of ICT-based innovation, turbulence can be driven by the fact that not all the leaders in a sector can successfully cope with an intensification of the spending in ICT occurring at the industry-level and with increased market contestability brought by Internet-based business models. Hence, part of these incumbents can lag behind international competitors with superior capabilities in developing and fine-tuning Internet-based business models. This might happen, for example, in sectors like retail and grocery - where "national champions" can be disrupted by the entrance of players like Amazon - newspapers and publishing, where again Amazon and the digital book are disrupting the entire value chain.

At the firm level, these trends imply that ICT can offer firms an avenue for new competitive actions (Sambamurthy *et al.*, 2003), which at the industry-level result in a greater level of turbulence and into trends of creative destruction and paradigm shifts.

The other argument in favour of a high level of turbulence characterizing industries with high information intensity is the fact that ICT-based innovations are characterized by weak appropriability regimes, that favour the observability and the imitability of innovation and also "inventing around" phenomena (Björkdahl, 2009). This can increase the hyper-competitive natures of sectors with high spending in ICT.

Based on these considerations, we offer the following hypothesis:

> *H4. A condition of high spending in ICT in an industry is associated with a higher level of turbulence (dynamism).*

The higher expected level of turbulence in sectors with a higher spending in ICT may also go hand-in-hand with a process of growth for small enterprises and entrepreneurial firms. High-growth phenomena for such organizations can be the consequence of distinct mechanisms. First, in sectors with more spending, some new entrants can use digital technologies to alter their way of doing business in the sector and the distribution of market shares in the industry and can thus bring a phase of creative destruction. Second, due to their high specialization, small and medium-sized enterprises can become "complementors" of web platforms like Amazon and Google and can exploit the growth of platforms to their advantage. Third, the more a sector start investing in ICT, the more likely can be co-specialization phenomena between the established firms' competencies and new digital startups that can support the former in embracing digital logics. This can be the case of software companies in the textile industry to support apparel makers in embracing e-commerce logics.

In sum, based on these considerations we may expect what follows:

> *H5. A condition of high spending in ICT in an industry is associated with a higher rate of high and medium growth enterprises.*

4 Empirical Methods

4.1 Data

Our empirical analysis is based on representative industry-level data on national accounting statistics collected from the Italian Bureau of Statistics (ISTAT) and an aggregation of firm-level data from AIDA, a Bureau Van Dijk dataset that collects financial report data on all the Italian enterprises. We built this dataset specifically for this study and we took into account industries at the three-digit level of ATECO (Classification of Economic Activity) code[1]. Since January 2008 ISTAT has adopted the new Ateco 2007 Classification of Economic Activities. The migration of economic statistics to the new classification follows a specific calendar for individual statistical surveys and the same for all EU countries. This classification is the national version of the European nomenclature, NACE Rev. 2 (Nomenclature of Economic Activities). Our final data set for this study consists of 231 industries and more than 1.3 million firms for which complete data on key variables of interest were available from 2008 to 2014. Appendix A provides the ATECO classification and the description of the 231 industries considered in this study. We captured industry-level data on the full range of aspects related to innovation available on ISTAT as well as on general firm characteristics and economic performance available on AIDA. Industry-level data on ICT spending before the 2008 and after 2014 were not available from ISTAT.

4.2 Variables

ICT spending as a proxy of process and product innovation. In the Community Innovation Survey (CIS) – used for firm-level studies – is stated that process innovation refers to any first-time introduction to a new or improved technology for the production of goods or services. Accordingly to the CIS and coherently with the Oslo Manual (OECD, 2005), which focuses on technology-related process innovation and distinguish it from purely organizational changes, we construct for this industry-level studies the proxy for process and product innovation as the ratio between ICT spending and sales revenues (Stiroh, 2002) estimated at the industry-level from 2008 and 2014 by ISTAT. Few industry-level studies have offered a quantitative measure of ICT investments and instead adopt a binary variable based on previous taxonomies (e.g., Porat and Rubin, 1977) to capture the information intensity of the industry.

Table B1 in Appendix B summarizes the definitions, operationalizations and the main references for all variables.

[1] Banks, insurance firms, and other financial service firms were excluded from the analysis due to the difference in their accounting schemes.

Table B1 about here

The majority of these measures have been widely used in IS research and innovation studies investigating the value of ICT and in some cases – such as dynamism, munificence, industry concentration and profitability dispersion – have their roots in strategic management research. Instead, to the best of our knowledge, both the rate of high-medium growth enterprises and the revenue share of high-medium growth enterprises in an industry have not been taken into account in IS research and innovation studies, due to the limited number of industry-level studies in this field. These measures were taken by studies on entrepreneurship investigating the phenomenon of small firms registering rapid and significant trends of growth in revenue (OECD, 2012). In this regard, OECD defines high growth enterprises (i.e., "gazelles") those firms with average annualized growth in turnover greater than 20% a year (10% for medium growth enterprises), over a three-year period, and with ten or more employees at the beginning of the observation period. Coherently with this definition, the incidence of high-medium growth SMEs in the industry structure was operationalized as the number of high-growth and medium-growth enterprises that could be defined as "gazelles".

Control variables. In estimating the effects of ICT spending on industry dynamics we checked for other variables that can affect the dependent variables under analysis. First, the year variables were used to take into account the economic cycle and in particular the economic crisis in the period between 2008 and 2014. Second, we took into account the number of firms in the industry, given its expected influence on the level of turbulence, munificence, market concentration and SMEs' presence shown by an industry. Also, the number of firms is expected to affect the diffusion process of ICT. In industries with a high number of enterprises, the diffusion of ICT solutions may take a longer time to involve the late majority (Moore, 1991) since there is a higher number of enterprises that have to be "infected" by the diffusion process and many of them are smaller and thus face more obstacles to innovation adoption. Therefore, sectors with a higher number of enterprises may show a less evident impact of ICT on outcome variables like munificence and industry turbulence.

