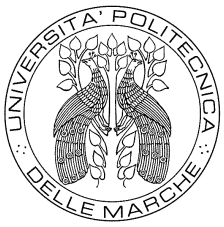

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FACTORS ENHANCING AI ADOPTION BY FIRMS. EVIDENCE FROM FRANCE

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Abstract

In this paper we consider firms involved in two waves (2019 and 2021) of the French ICT survey to distinguish between early and late adopters of AI technologies and to highlight some relevant antecedents that facilitated the former to keep and the latter to start adopting them. The implementation of data security systems, the training and recruitment of employees for ICT, and the use of websites and social media for collecting information on customers, increase the probability of keeping and starting the AI adoption. We also show that the impact of these factors differs according to the business function AI technologies are used for. They appear to be more relevant for the administration and marketing functions. Furthermore, the usage of AI for marketing is also fostered by the antecedent use of e-commerce and CRM applications. These findings support the hypothesis that the AI adoption by firms is shaped by a hierarchical trajectory, from less to more complex and demanding technologies in terms of complementary investments in ICT and skills.

JEL Class.: O31, O33

Keywords: Artificial Intelligence, Digital technologies and skills, IT security systems, French firms.

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Factors enhancing AI adoption by firms. Evidence from France

Alessia Lo Turco Alessandro Sterlacchini

1 Introduction

The term Artificial Intelligence (AI) encompasses a broad range of computer-based technologies and systems characterised by the capability to autonomously learn and perform tasks that typically require human intelligence, with minimal or even with no human interaction. A detailed definition is provided by Eurostat: "Artificial intelligence refers to systems that use technologies such as: text mining, computer vision, speech recognition, natural language generation, machine learning, deep learning to gather and/or use data to predict, recommend or decide, with varying levels of autonomy, the best action to achieve specific goals." The economic importance of AI is potentially huge. Bank of America estimates that global revenues associated with AI software will be$900 billion by 2026, compared with $318 billion in 2020. According to some estimates by PwC, AI will contribute more than $15 trillion to the global economy by 2030.[1] For this reason empirical research is striving to understand the determinants and effects of AI usage by firms. In particular, to investigate these issues at the firm level, several studies have relied on patent data related to AI technologies (see, among others, Alderucci et al., 2020; Damioli et al., 2023; Igna and Venturini, 2023; Sterlacchini, 2024).

Nevertheless, it is important to note that in these cases the focus is on the supply of AI technologies (as indicated by patented inventions) rather than their actual adoption. Data pertaining to the usage of AI at the firm level have been mainly gathered through ad-hoc surveys.[2]

In this paper, we attempt to identify some "antecedents" of the adoption of AI technologies by firms. By this term, we are referring to variables that are observ-

[1] See $https://business.bofa.com/en-us/content/economic-impact-of-ai.html$

[2] An alternative approach to obtain similar information has been developed by Babina et al. (2024). They utilize a combination of job postings and worker resumes datasets to measure the stock of AI workers employed by US companies, which serves as a proxy for AI investments.

able both prior to and during the adoption process. For this purpose we analyse the results coming from the same set of firms that was involved in two waves of the French ICT survey, carried out in 2019 and 2021 and concerned with previous years, 2018 and 2020. In this way, it is possible not only to distinguish between early and late adopters of AI technologies, but also to highlight some relevant factors, referring to 2018, that facilitated the former to keep and the latter to start adopting them in 2020. As compared to most previous studies, which are limited to highlight the factors concomitant to the adoption of advanced technologies, this represents the main contribution of our study. As a further contribution, we test whether the effects exerted by the antecedents of AI adoption differ between the business functions in which such technologies are used.

The main results of our empirical analysis are the following. The implementation of data security systems, the training and recruitment of employees for ICT, and the use of websites and social media for collecting information on customers increase the probability of keeping and starting the AI adoption. The same factors turn out to be more relevant for the administration and marketing functions. Furthermore, the usage of AI for marketing is also fostered by the antecedent use of e-commerce and CRM applications. All together, these findings support the hypothesis that the AI adoption by firms is shaped by a hierarchical trajectory, from less to more complex and demanding technologies in terms of complementary investments in ICT and skills.

The paper is organised in the five Sections. Section 2 provides a selective review of firm level surveys on AI usage along with other studies concerning the adoption of advanced technologies. Based on the findings and insights gleaned from the empirical literature, we derive the main research questions addressed by our study. Section 3 illustrates the adopted empirical strategy in terms of data sources and measurement of dependent (AI adoption) and independent variables (antecedents). Moreover, descriptive evidence for such variables is provided. In Section 4 we report and comment the main results of regression analyses. Concluding remarks are contained in Section 5.

2 AI adoption by firms: literature review and research questions

In this section, rather than providing an exhaustive review of the many surveys carried out on the adoption of AI technologies by firms (see, for instance, Kazakova

et al., 2020; Montagnier and Ek, 2021; Calvino and Fontanelli, 2023b), we shall focus on three recent studies that use data coming from surveys concerned with German, French and US firms.