4.3 Econometric Analysis

Estimator and instruments. To avoid concerns related to endogeneity (Wooldridge, 2002) and to control for all the other factors related to industry characteristics and structural changes that may influence the competitive dynamics and the innovation process, we apply two-stage least squares instrumental-variables (IV) estimators based on panel regression models with industry time and fixed effects. In this setting, the IV regressions cover the fixed-effects case which takes care of time-invariant

unobserved effects (Wooldridge, 2002). Also, we considered Huber-White robust standard errors (i.e., robust to heteroskedasticity and autocorrelation) in all our models.

The instrument set was chosen based on earlier studies that identified the lagged versions of endogenous variables (i.e., ICT spending) as suitable instruments (Brynjolfsson and Hitt, 1996; Mithas *et al*., 2012). ICT spending cannot be expected to have an instantaneous effect on competitive dynamics, and therefore we lagged their impact to mitigate the endogeneity of this measure (Caroli and Van Reenen, 2001). Also, it is to be expected that a high share of qualified employees and training investments increase the impact of ICT spending (Zwick, 2003). In this regard, previous studies suggest that human capital increases the estimated impact of ICT spending (Bresnahan *et al.*, 2002) by demonstrating that the interaction terms between ICT spending and worker skills – as well as between ICT spending and reorganizations – are positive and significant. Thus, human capital characteristics – operationalized as the ratio between labour costs (which considers wages and training activities) and the number of employees – are taken account of. This allows us to avoid omitted variables bias, unobserved heterogeneity (i.e., firms with ICT investments that might have been more "information intensive" than their competitors before investing in ICT technologies) and endogeneity of ICT spending (i.e., firms with the best relation between ICT investments costs and benefits that were most likely to invest in ICT).

In sum, the instrument set for the once-lagged values of the ICT spending (Brynjolfsson and Hitt, 1996; Mithas *et al*., 2012) consists of the once-lagged and twice-lagged values of human capital industry's characteristics. All instruments pass the underidentification test (i.e., explain a substantial portion of the variance of the endogenous variables) and specifically the Kleibergen-Papp test (Kleibergen and Paap, 2006) results in an LM statistic of 1.361 ($p < 0.001$) for Model 1 and 1.348 ($p < 0.001$) for all the others. All instruments pass the underidentification test resulting sufficiently correlated with the endogenous variable. Also, all instruments pass the overidentification restrictions resulting not correlated with the error term (Baum 2006). In particular, as we present heteroskedastic-robust estimator, we conduct the Sargan / Hansen J statistic (Arellano *et al., 2012).* It reports value of 0.265 for Model 1 and 0.743 for all the others indicating that the null hypothesis is not rejected. Thus, our instruments are valid.

5 Findings

5.1 Descriptive Statistics and Hypotheses Validation

Table B2 in Appendix B presents descriptive statistics of the key variables.

Table B2 about here

Table B3 in Appendix B presents the results of the two-stage least squares instrumental-variables (IV) estimators based on panel regression models with industry time and fixed effects. All seven regression models have the same dependent variable (i.e., ICT spending) – except for Model-1 (Column 1) that also takes in the lagged value of the *revenue growth rate*. All the models include the full control vector as discussed in the methodology section.

In Hypothesis H1, we posited that "*a condition of high spending in ICT in an industry is associated with a higher munificence (i.e., growth in industry revenue)".* Model-1 (Column 1) shows that the coefficient of the *revenue growth rate* is positive and significant (coefficient = 2.3785, $p < 0.05$) providing some first evidence of support for H1. Model-2 (Column 2) corroborates this result showing a positive and significant effect of the ratio between ICT investments and industry revenue on *industry munificence* (coefficient = 62.3372, $p < 0.05$). Therefore, H1 is supported.

Hypothesis H2 predicted that "*a condition of high spending in ICT in an industry is associated with a higher concentration of sales revenue".* Model-3 (Column 3) shows a positive and high significant effect of ICT spending on industry concentration (coefficient = 8.7591, $p < 0.001$). Thus, H2 is supported.

In Hypotheses H3 we posited that "*a condition of high spending in ICT at the industry level is associated with greater profit dispersion within the industry"*. Model-4 (Column 4) shows a positive and significant effect of ICT spending on the *profit dispersion* within the industry thus supporting H3 (coefficient = 6.1654, $p < 0.05$).

Hypothesis H4 predicted that "*a condition of high spending in ICT in an industry is associated with a higher level of turbulence (dynamism)".* Model-5 (Column 5) shows a positive and significant effect of ICT spending on the level of *industry turbulence* (coefficient = 34.9938, $p < 0.01$). Therefore, H4 is supported.

Finally, in Hypothesis H5 we posited that "*a condition of high spending in ICT in an industry is associated with a higher rate of high and medium growth enterprises*". Model-6 (Column 6) shows that the coefficient of the *rate of high-medium growth enterprises* is negative and partially significant

(coefficient = -17.3550, $p < 0.10$) providing some first evidence of reject for H5. Model-7 (Column 7) probes this result showing a negative and significant effect of ICT spending on the *revenue share of high-medium growth enterprises* (coefficient = -7.5809, $p < 0.05$). Thus, H5 is not validated.

Table B3 about here

---

6 Discussion

6.1 Main Findings

This study investigates the effects of ICT spending on competitive dynamics for a large and representative Italian industry-level panel data set. Our model is tested on a seven-year panel (2008-2014) of 231 Italian industries and more than one million firms using two-stage least squares instrumental-variables (IV) estimators with industry time and fixed effects.

The results suggest a bi-directional causality between the ICT spending and the industry competitive environment. Specifically, our results suggest that munificent industries and higher ICT spending are interrelated facts, showing that in sectors with more growth opportunities firms invest more in ICT. Higher spending in ICT also leads to higher industry concentration, greater profit dispersion and higher competitive turbulence in the sector. Also, the paper shows that in industries with more spending in ICT, SMEs and start-ups can rarely take advantage of their ICT-based innovation to start high-growth phenomena.

6.2 Research Implications

Prior research in this area has focused on how ICT creates value by favouring product innovation (Pavlou and El Sawy, 2006), process innovation (Benner and Tushman, 2003), productivity growth (Brynjolfsson and Hitt, 1996; Bharadwaj, 2000) and profitability (Sambamurthy *et al*., 2003; Mithas *et al*., 2012). However, there has been little quantitative analysis of how these effects impact on industry-level dynamics (Wade and Hulland, 2004; Chiasson and Davidson, 2005).

This study provides an attempt to close this gap by extending and enriching the results of recent literature which found evidence of higher dispersion in performance (Brynjolfsson *et al.*, 2008; McAfee and Brynjolfsson, 2008; Faggio *et al*., 2010) and increased market concentration (Brynjolfsson *et al.*, 2008) due to ICT spending in the US and UK. Such evidence may not be necessarily generalized in countries where the diffusion of ICT-based innovation is slower due to differences in innovation regimes and where the economic environment has provided more limited opportunities of business growth compared to countries that have had a faster recovery from the industrial crisis of 2008 (e.g., Germany, the US and the UK). Italy is an example of such context and provided the setting of our research. Compared to this stream of studies, we provide new evidence that ICT spending generates growth phenomena at the industry-level that involves a limited tier of more innovative companies. In such tier - contrary to expectations - small firms are less likely to enter, since our data shows that high-growth phenomena of entrepreneurial firms and SMEs are less likely the more an industry spends in ICT (coefficients of Model 6 and Model 7 in Table B3 in Appendix B are negative and statistically significant). Our novelty aspect

is also related to the wider number of sectors we have taken into account compared to past research: our data cover the industry structure of a whole economy and includes also service industries, which have been overlooked by the majority of past studies (e.g., Reichstein and Salter, 2006; Tambe et al., 2012; Acemoglu *et al*., 2014; Trantopoulos *et al*., 2017) on the business value of ICT that focused on specific segment of industries (e.g., only manufacturing) or firms (e.g., only large and global).

Taken together, these results extend the evidence that ICT provides firms with a greater number of competitive actions and digital options (Sambamurthy *et al*., 2003), by showing that these effects lead to higher revenue growth at the industry-level even in countries like Italy where the economic cycle has seen a slower recovery from the crisis occurred in 2008. However, such growth phenomena due to ICT are pulled by a limited percentage of large and well-established enterprises which does not typically include startups and small firms. This might be the consequence of the weaknesses that the industries of venture capital funds, startup accelerators, private equity funds have in Italy in providing support to entrepreneurial firms and SMEs, respectively. This is an Italian peculiarity that has been extensively reported in studies of the last decade (Hall *et al.*, 2013; Colombo *et al.*, 2007; Malerba, 2006). The limited entrepreneurial and high-growth phenomena related to high ICT spending in an industry also contributes to understanding the nature of disruption related to digital transformation in countries like Italy. The highest turbulence occurred in industries with higher ICT spending seems related to a limited tier of large enterprises rather than by entrepreneurial firms that have been able to apply new business logics or new product/service architecture in the industry. Rather, disruption could be triggered by foreign players (like digital platforms) that can enter the domestic market in Italy with a limited base of direct investments. We better discuss this topic later on when we address the limitation of our study.

6.3 Implications for practice

Our study has relevance for managers involved in ICT-enabled innovations and policy-makers involved in building programs to foster innovation. Specifically, our evidence of high turbulence (i.e., dynamism) in industries associated with high ICT spending suggests managers that the returns of their ICT investment initiatives can be lower over the long term in such industries. In this vein, our results reinforce the idea of high competitive uncertainty and weak appropriability regimes existing around ICT-based innovations, recalling the importance for managers - in "information intensive" sectors - to assess the return of their digital innovation initiatives on a short time interval. Also, our results serve to inform entrepreneurs that high-growth phenomena based on digital strategies are less likely to occur in countries like Italy that provides less institutional support (e.g., funding) to startups. A similar conclusion can be drawn also for managers of SMEs, given the high market concentration associated with higher spending in ICT. By contrast, our findings suggest the less industries invest in ICT, the more

firms can potentially extract higher returns from their ICT initiatives, as recalled by recent studies (Neirotti and Paolucci, 2014).

Our results also suggest the threats that an increasing rate of ICT spending can imply for firms that do not own the precondition for such investments (i.e., complementary investments in human capital) when normative and coercive pressures arise at the industry-level. In fact, our evidence shows increasing profitability divides when an industry increases ICT spending.

Based on our results, policy-making can infer that initiatives aimed at foster digitalization and ICT investments should not only look at encouraging spending in ICT (with the means of tax aids) for startups and SMEs but should sustain their business growth with dedicated measures for fostering entrepreneurship, the acquisition of crucial resources (e.g., human capital), and the support in the exploration of how disruptive digital technologies can be applied (e.g., through more collaboration with research centres and universities). Except for this caveat, the results confirm the goodness of policies (e.g., tax aids) aimed at encouraging ICT investments, by showing that ICT spending leads to high growth in revenues at the industry-level. However, policy-makers should be aware of the facts that these measures are not enough to limit increased heterogeneity and performance divides within industry. In this vein, implementing responsible innovation policy – which has recently emerged as a new approach in the context of ICT-based innovation (Martinuzzi *et al*., 2018) – requires collaboration of various stakeholders in order to find sustainable solutions that can allow firms to stay competitive in a rapidly changing world by assuring societal desirability of the innovation process and its marketable products (Stahl *et al*., 2017). Our study serves to inform policy-makers about the importance of finding measures that can support followers and laggards in ICT adoption, and especially firms with a poor endowment of factors that are complementary to ICT investments. Therefore, policy needs to be sensitive to specific industry-related factors - such as management practices and human capital - and industry-specific challenges - such as tensions between the need to short-term profit versus long-term stability (Chatfield *et al*., 2017). In doing so, policy-makers could build on our findings, and on previous knowledge from the fields of responsible innovation, to extend beyond existing research governance and policy instruments such as technology assessment, philosophy and ethics of technology and risk management (Chatfield *et al*., 2017; Dreyer *et al*., 2017), thus developing new instruments to foster innovation at the industry-level.