Rammer et al. (2022) analyse the adoption of AI technologies in 2018, utilizing data gathered from a German survey that included a representative sample of firms employing at least 5 individuals. The findings reveal an overall adoption rate of approximately 7%, with the software and IT services sector leading at 18%, closely followed by professional services at 14%. In the manufacturing sector, the electronics and electrical equipment industry stands out with the highest adoption rate of AI at 11%. Larger firms with 1000 or more employees have a significantly higher adoption rate of 31% compared to smaller companies. Rammer et al. find that that companies that embrace AI more extensively also enjoy a larger share of sales attributed to new products. Greater adoption rates of AI are also associated with process innovations, leading to cost reductions.[3]

Calvino and Fontanelli (2023a) utilize data obtained from the 2019 French ICT survey conducted on a representative sample of firms with more than 9 employees. From such a survey it emerges that in 2018 11.4% of French firms have implemented AI technologies, with larger firms showing higher rates of adoption. The utilization of AI is particularly widespread in the ICT sector, where 26% of companies have integrated AI into their operations. Close on its heels is the professional services sector, with 17% of firms adopting AI technologies. The French survey also allows one to distinguish AI users between "buyers" and AI "developers". The former are firms using AI technologies developed by external providers, while the latter use AI systems developed in-house. Both AI buyers and developers are larger than other firms, but AI developers are also younger and primarily found within the ICT sector. The authors show that the firms adopting AI are more likely to employ ICT specialists, to carry out ICT training for their employees, to have a fast broadband connection and to use other digital technologies. Furthermore, AI users generally exhibit higher levels of productivity. However, it is important to note that this positive relationship is dependent on the performance of larger firms and is particularly pronounced within the ICT sector and among AI developers.

Acemoglu et al. (2022) examine the findings of a recent module incorporated into the 2019 Annual Business Survey, which was conducted in the United States by the Census Bureau in collaboration with the National Center for Science and

[3]In a related study, Czarnitzki et al. (2023) find that the adoption of AI technologies positively affects the productivity of German firms, both in terms of sales and value added.

Engineering. This module aimed to gather information regarding the utilization of five advanced technologies: AI, robotics, dedicated equipment, specialized software, and cloud computing. The survey involved over 300,000 US firms with the reference period spanning from 2016 to 2018. The adoption rate of AI is quite low, as indicated by a only 3.2% of the firms surveyed. However, this figure significantly rises with firm size as witnessed by the fact that AI users employ approximately 12.6% of the total workforce. Within the same size class, younger firms are more inclined to embrace AI technologies compared to their older counterparts. When examining the sector rates of adoption, it emerges that AI users are more prevalent in the information sector, accounting for around 9% of firms, followed by professional services at 6%. The primary motivation behind AI adoption lies in the pursuit of quality improvements, with 50% of users citing this as their driving force. Additionally, 36% of users aim to upgrade their processes, while 28% seek to automate them. With respect to the employment effect of AI, Acemoglu et al. emphasize that the use of AI seems more likely to increase the demand for skills, while the impact on the employment level remains ambiguous.

In summary, the above surveys on the adoption of AI technologies consistently indicate that the utilization of AI is prevalent among large firms and within the IT and professional services sectors. Furthermore, the adoption of AI is associated with the implementation of other advanced technologies, while a negative correlation is observed with the age of the firm. It is worth noting that the higher rates of adoption observed in Europe, particularly in France, may be partially attributed to the exclusion of smaller firms from the samples.

The studies just reviewed, along with providing descriptive analyses, examine the impacts of AI usage on different economic performances (innovation, productivity, and employment).

Our paper, instead, is focused on the determinants of AI adoption. More specifically, our research question is the following:
What are the prerequisites or antecedents that help explaining the adoption of AI by firms?

As stressed by Zolas et al. (2021) even after controlling for crucial firm characteristics (such as size, age and sector) a substantial heterogeneity in AI adoption remains. Some studies (e.g. Cho et al., 2023; Calvino and Fontanelli, 2023b) have emphasised that to reap the full benefits of some advanced technologies they need to be adopted in bunches. We agree that technological complementarities play an extremely important role in explaining adoption patterns by firms. However, to

properly address our research question it is not sufficient to observe that some technologies are used in tandem at a given point of time. Instead, we contend that in the adoption of AI technologies there is a hierarchical trajectory: i.e. a progression from less to more complex and demanding technologies not only in terms of hardware and software investments but especially with respect to skill requirements and organizational changes.

Antecedents to this line of argument can be found in the past wave of studies focused on the adoption of Advanced Manufacturing Technologies (see, among others, Colombo and Mosconi, 1995; Arvanitis and Hollenstein, 2001; Spanos and Voudouris, 2009). By controlling for the usual firm characteristics as well as other relevant variables, these works showed that the probability of using more advanced technologies (e.g. Flexible Manufacturing System) was positively affected by the previous adoption of less advanced ones (e.g. Numerically Controlled Machines). Accordingly, a process of cumulative learning was at work, characterized by the adoption of technologies which embodied constituent elements of the new ones.