6.4 Limitations and directions for further research

In raising these points, our study has some limitations that are inherent in our research design and data availability.

First, despite our data cover the industry structure of a whole economy, as an econometric study of a single country will naturally be limited in its level of detail about the effects of ICT spending on

industrial and competitive dynamics. Although our results should be tested against the Italian background, this study opens doors to further research on the intersection between Information Systems and innovation literature.

Second, due to our industry focus, we have not directly analysed the attributes and the diffusion of ICT-based innovation, but we have indirectly investigated their effects in industries associated with high ICT spending. The lack of data on ICT-based innovation in our research is motivated by the fact that such information is not available with a panel perspective on a broad array of industries, seen at the three-digit level of ATECO code. Future work should be thus addressed at capturing the effects of ICT through a scale that operationalize the information content of the industry (i.e., ICT spending) and the field of application of ICT in core processes. Given the paradigm shift in the competitive relevance of ICT that may have been occurring after 2014 (i.e., ICT is becoming more pervasive also in less information intensive contexts such as apparel, appliances, car-making, industrial machinery), the need for new measures for ICT-based innovation may be particularly important for studies that will analyse the business value and the competitive impact of ICT in more recent years. In this study, the lack of reliable data on industry-level performance from national statistics impeded to observe competitive dynamics after 2014. However, we may expect that the trends of dynamism and market concentration found in this study may have become more intense in recent years and may have involved also more traditional sectors that are now amenable to the "digital revolution".

Third, part of our findings on turbulence and market concentration can be in part also affected by the economic recession that started in 2008. Despite we apply two-stage least squares instrumental-variables (IV) estimators with industry time and fixed effects which takes care of time-invariant unobserved effects (Wooldridge, 2002) and we control for year dummy variables in our empirical models, some results would have been more or less prominent in a period of "business as usual". For example, the crisis could have altered and mitigated the ability of firms to use ICT to create options for new competitive actions, thereby resulting in a lower level of munificence for sectors associated with high ICT spending compared to a hypothetical situation of economic stability. By contrast, the prolonged economic recession could have generated higher turbulence, thereby reinforcing the inherent effect related to industries associated with high ICT spending shown in this study.

Finally, part of the ICT effects on industry dynamics remains difficult to capture because it may be invisible in national accounting statistics for two reasons. First, the output measurements at country level do not take into account the revenue and the cost generated by some global players like web platforms, since these firms can provide services in the country from the "cloud" and with no need of a local presence in the sale of ICT-based services. Thus, a great part of their revenues produced at a local level in a country like Italy may only partially enter into the national accounting statistics of the country. Second, some new born-digital services have zero price and are thus invisible in the national statistics

(Brynjolfsson and McAfee, 2014). They add value to the economy in the form of greater consumer surplus but not to the GDP: as such they may not enter into national statistics. For example, free messages and free calls like the services provided by WhatsApp instead of a traditional telephone service can make billions of euros disappear from companies' revenues and the GDP statistics.

Despite these limitations, this study enriches our understanding on the disruptive effects exerted by the digitalization of the innovation process from 2008 to 2014 and provides a base from which to continue the investigation of industrial change and competitive dynamics and how they influence the origin of competitive advantages at the firm level.

REFERENCES

ACEMOGLU, D., DORN, D., HANSON, G. H., and PRICE, B. (2014), "Return of the Solow paradox? IT, productivity, and employment in US manufacturing". *American Economic Review*, Vol. 104 No. 5, pp. 394-99.

ANDREWS, D., CRISCUOLO C. and GAL P.N. (2015), "Frontier firms, technology diffusion and public policy: micro evidence from OECD countries", *OECD Productivity Working Papers, No. 2*, OECD Publishing, Paris. *doi: 10.1787/5jrql2q2jj7b-en*.

ARELLANO, M., HANSEN, L. P., and SENTANA, E. (2012), "Underidentification?", *Journal of Econometrics*, Vol. 170 No. 2, pp. 256-280.

ARRIGHETTI, A., LANDINI, F., and LASAGNI, A. (2014), "Intangible assets and firm heterogeneity: Evidence from Italy", *Research Policy*, Vol. 43 No. 1, pp. 202-213.

BARNEY, J. (1991), "Firm resources and sustained competitive advantage". *Journal of Management*, Vol. 17 No. 1, pp. 99-120.

BAUM, C.F. (2006), "An introduction to modern econometrics using STATA", *Stata Press, College Station, TX*.

BELL, M. and PAVITT K. (1993) "Technological accumulation and industrial growth: contrasts between developed and developing countries", *Industrial and Corporate Change*, Vol. 2, No. 2, pp. 157–210.

BENNER, M.J. and TUSHMAN, M.L. (2003), "Exploitation, Exploration, and Process Management: The Productivity Dilemma Revisited", *Academy of Management Review*, Vol. 28 No. 2, pp. 238-256.

BHARADWAJ, A. (2000), "A resource-based perspective on information technology capability and firm performance: An empirical investigation", *MIS Quarterly*, Vol. 24 No. 1, pp. 169–196.

BJÖRKDAHL, J., (2009), "Technology cross-fertilization and the business model: The case of integrating ICTs in mechanical engineering products", *Research Policy*, Vol. 38 No. 9, pp. 1468-1477.

BLOOM, N., and VAN REENEN, J. (2007), "Measuring and explaining management practices across firms and countries", *The Quarterly Journal of Economics*, Vol. 122 No. 4, pp. 1351-1408.

BRESNAHAN, T. F., BRYNJOLFSSON, E., and HITT, L. M. (2002), "Information technology, workplace organization, and the demand for skilled labor: firm-level evidence", *The Quarterly Journal of Economics*, Vol. 117 No. 1, pp. 339-376.

BRYNJOLFSSON, E. and HITT, L.M. (1996), "Productivity, Business Profitability, and Consumer Surplus: Three Different Measures of Information Value", *MIS Quarterly*, Vol. 20 No. 2, pp. 121–142.

BRYNJOLFSSON, E., MCAFEE, A., SORELL, M. and ZHU, F. (2008), "Scale Without Mass: Business Process Replication and Industry Dynamics", *Harvard Business School Technology and Operations Mgt. Unit Research Paper* 07-016.

BRYNJOLFSSON, E. and MCAFEE, A. (2014), "The second machine age: work, progress, and prosperity in a time of brilliant technologies", *W. W. Norton and Company, New York, NY*.

CAROLI, E. and VAN REENEN, J. (2001), "Skill biased organisational change: evidence from a panel of British and French establishments", *The Quarterly Journal of Economics*, Vol. 116 No. 4, pp. 1449-1492.

CHATFIELD K., BORSELLA E., MANTOVANI E., PORCARI A., STAHL B.C. (2017), "An investigation into risk perception in the ict industry as a core component of responsible research and innovation",

Sustainability, Vol. 9 No. 8, pp. 1424.

CHIASSON, M., and DAVIDSON, E. (2005), "Taking Industry Seriously in Information Systems Research", *MIS Quarterly*, Vol. 29 No. 4, pp. 591-605.

COLOMBO, M.G., GRILLI, L. and VERGA, C. (2007), "High-tech start-up access to public funds and venture capital: evidence from Italy", *International Review of Applied Economics*, Vol. 21 No. 3, pp. 381–402.

D'AVENI, R. (1994), "Hypercompetition: Managing the dynamics of strategic management", *Free Press, New York, NY*.

DAVID, H., LEVY, F. and MURNANE, R.J. (2003), "The skill content of recent technological change: An empirical exploration", *The Quarterly Journal of Economics*, Vol. 118 No. 4, pp. 1279–1333.

DESS, G.G. and BEARD, D.W. (1984), "Dimensions of Organizational Task Environments", *Administrative Science Quarterly* Vol, 29 No.1, pp. 52–73.

DIBRELL, C., DAVIS, P.S. and CRAIG, J. (2008), "Fueling Innovation through Information Technology in SMEs", *Journal of Small Business Management*, Vol. 46 No. 2, pp. 203-218.

DIERICKX. I, and COOL. K, (1989), "Asset stock accumulation and sustainability of competitive advantage", *Management Science* Vol. 35 No. 12, pp. 1504–1511.

DREYER M., CHEFNEUX L., GOLDBERG A., VON HEIMBURG J., PATRIGNANI N., SCHOFIELD M., SHILLING C. (2017) "Responsible innovation: a complementary view from industry with proposals for bridging different perspectives", *Sustainability*, Vol. 9 No. 10, pp. 1719.

EISENHARDT, K.M. and MARTIN, J.A. (2000), "Dynamic capabilities: what are they?", *Strategic Management Journal*, Vol. 21 No. 10/11, pp. 1105–1121.

EUROSTAT (2014), "Business demography and high growth enterprise by NACE Rev. 2 and NUTS 3 regions", *https://data.europa.eu/euodp* [Accessed 20 March 2017]

FAGGIO, G., SALVANES, K. G., and VAN REENEN, J. (2010), "The evolution of inequality in productivity and wages: panel data evidence", *Industrial and Corporate Change*, Vol. 19 No. 6, pp. 1919-1951.

FRANKLIN, M., SEARLE, N., STOYANOVA, D., and TOWNLEY, B. (2013), "Innovation in the application of digital tools for managing uncertainty: the case of UK independent film", *Creativity and Innovation Management*, Vol. 22 No. 3, pp. 320-333.

HALL, B.H., LOTTI, F., and MAIRESSE J. (2013), "Evidence on the impact of R&D and ICT investments on innovation and productivity in Italian firms",. *Economics of Innovation and New Technology*, Vol. 22 No. 3, pp. 300–328.

HOU, K., and ROBINSON, D.T. (2006), "Industry concentration and average stock returns", *The Journal of Finance*, Vol. 61 No. 4, pp. 1927-1956.

KEATS, B.W. and HITT, M.A. (1988), "A causal model of linkages among environmental dimensions, macro organizational characteristics, and performance", *Academy of Management Journal*, Vol. 31 No. 3, pp. 570–598.

KLEIBERGEN, F., and PAAP, R. (2006), "Generalized reduced rank tests using the singular value decomposition", *Journal of Econometrics*, Vol. 133 No. 1, pp. 97-126.

KNOTT, A.M., BRYCE, D.J. and POSEN, H.E. (2003), "On the strategic accumulation of intangible assets", *Organization Science*, Vol. 14 No. 2, pp. 192–207.

IANSITI, M., and LAKHANI, K.R. (2014), "Digital ubiquity: How connections, sensors, and data are revolutionizing business", *Harvard Business Review*, Vol. 92 No. 11, pp. 91-99.

LANDINI, F. (2016). "Distortions in firm selection during recessions: a comparison across european countries", *SEP Working Papers 2016/4*, LUISS School of European Political Economy.

LU, Y. and RAMAMURTHY K.R. (2011), "Understanding the link between information technology capability and organizational agility: An empirical examination", *MIS Quarterly,* Vol. 35 No. 4, pp. 931–954.

LUCAS, H.C., AGARWAL, R., CLEMONS, E.K., EL SAWY, O.A. and WEBER, B. (2013), "Impactful research on transformational information technology: An opportunity to inform new audiences", *MIS Quarterly,* Vol. 37 No. 2, pp. 371–382.