A similar process characterises the AI adoption by firms. According to the findings of the new modules included in the US Annual Business Survey (see above), Zolas et al. (2021) find that the adoption of advanced digital technologies, including AI, follows a hierarchical pattern, moving from the digitization of business information to the adoption of cloud services and, then, AI systems. Hence, the most sophisticated technologies are more likely to be used only when more basic applications are used, "suggesting interdependence between technology applications and potentially a cumulative progression of adoption" (ibid., p. 3). In the same vein, Jacobides et al. (2021) stress that the AI adoption is fostered by two main enablers: hardware and software infrastructures (allowing enough computing power) and data management and processing (allowing high amounts of digital information, aka "big data").[4]

For an empirical test of the above sequential pattern, the adoption behaviour of firms should be observed in different points of time. In our case we exploit the information coming from the firms that were involved in two waves of the French ICT survey referring to the years 2018 and 2020. Both surveys included questions on the usage of AI as well as other ICTs. Along with the generic use of them, we also examine their adoption in the main business functions of companies:

[4] Also with respect to the supply of AI technologies Igna and Venturini (2023) find that the extent of AI patents is higher for firms that were able to develop inventions in the areas of network and communication, high-speed computing and data analysis.

production, administration and marketing.[5] Hence, the additional hypothesis to be tested is that the factors enhancing the adoption of AI technologies differ according to business functions they are used for.

By considering the same set of firms in different years, we were able not only to distinguish between early and late adopters but also to highlight some relevant antecedents that facilitated the former to keep adopting AI technologies and the latter to start doing that. With respect to early adopters, it should be stressed that to start using new advanced technologies in a given period does not ensure that they will be used in the future. Baldwin and Lin (2002) and more recently Stornelli et al. (2021) have identified different factors that can lead to adoption failures and, hence, to the abandonment of advanced technologies. Among them, a relevant role is played by the shortage of skills and the need of re-training existing employees coupled by organization-related problems: the latter are due to the difficulties in introducing complementary changes in all the business functions (required for an effective integration of new technologies), along with workers' resistance and inadequate management attitude. Identifying these impediments in advance can be challenging, as they often emerge during the innovation process following the adoption decision.

Similar arguments apply in examining the adoption and exploitation of AI technologies. Some scholars have stressed that for a successful AI adoption, companies have to restructure all their business functions and business models (see, among others, Bresnahan, 2019 and Iansiti and Lakhani, 2020). Others, have emphasised the need of changing work organization and workers' tasks: the skills required to manage and customize AI solutions cannot be achieved by solely recruiting new specialists but also by re-training the existing staff (cf. Deloitte, 2018; Tabrizi et al., 2019; Kinkel et al., 2022). The latter is essential to minimize the resistance to change of workers (mainly due to the fear that the adoption of AI may jeopardize their jobs). A peculiar and relevant problem for a successful adoption of AI technologies refers to data security concerns. According to a survey involving the executives of large companies, data security vulnerability emerged as one of the main concern for the development of AI initiatives (Deloitte, 2018). To minimize the risk of cyber attacks and comply with data protection laws ad regulations, AI adopters should enhance their defenses by prioritizing IT security from the outset

[5]This is in line with previous studies on the adoption of Advanced Manufacturing Technologies (AMT) Spanos and Voudouris (2009) distinguished ATM applied in three broad functional categories: design, production, and administration. Arvanitis and Hollenstein (2001), instead, considered six functional groups: design, planning, fabrication, handling, quality control, and communication.

of the process.

In the remainder of this work we will therefore contribute to the above mentioned stream of research by inspecting the predetermined factors that enhance AI adoption by firms.

3 Empirical Strategy

3.1 Data Sources, AI measures and antecedents

For the empirical analysis, we exploit the microdata provided by the French ICT Survey ("Enquête sur les Technologies de l'Information et de la Communication (TIC)"). This survey, carried out by INSEE, collects information on the adoption of ICT and advanced digital technologies by French firms with at least 10 employees (see, above, Calvino and Fontanelli, 2023a). We make use of two waves of such a survey: the first administered in 2019 collecting data for 2018 and the second carried out in 2021 with data referring to 2020. A rotating sample of about 8,800 firms was considered in each survey.

However, for the purpose of our study, we restrict the analysis to 1,753 firms that were involved in both surveys. In this way we are able to distinguish four groups of firms: those that have adopted AI technologies in 2018 and continued to do so in 2020; the early adopters that have stopped to do so in 2020; the firms that have adopted AI only in 2020; those that never adopted AI. Most importantly, some relevant variables capturing the firms' attitude towards digital technologies in 2018 are used as "antecedents" of AI adoption in 2020. Among them we consider: the recruitment of ICT specialists and the ICT training of employees; the use of electronic commerce and Customer Relation Management (CRM) applications; the use of the company website as well as social media for analysing the behaviour of actual and potential customers; the implementation of IT security systems of different complexity. Along with the impact of these variables, we also control for other firm characteristics and, primarily, for their employment size and sector of activity.

The survey concerns firms belonging to the following NACE rev. 2 sectors: section C - *Manufacturing*; section D - production and distribution of electricity, gas, steam and air conditioning - and section E - production and distribution of water, sanitation, management waste and decontamination - that we group in *Utilities*; section F - *Construction*; section G - trade, automobile and motorcycle repair

- and section H - transport and storage - that we group in *Trade and Transport*; section J - *Communication and ICT*; section M - *Professional services*; section N - administrative and support service activities - and group 95.1 - repair of computers and communications equipment - , section I - accommodation and catering - and section L - real estate activities - that we group into *Other*.

The French survey allows us to consider the functional distribution of AI technologies (see Section 2). Hence, we define an AI adopter as a firm that used AI technologies in at least one of the following business functions: production of goods and services, administration and marketing. Obviously, because the options are not mutually exclusive, some firms may have applied AI in two or all functions. In the remainder of the analysis we will show some descriptive statistics for the firms involved in the 2021 survey as well as for those participating in both 2019 and 2021 surveys. Instead, in the empirical estimations we will only focus on the latter set of firms.

3.2 Descriptive Evidence

Table 1 shows the distribution of AI users and non-users by firm size. The top panel refers to all 8,636 firms surveyed in 2021, while the lower panel refers to the 1,753 firms surveyed in 2021 that were already involved in the 2019 survey on the use of advanced digital technologies. In the year 2020 the average rate of adoption (10.3%) is slightly below that found by Calvino and Fontanelli (2023a) for the French firms in 2018 (11.4%), suggesting that the usage of AI has not increased. Consistently with the findings of previous surveys (cf. Section 2), from both panels it emerges that the percentage of AI users increases with firm size and reaches a maximum of around 41% for the firms with more than 999 employees. The comparison between the two panels reveals that the sub-sample of firms surveyed across both waves is biased in favour of very large firms, i.e. those with 500 employees and more. This is due to the fact that the latter, as opposed to the firms with a smaller size, were not sampled so that their probability of taking part in both surveys was much higher.

Table 2 shows the distribution of AI users by industry division. From the top panel of the Table, the first three industries in terms of share of firms adopting AI are Communication and ICT (18.6%), Professional Services (13.1%), and Manufacturing (11.3%). Again, these findings are in line with those arising from previous surveys. Due to the bias in favour of very large firms, the shares of adopters for these three industries are much higher when the sub-sample of previously surveyed

firms is considered. However, the industry ranking is not changed.

Table 1: AI Users by Firm Size

	AI Users	Distribution by Size	Share of AI Firms
All firms in 2021 wave			
less than 50	161	18.02%	3.26 %
from 50 to 249	142	15.90%	8.89%
from 250 to 499	104	11.65%	18.98%
from 500 to 999	193	21.62%	22.68%
1000 and more	293	32.81%	41.44%
Total	893	100%	10.34%
Firms in 2021 wave also surveyed in 2019			
less than 50	14	2.93%	5.32%
from 50 to 249	14	2.93%	17.50%
from 250 to 499	18	3.77%	22.22%
from 500 to 999	165	35.51%	23.81%
1000 and more	267	55.86%	41.98%
Total	478	100%	27.27%

Source: TIC waves 2019 and 2021, INSEE. Own computation.

Table 2: AI Users by Industry Division

Division	AI Users	Distribution by Industry	Share of AI Firms
All firms in 2021 wave			
Manufacturing	250	28.00%	11.25%
Utilities	20	2.24%	8.66%
Construction	31	3.47%	3.97%
Trade and Transport	229	25.64%	9.01%
Communication and ICT	119	13.32%	18.65%
Professional Services	213	23.85%	13.10%
Other	31	3.47%	5.19%
Total	893	100%	10.34%
Firms in 2021 wave also surveyed in 2019			
Manufacturing	152	31.80%	32.97%
Utilities	7	1.46%	23.33%
Construction	14	2.93%	15.56%
Trade and Transp	144	30.13%	20.93%
Communication and ICT	44	9.21%	39.29%
Professional Services	104	21.76%	33.12%
Other	13	2.72%	22.41%
Total	478	100%	27.27%

Source: see Table 1.

By restricting the analysis to the firms involved in both surveys, Table 3 cross-references the functional and technological distributions of AI usage for the 478 firms that adopted AI in 2020 (see the previous Tables). The majority of them (349) made use of AI for the function of administration, followed by production (234) and marketing (203). With respect to AI technologies, machine learning turns out to be the most diffused technology in all business functions. AI for language analysis prevails in marketing and administration, while AI for image recognition and machinery automation are more present in production. Finally AI for the au-

Table 3: AI usage by business function and technology

AI Technology	Share of AI user in Production	Administration	Marketing
Image	118 (50%)	156 (45%)	75 (37%)
Machine Learning	146 (62%)	222 (64%)	149 (73%)
Language	112 (48%)	206 (59%)	134 (66%)
Task automation	135 (58%)	204 (58%)	125 (62%)
Machinery automation	107 (46%)	86 (25%)	44 (22%)
Total Users	234	349	203

Source: see Table 1.

tomation of tasks is more homogeneously distributed in all functions.

Table 4 documents that 47% of the 478 firms that adopted AI technologies in 2020 had already adopted them in 2018, while 53% started to do so only later. More surprisingly, the same table shows that of the 411 AI adopters in 2018 about 46% (188) have stopped to do so two years later. Tables A.3-A.5 in the Appendix show that the share of AI abandonment is particularly high when the adoption refers to the production function followed by that of marketing. Furthermore, for the latter function the number of AI adopters in 2020 is a bit lower than that recorded in 2018.