MALERBA, F. (2006), "Innovation and the evolution of industries", *Journal of Evolutionary Economics,* Vol. 16 No. 1/2, pp. 3–23.

MALHOTRA, R. and TEMPONI, C. (2010), "Critical decisions for ERP integration: Small business issues", *International Journal of Information Management,* Vol. 30 No. 1, pp. 28–37.

MARTINUZZI, A., BLOK, V., BREM, A., STAHL, B., SCHÖNHERR, N. (2018) "Responsible research and innovation in industry - challenges, insights and perspectives". *Sustainability*, Vol. 10 No. 3, pp. 702.

MATA, F., FUERST, W., and BARNEY, J. (1995), "Information Technology and Sustained Competitive Advantage: A Resource-Based Analysis", *MIS Quarterly*, Vol. 19 No. 4, pp. 487-505.

MAURI, A. J., and MICHAELS, M. P. (1998), "Firm and industry effects within strategic management: An empirical examination". *Strategic Management Journal*, Vol. 19 No. 3, pp. 211-219.

MCAFEE. A, and BRYNJOLFSSON, E. (2008), "Investing in the ICT That Makes a Competitive Difference", *Harvard Business Review,* Vol. 86 No. 7/8, pp. 98–107.

MITHAS,. S, TAFTI, A., BARDHAN, I. and MEIN, G.J. (2012), "Information technology and firm profitability: mechanisms and empirical evidence", *MIS Quarterly,* Vol. 36 No. 1, pp. 205–224.

MOORE, G.A. (1991), "Crossing the chasm: Marketing and selling high-tech products to mainstream consumers", *HarperBusiness, New York, NY.*

NEIROTTI, P. and PAOLUCCI, E. (2007), "Assessing the strategic value of Information Technology: An analysis on the insurance sector", *Information and Management,* Vol. 44 No. 6, pp. 568–582.

NEIROTTI, P. and PAOLUCCI, E. (2014), "Industry and firm effects on ICT diffusion processes: Firm-level evidence in Italian enterprises", *Industrial and Corporate Change,* Vol. 23 No. 3, pp. 717–757.

NEIROTTI, P. and RAGUSEO, E., (2017), "On the contingent value of IT-based capabilities for the competitive advantage of SMEs: Mechanisms and empirical evidence", *Information & Management*, Vol. 54 No. 2, pp. 139-153.

NOLAN, R.L. (1979), "Managing the crises in data-processing", *Harvard Business Review,* Vol. 57 No. 2, pp. 115–126.

OECD (2005), "Oslo Manual - Guidelines for Collecting and Interpreting Innovation Data", 3rd Edition, *The Measurement of Scientific and Technological Activities, OECD Publishing,* Paris. *doi: 10.1787/9789264013100-en.*

OECD (2012), "High-growth enterprise rate, in OECD., Entrepreneurship at a Glance*", OECD Publishing, Paris. doi: 10.1787/entrepreneur_aag-2012-16-en.*

OECD (2013a), "OECD Science, Technology and Industry Scoreboard 2013: Innovation for growth", *OECD Publishing, Paris. doi: 10.1787/sti_scoreboard-2013-en*.

OECD (2013b), "Italy, in OECD., Education at a Glance 2013: OECD Indicators", *OECD Publishing, Paris. doi: 10.1787/eag-2013-57-en.*

OECD (2017), "ICT investment (indicator)". *doi: 10.1787/b23ec1da-en*

OVERBY, E., BHARADWAJ, A., and SAMBAMURTHY V. (2006), "Enterprise agility and the enabling role of information technology", *European Journal of Information Systems,* Vol. 15 No. 2, pp. 120–131.

PAVLOU, P. A., and EL SAWY, O. A. (2006), "From IT leveraging competence to competitive advantage in turbulent environments: the case of new product development", *Information Systems Research* Vol. 17 No. 3, pp. 198-227.

PORAT, M.U. and RUBIN, M.R. (1977), "The information economy: definition and measurement (9 volumes)", *Office of Telecommunications Special Publication* 77-12, *US Department of Commerce, Washington, DC*.

PORTER, M.E. (2001), "Strategy and the Internet, *Harvard Business Review,* Vol. 79 No. 3, pp. 62–78.

PORTER, M.E. and HEPPELMANN, J.E. (2014), "How Smart, Connected Products Are Transforming Competition", *Harvard Business Review,* Vol. 92 No. 11, pp. 64–88.

POWELL, W. W., and DIMAGGIO, P. J. (Eds.) (2012), "The new institutionalism in organizational analysis", *University of Chicago Press, Chicago and London*.

RAYMOND, L. and UWIZEYEMUNGU, S. (2007), "A profile of ERP adoption in manufacturing SMEs", *Journal of Enterprise Information Management*, Vol. 20 No. 4, pp. 487-502.

REICHSTEIN, T., and SALTER, A. (2006), "Investigating the sources of process innovation among UK manufacturing firms", *Industrial and Corporate Change*, Vol. 15 No. 4, pp. 653-682.

ROBERTS N., GALLUCH, P. S., DINGER, M., and GROVER, V. (2012), "Absorptive capacity and information systems research: review, synthesis, and directions for future research", *MIS Quarterly* Vol. 36 No. 2, pp. 625-648.

RUMELT, R.P. (1984), "Towards a strategic theory of the firm", *In: R. Lamb ed. Competitive Strategic Management*, pp. 556–570, *Prentice-Hall, Englewood Cliffs, NJ*.

SAMBAMURTHY, V., BHARADWAJ, A. and GROVER, V. (2003), "Shaping Agility through Digital Options: Reconceptualizing the Role of Information Technology in Contemporary Firms", *MIS Quarterly*, Vol. 27 No. 2, pp. 237–263.

SCOTT, R. (1987) "The adolescence of institutional theory", *Administrative Science Quarterly*, Vol. 32, No. 4, pp. 493-511.