Table 4: AI use by Wave

	Total	2019 wave		
		yes	no	Total
2021 wave	yes	223	255	478
	% row	*46.65*	*53.35*	*100*
	% column	*54.26*	*19.00*	*27.27*
	no	188	1087	1275
	% row	*14.75*	*85.25*	*100*
	% column	*45.74*	*81.00*	*72.63*
	Total	411	1342	1753
	% row	*23.45*	*76.55*	*100*
	% column	*100*	*100*	*100*

Source: see Table 1.

Why have so many firms abandoned AI technologies? In line with the arguments stressed in the end of Section 2, the main reason could be that they were unable to accompany the AI adoption with complementary investments in ICT and skills (e.g. IT security systems, ICT training of employees). This is supported by the fact that the incidence of abandonment was much higher for smaller firms. Indeed, the median size of the firms that continued to adopt AI is twice as large, and their mean size is three times larger than those of the firms that ceased to use AI technologies.

Secondly, it should be taken into account that the reference year of the second

survey is that of the COVID19 pandemic so that it is likely that the sharp fall in economic activities during 2020 also involved a reduction of innovation expenditures, including those for AI adoption. To inspect to what extent the AI abandonment was driven by the pandemic we used for comparative purposes the abandonment rate of robots coming from the same survey and referring to the years 2017 and 2019. On average, 20% of French companies ceased using robots after two years, but among non-manufacturing firms this share was about 50%. Hence, as our sample primarily consists of non-manufacturing firms, the rate of abandonment of AI technologies is not surprising. Therefore, we contend that the impact of the COVID-19 pandemic, if any, was minimal.

4 Empirical model and results

To inspect the determinants of AI adoption by firms we rely on the following empirical model:

$$AI_{it} = \alpha + \beta AI_{it-2} + \gamma' X_{it-2} + \epsilon_{it} \tag{1}$$

where AI_{it} denotes a dummy variable equal to 1 if firm i adopts AI at time t, that is in 2020, and zero otherwise. As mentioned above, as alternative dependent variables we also consider AI adoption in production, administration and marketing. AI_{it-2} is a dummy variable equal to 1 for the firms that were already using AI technologies in 2018, while X_{it-2} is a vector of firm level characteristics always referring to 2018. Along with dummies for firm sizes (see Table 1) and industry divisions (cf. Table 2), the vector includes electronic commerce and CRM usage, ICT personnel training and recruitment, the security system level adopted, and the use of web and social media.

Table 5 reports descriptive statistics for the dependent variables (AI users in 2020, also distinguished between usage in production, marketing and administration) and the set of independent variables which are taken from the previous wave (p.w.) of the survey, referring to the year 2018. Appendix A.1 details the definition of each dependent and explanatory variable used in the following regression analyses. For estimation purposes we employ a Linear Probability Model (LPM), i.e. we apply OLS to the binary outcome of AI adoption in 2020. As compared to Probit or Logistic models, LPM has the advantage of providing results that can be interpreted as mean marginal effects.

Table 6 shows the baseline results of our regression analyses. For the firm

Table 5: Descriptive Statistics

Variable	Obs	Mean	Std. dev.	Min	Max
AI user	1,753	0.273	0.445	0	1
AI user in Production	1,753	0.133	0.340	0	1
AI user in Marketing	1,753	0.199	0.399	0	1
AI user in Administration	1,753	0.156	0.320	0	1
AI user (p.w.)	1,753	0.234	0.424	0	1
AI user in Production (p.w.)	1,753	0.135	0.342	0	1
AI user in Marketing (p.w.)	1,753	0.120	0.325	0	1
AI user in Administration (p.w.)	1,753	0.156	0.363	0	1
El. Commerce (p.w.)	1,753	0.524	0.721	0	2
ICT Training and Recruitment (p.w.)	1,753	1.337	0.807	0	2
Security Systems (p.w.):					
Basic	1,753	-0.170	0.888	-2.78	1.83
Intermediate	1,753	0.728	0.721	-2.09	1.56
Advanced	1,753	-0.116	0.985	-2.78	3.63
CRM (p.w.)	1,753	1.118	0.886	0	2
Web/Social Media (p.w.)	1,703	1.275	0.671	0	2

Source: see Table 1.

size the reference category is firms with less than 50 employees while "Other" for industry.

The results for the probability of AI usage (regardless of the business function) are illustrated in first column of Table 6. First of all, the AI adoption in 2018 (p.w.) increases the probability of AI adoption in 2020 by 24.7%. The magnitude of the impact appears to be lower than one might expect but this is consistent with the fact that a remarkable percentage of AI adopters in 2018 have stopped to do so two years later (see Table 4 in the previous section). Accordingly, along with the adoption in a previous period, other firm choices and/or characteristics, always referring to the previous period, should be taken into account to better estimate the probability of AI adoption in a subsequent period. In this regard, a firm size from 500 to 999 employees raises the likelihood of AI adoption by 7.2% while a 17.4% increase applies to firms with more than 999 employees. The other variables that exerted an additional positive impact are: the provision of ICT training for employees coupled with the recruitment of ICT specialists; the use of websites and social media for getting information on potential customers; the scores achieved for the implementation of IT security systems with an intermediate level of complexity. Being these factors included as categorical variables (ICT training and recruitment and Web/Social Media, ranging from 0 to 2) or continuous variables (scores for Intermediate Security Systems) their estimated parameters cannot be interpreted in a straightforward way. It should be added that the firms with higher scores for the implementation of basic IT security systems in 2018 recorded a lower probability of AI adoption in 2020. Finally, coefficients of industry dummies are not

Table 6: Baseline Results

	AI user	AI-Prod	AI-Adm	AI-Mark	AI-Prod	AI-Adm	AI-Mark
AI user previous wave (p.w.)	0.247***	0.123***	0.194***	0.142***			
	[0.024]	[0.020]	[0.022]	[0.018]			
El. Commerce p.w.	-0.021	-0.009	-0.02	0.028**	-0.012	-0.017	0.023*
	[0.017]	[0.013]	[0.015]	[0.012]	[0.013]	[0.015]	[0.012]
ICT Training and Recruitment p.w.	0.039***	0.012	0.044***	0.011	0.014	0.045***	0.016
	[0.014]	[0.012]	[0.013]	[0.011]	[0.012]	[0.013]	[0.011]
Security Systems: Basic	-0.038***	-0.040***	-0.035***	-0.023**	-0.039***	-0.032***	-0.022**
	[0.012]	[0.010]	[0.011]	[0.009]	[0.010]	[0.011]	[0.009]
Security Systems: Intermediate	0.057***	0.024*	0.040**	0.017	0.026*	0.044***	0.021
	[0.018]	[0.014]	[0.016]	[0.013]	[0.014]	[0.016]	[0.013]
Security Systems: Advanced	0.013	0.005	0.011	0.020**	0.006	0.010	0.021***
	[0.011]	[0.009]	[0.010]	[0.008]	[0.009]	[0.010]	[0.008]
CRM p.w.	0.013	-0.008	0.003	0.032***	-0.007	0.010	0.026***
	[0.013]	[0.010]	[0.012]	[0.010]	[0.010]	[0.012]	[0.010]
Web/Social Media p.w.	0.055***	0.006	0.041**	0.039***	0.009	0.047***	0.035***
	[0.018]	[0.014]	[0.016]	[0.013]	[0.014]	[0.016]	[0.013]
Employees = 2, from 50 to 249	0.046	0.048	-0.017	-0.018	0.047	-0.013	-0.012
	[0.055]	[0.044]	[0.050]	[0.041]	[0.044]	[0.050]	[0.040]
Employees = 3, from 250 to 499	0.018	-0.001	0.018	0.035	-0.011	0.022	0.029
	[0.056]	[0.045]	[0.051]	[0.042]	[0.045]	[0.052]	[0.041]
Employees = 4, from 500 to 999	0.072**	0.025	0.058*	0.049*	0.022	0.060*	0.041
	[0.036]	[0.029]	[0.033]	[0.027]	[0.029]	[0.033]	[0.027]
Employees = 5, 1000 and more	0.174***	0.111***	0.132***	0.089***	0.109***	0.139***	0.084***
	[0.038]	[0.030]	[0.034]	[0.028]	[0.030]	[0.035]	[0.028]
Utilities	-0.008	-0.012	0.140*	-0.020	-0.009	0.126	-0.012
	[0.091]	[0.074]	[0.084]	[0.068]	[0.074]	[0.084]	[0.067]
Construction	-0.045	-0.004	0.051	0.005	-0.011	0.064	0.002
	[0.070]	[0.057]	[0.064]	[0.052]	[0.057]	[0.065]	[0.052]
Trade&Transport	0.044	0.003	0.111**	0.072*	0.003	0.119**	0.064
	[0.057]	[0.046]	[0.052]	[0.042]	[0.046]	[0.052]	[0.042]
Professional Services	0.080	-0.008	0.172***	0.055	-0.012	0.171***	0.053
	[0.059]	[0.048]	[0.055]	[0.044]	[0.048]	[0.055]	[0.044]
Communication and ICT	0.082	-0.040	0.174***	0.057	-0.050	0.195***	0.050
	[0.067]	[0.054]	[0.061]	[0.050]	[0.054]	[0.062]	[0.049]
Manufacturing	0.062	0.109**	0.095*	-0.009	0.109**	0.095*	-0.003
	[0.058]	[0.047]	[0.053]	[0.043]	[0.047]	[0.053]	[0.043]
AI user in Production (p.w.)					0.149***		
					[0.024]		
AI user in Administration (p.w.)						0.195***	
						[0.026]	
AI user in Marketing (p.w.)							0.237***
							[0.023]
Constant	-0.105	-0.008	-0.172***	-0.141***	-0.002	-0.186***	-0.121**
	[0.064]	[0.052]	[0.059]	[0.048]	[0.052]	[0.059]	[0.047]
Observations	1,703	1,703	1,703	1,703	1,703	1,703	1,703
R-squared	0.209	0.120	0.173	0.153	0.119	0.165	0.174

* Significant at 10% level; ** significant at 5% level; *** significant at 1% level.

significant.