STAHL B.C., OBACH M., YAGHMAEI E., IKONEN V., CHATFIELD K., BREM A. (2017) "The responsible research and innovation (rri) maturity model: linking theory and practice", *Sustainability*, Vol. 9 No. 6, pp. 1036.

STIROH, K.J. (2002), "Information technology and the US productivity revival: A review of the evidence", *Business Economics*, Vol. 37 No. 1, pp. 30-37.

STOEL, M.D. and MUHANNA, W.A. (2009), "ICT capabilities and firm performance: A contingency analysis of the role of industry and ICT capability type", *Information and Management,* Vol. 46 No. 3, pp. 181–189.

TAMBE, P., HITT, L. M., and BRYNJOLFSSON, E. (2012), "The extroverted firm: How external information

practices affect innovation and productivity", *Management Science*, Vol. 58 No. 5, pp. 843-859.

TRANTOPOULOS, K., VON KROGH, G., WALLIN, M. W., and WOERTER, M. (2017), "External knowledge and information technology: Implications for process innovation performance", *MIS Quarterly*, Vol. 41 No. 1, pp. 287-300.

WADE, M. and HULLAND, J. (2004), "The resource-based view and information systems research: Review, extension, and suggestions for future research", *MIS Quarterly*, Vol. 28 No. 1, pp. 107–142.

WOOLDRIDGE, J. M. (2002), "Econometric analysis of cross section and panel data", *MIT Press, Cambridge, MA.*

ZWICK, T. (2003), "The impact of ICT investment on establishment productivity", *National Institute Economic Review*, Vol. 184 No. 1, pp. 99-110.

FIGURE 1

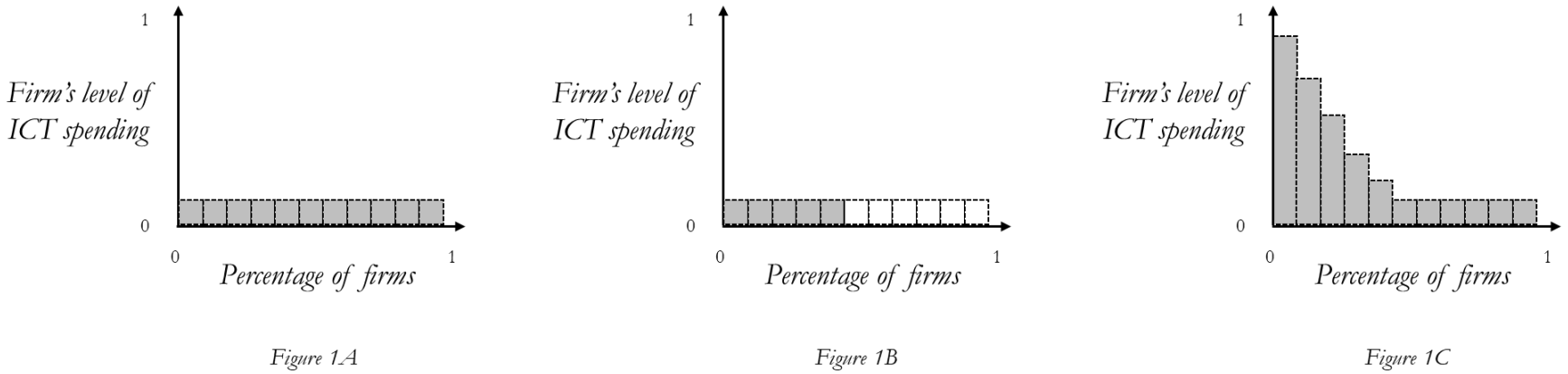

Figure 1 Different level of firm's ICT spending at the industry-level.

***Note**: Each vertical bar represents the ICT spending of each individual firm in the industry. The grey area represents the overall ICT spending at the industry-level.*

ICT-based innovation and its competitive outcome: the role of information intensity

APPENDIX A

ATECO (Classification of Economic Activity) classification and description of the 231 industries considered in the study.

Since January 2008 ISTAT has adopted the new Ateco 2007 classification of economic activities. The migration of economic statistics to the new classification follows a specific calendar for individual statistical surveys and the same for all EU countries. This classification is the national version of the European nomenclature, NACE Rev. 2, published in the Official Journal of 20 December 2006 (Regulation (EC) no 1893/2006 of the European Parliament and of the Council of 20 December 2006).

https://drive.google.com/open?id=1m7kibCSwYZlX0uQzEUE_Ucv5A4Znr4RR

ICT-based innovation and its competitive outcome: the role of information intensity

APPENDIX B

Table B1

Table B1. Description, operationalization and main references of the key variables

Variable Name	Variable operationalization	Main references
ICT spending	ICT investments on industry revenue between 2008 and 2014	Stiroh (2002)
Human capital	Total labour cost (which considers wages and training activities) divided by the corresponding number of employees from 2008 and 2014	(Brynjolfsson and Hitt, 1996; Bresnahan *et al*., 2002)
Revenue Growth	Logarithmic growth rate for the industry sales revenue between 2008 and 2014 (value deflated to 2008)	(Brynjolfsson and Hitt, 1996)
Industry Munificence	Industry total sales from 2008 to 2014 (value deflated to 2008 in thousands of euros) were regressed on the year variable. Munificence was thus calculated as the regression slope coefficient divided by the average industry sales	(Dess and Beard, 1984; Stoel and Muhanna, 2009)
Industry Competition (Market Concentration)	Measure of industry concentration, following the procedure described in Hou and Robinson (2006). The Herfindahl index for industry j is measured as follows: $Herfindhal_{\ j} = \sum_{i} s_{ij}^2$ where s_{ij} is the market share of firm i in industry j	(Hou and Robinson, 2006)
Profitability Dispersion	Interquartile range (IQR) in Return on Assets (ROA) between 2008 and 2014	(Brynjolfsson *et al.*, 2008)
Industry Turbulence (Dynamism)	Industry total sales from 2008 to 2014 (value deflated to 2008 in thousands of euros) were regressed on the year variable. Dynamism was thus calculated as standard error of the regression slope coefficient divided by the average industry sales	(Dess and Beard, 1984; Stoel and Muhanna, 2009)
Rate of High Growth enterprises	High-growth enterprises (or "gazelles") are enterprises with average annualized growth in turnover greater than 20% a year, over a three-year period, and with ten or more employees at the beginning of the observation period. The variable takes into account the number of firms falling in this condition over the total number of firms in the industry	(OECD, 2012)
Rate of Medium Growth enterprises	Medium-growth enterprises are enterprises with average annualized growth in turnover greater than 10% a year, over a three-year period, and with ten or more employees at the beginning of the observation period. The variable takes into account the number of firms falling in this condition over the total number of firms in the industry	(OECD, 2012)
Revenue share of High-Medium Growth enterprises	The revenue share of high-medium growth enterprises on the total industry revenue	(OECD, 2012)