The other columns of Table 6 show the separate results for the AI adoption in different business functions. In columns 2-4 the previous wave AI adoption is not distinguished by business function, while in columns 5-7 the antecedent adoption refers to the specific business function considered. In both cases, the findings are almost the same.

The adoption of AI technologies in production (encompassing logistics operations) is significantly affected by a few variables. Along with the antecedent adoption,[6] the probability of using AI for production is significantly higher for very large firms (with 1,000 employees and more) and for those belonging to manufacturing. Instead, a higher score achieved for the use of basic security systems in 2018 depresses the probability of AI adoption in 2020.

More interesting and significant results emerge moving to the other business functions. The probability of AI adoption in the administration function (which also includes human resource management and recruitment) is positively affected not only by the antecedent adoption and the largest firm size, but also by the usage of web and social media and ICT training and recruitment. The scores obtained from the implementation of basic and intermediate IT security systems have opposite effects: negative and positive respectively. Finally, firms belonging to Trade & Transport, Professional services, and Communication & ICT record a higher probability of AI adoption for administration purposes. Instead, industry dummies do not significantly affect the usage of AI technology in the marketing function. Here, together with the previous usage and the largest size of firms, positive impacts emerge for the antecedent use of: web and social media, e-commerce, and CRM (Customer Relationship Management) applications. Furthermore, high scores in implementing advanced IT security systems increase the likelihood of AI adoption in marketing. Conversely, high scores in basic security measures have a negative effect.[7]

In a further analysis we focus on the French firms that started to adopt AI

[6]Previous usages raise the probability of the subsequent ones by 12.3 and 14.9% respectively. Such increases are lower than those recorded in other business functions. This is consistent with the fact that the share of firms that stopped to adopt AI technologies is higher when production is taken into account as opposed to administration and marketing (see Tables A.3-A.5 in the Appendix).

[7]The above analysis was extended to include further potential drivers of AI adoption. First, we included the firm's tangible and intangible assets in 2018 (retrieved from FARE balance sheet data); second, the use of a fast broadband connection (connection speed equal or more than 100 Mbps). In both cases, the baseline findings are unaltered, while the additional controls turn non-significant or barely significant.

Table 7: Results -AI Starters

	AI user	AI-Prod	AI-Adm	AI-Mark
El. Commerce p.w.	-0.004	-0.019	-0.008	0.030**
	[0.018]	[0.014]	[0.016]	[0.012]
ICT Training and Recruitment p.w.	0.022	0.002	0.040***	0.005
	[0.015]	[0.012]	[0.013]	[0.010]
Security Systems: Basic	-0.040***	-0.039***	-0.044***	-0.012
	[0.012]	[0.009]	[0.011]	[0.008]
Security Systems: Intermediate	0.057***	0.025*	0.030**	0.023**
	[0.018]	[0.013]	[0.015]	[0.012]
Security Systems: Advanced	0.002	-0.007	0.004	0.009
	[0.012]	[0.009]	[0.010]	[0.008]
CRM p.w.	0.012	-0.008	0.001	0.027***
	[0.013]	[0.010]	[0.012]	[0.009]
Web/Social Media p.w.	0.043**	0.020	0.023	0.015
	[0.018]	[0.014]	[0.016]	[0.012]
Employees = 2, from 50 to 249	0.032	0.035	-0.020	0.014
	[0.056]	[0.043]	[0.049]	[0.037]
Employees = 3, from 250 to 499	0.033	-0.018	0.007	0.047
	[0.060]	[0.045]	[0.052]	[0.039]
Employees = 4, from 500 to 999	0.085**	0.032	0.060*	0.046*
	[0.037]	[0.028]	[0.032]	[0.024]
Employees = 5, 1000 and more	0.157***	0.090***	0.114***	0.079***
	[0.039]	[0.030]	[0.034]	[0.025]
Utilities	-0.098	-0.011	0.029	-0.029
	[0.096]	[0.073]	[0.083]	[0.062]
Construction	-0.105	-0.040	-0.019	-0.016
	[0.076]	[0.057]	[0.066]	[0.049]
Trade&Transport	0.001	-0.002	0.059	0.034
	[0.061]	[0.047]	[0.054]	[0.040]
Professional Services	0.031	0.001	0.115**	0.024
	[0.065]	[0.049]	[0.056]	[0.042]
Communication and ICT	0.114	0.004	0.159**	0.116**
	[0.076]	[0.057]	[0.066]	[0.049]
Manufacturing	0.023	0.067	0.037	-0.007
	[0.063]	[0.048]	[0.055]	[0.041]
Constant	-0.039	0.005	-0.088	-0.083*
	[0.069]	[0.052]	[0.060]	[0.045]
Observations	1,294	1,294	1,294	1,294
R-squared	0.105	0.072	0.097	0.078

* Significant at 10% level; ** significant at 5% level; *** significant at 1% level.