Table B2

Table B2. Descriptive statistics					
Variable Name	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
ICT spending	1,576	0.0016	0.0038	7.47e-07	0.0851
Human capital (LOG)	1,588	0.0042	0.0138	0.0000	0.2659
Revenue Growth (LOG)	1,351	-0.0069	0.2089	-1.8206	1.7774
Industry Munificence	231	0.0797	1.7546	-6.5476	5.6952
Industry Competition (Market Concentration)	1,617	0.1097	0.1452	0.0071	0.9286
Profitability Dispersion	1,617	9.6574	3.2890	2.5175	19.69
Industry Turbulence (Dynamism)	231	-0.1192	1.6635	-2.26684	7.3938
Rate of High-Medium Growth enterprises	1,014	1.3894	0.6254	0.0000	3.0547
Revenue share of High-Medium Growth enterprises	1.045	0.1654	0.1453	0.0000	1.0000

Table B3

Table B3. IV two-stage least squares regression models with industry time and fixed effects, 2008-2014

	Model-1	*Model-2*	*Model-3*	*Model-4*	*Model-5*	*Model-6*	*Model-7*
	H1	*H1*	*H2*	*H3*	*H4*	*H5*	*H5*
Regressors	***Revenue growth rate***	***Industry Munificence***	***Market Concentration***	***Profitability Dispersion***	***Industry Turbulence (dynamism)***	***Rate of high-medium growth enterprises***	***Revenue share of high-medium growth enterprises***
ICT spending	2.3785*	62.3372*	8.7591***	6.1654*	34.9938**	-17.3550†	-7.5809*
	(0.0758)	*(8.9220)*	*(7.5110)*	*(1.3401)*	*(9.0523)*	*(3.5375)*	*(2.9443)*
Year dummy 2011	0.0028		-0.0031	0.2400†		-0.1521**	-0.0691***
	(0.0133)		*(0.0050)*	*(0.1221)*		*(0.1492)*	*(0.0107)*
Year dummy 2012	0.0653***		-0.0065	0.8487***		-0.1358**	-0.0642***
	(0.0126)		*(0.0051)*	*(0.1217)*		*(0.0500)*	*(0.0108)*
Year dummy 2013	0.0620***		-0.0097**	0.6177***		-0.0055	-0.0741***
	(0.0124)		*(0.0048)*	*(0.1218)*		*(0.0496)*	*(0.0107)*
Year dummy 2014	0.0403*		-0.0134***	0.6747***		-0.1257†	-0.0563***
	(0.0126)		*(0.0064)*	*(0.1229)*		*(0.0236)*	*(0.0254)*
Number of firms *(LOG)*	-0.2131***	-0.5121*	-0.0257	0.9115†	0.0356†	0.3790***	-0.0198***
	(0.0481)	*(0.0814)*	*(0.0223)*	*(0.4814)*	*(0.0662)*	*(0.0223)*	*(0.0048)*
Industry revenue *(LOG)*	0.6564***	0.1026†	0.0070	-0.2731	-0.1438†	-0.2829**	-0.0401***
	(0.0295)	*(0.1816)*	*(0.0131)*	*(0.2953)*	*(0.1553)*	*(0.0546)*	*(0.0118)*
Lagged values of the growth rate variables	-0.4209***						
	(0.0217)						
Constant	1.2857***	1.4981*	0.1451**	2.2305	0.3572*	0.4693***	0.3003***
	(0.6496)	*(0.5998)*	*(0.2566)*	*(3.7922)*	*(0.4410)*	*(0.1101)*	*(0.0239)*
Observations	1109	231	1110	1110	231	764	789
adj. R^2	0.5255	0.3865	0.2631	0.2987	0.3354	0.3563	0.2466

Notes: Robust standard errors (in parentheses) are clustered at the industry level (i.e., robust to heteroskedasticity and autocorrelation). Instrumented: Once-lagged ICT spending on revenue. Instruments: Once-lagged and twice-lagged values of Human capital, Year dummies, Number of firms (LOG), Industry revenue (LOG).

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

About the authors

Paolo Neirotti is Associate Professor at the Politecnico di Torino, where he teaches Strategic Management. His research interests focalize on digital transformation and its consequences on the industrial- and firm-level changes. The settings of his research are creative sectors, the hospitality industry, the manufacturing sector for what regards the new forms of work enabled by digital innovation, and the product development process. The outcome of his research has been published in journals like Industrial and Corporate Change, Technology Forecasting and Social Change, Long Range Planning, and Information & Management.

Danilo Pesce is a PhD Candidate at Politecnico di Torino, Italy. Danilo's PhD dissertation is focused on an empirical investigation of the organizational and industry-level changes triggered by digital technologies adoption. Danilo Pesce is the corresponding author and can be contacted at: danilo.pesce@polito.it

Acknowledgements

This work has been partially supported by "Ministero dell'Istruzione, dell'Università e della Ricerca" Award "TESUN-83486178370409 finanziamento dipartimenti di eccellenza CAP. 1694 TIT. 232 ART. 6".