Table 8: Results - Dummies for Categorical Variables

	AI user	AI-Prod	AI-Adm	AI-Mark	AI-Prod	AI-Adm	AI-Mark
AI user previous wave (p.w.)	0.251***	0.124***	0.195***	0.143***			
	[0.025]	[0.020]	[0.023]	[0.018]			
El. Commerce p.w. = 1, BtoB or BtoC	0.009	0.007	-0.003	0.042**	0.003	-0.002	0.032
	[0.026]	[0.021]	[0.024]	[0.020]	[0.021]	[0.024]	[0.019]
El. Commerce p.w. = 2, BtoB and BtoC	-0.055	-0.023	-0.049	0.046*	-0.028	-0.044	0.038
	[0.034]	[0.028]	[0.031]	[0.026]	[0.028]	[0.032]	[0.025]
ICT Training and Recruitment p.w. = 1, Training or Recruitment	0.071**	0.018	0.057*	0.022	0.015	0.054*	0.026
	[0.032]	[0.026]	[0.029]	[0.024]	[0.026]	[0.029]	[0.023]
ICT Training and Recruitment p.w. = 2, Training and Recruitment	0.085***	0.025	0.091***	0.028	0.027	0.092***	0.036
	[0.030]	[0.024]	[0.028]	[0.022]	[0.024]	[0.028]	[0.022]
Security Systems: Basic	-0.038***	-0.039***	-0.036***	-0.024***	-0.038***	-0.033***	-0.023**
	[0.012]	[0.010]	[0.011]	[0.009]	[0.010]	[0.011]	[0.009]
Security Systems: Intermediate	0.057***	0.025*	0.041**	0.018	0.027*	0.045***	0.022
	[0.018]	[0.014]	[0.016]	[0.013]	[0.014]	[0.016]	[0.013]
Security Systems: Advanced	0.012	0.005	0.010	0.018**	0.006	0.009	0.020**
	[0.011]	[0.009]	[0.010]	[0.008]	[0.009]	[0.010]	[0.008]
CRM p.w. = 1, Client Info or Marketing	0.008	-0.023	-0.005	0.001	-0.024	-0.002	0.004
	[0.028]	[0.023]	[0.026]	[0.021]	[0.023]	[0.026]	[0.021]
CRM p.w. = 2, Client Info and Marketing	0.023	-0.018	0.004	0.062***	-0.016	0.017	0.051***
	[0.026]	[0.021]	[0.024]	[0.019]	[0.021]	[0.024]	[0.019]
Web/Social Media p.w. = 1, Web Info or Social Media	0.061*	0.037	0.030	0.002	0.043	0.032	0.01
	[0.033]	[0.026]	[0.030]	[0.024]	[0.026]	[0.030]	[0.024]
Web/Social Media p.w. = 2, Web Info and Social Media	0.112***	0.023	0.076**	0.060**	0.031	0.086**	0.057**
	[0.037]	[0.030]	[0.034]	[0.028]	[0.030]	[0.034]	[0.027]
Employees = 2, from 50 to 249	0.034	0.042	-0.023	-0.023	0.042	-0.018	-0.016
	[0.055]	[0.044]	[0.050]	[0.041]	[0.044]	[0.051]	[0.040]
Employees = 3, from 250 to 499	0.006	-0.004	0.010	0.027	-0.014	0.016	0.022
	[0.056]	[0.045]	[0.052]	[0.042]	[0.045]	[0.052]	[0.042]
Employees = 4, from 500 to 999	0.063*	0.021	0.054	0.045*	0.018	0.056*	0.038
	[0.036]	[0.029]	[0.033]	[0.027]	[0.029]	[0.034]	[0.027]
Employees = 5, 1000 and more	0.164***	0.106***	0.127***	0.084***	0.104***	0.134***	0.080***
	[0.038]	[0.031]	[0.035]	[0.028]	[0.031]	[0.035]	[0.028]
Utilities	-0.008	-0.009	0.139*	-0.021	-0.006	0.125	-0.014
	[0.091]	[0.074]	[0.084]	[0.068]	[0.074]	[0.084]	[0.067]
Construction	-0.05	-0.011	0.051	0.008	-0.018	0.064	0.005
	[0.070]	[0.057]	[0.065]	[0.052]	[0.057]	[0.065]	[0.052]
Trade&Transport	0.033	-0.001	0.103*	0.061	-0.004	0.111**	0.057
	[0.057]	[0.046]	[0.053]	[0.043]	[0.046]	[0.053]	[0.042]
Professional Services	0.077	-0.009	0.171***	0.056	-0.013	0.171***	0.054
	[0.060]	[0.048]	[0.055]	[0.044]	[0.048]	[0.055]	[0.044]
Communication and ICT	0.081	-0.042	0.173***	0.053	-0.051	0.193***	0.048
	[0.067]	[0.054]	[0.061]	[0.050]	[0.054]	[0.062]	[0.049]
Manufacturing	0.053	0.103**	0.089*	-0.016	0.104**	0.090*	-0.008
	[0.058]	[0.047]	[0.053]	[0.043]	[0.047]	[0.054]	[0.043]
AI user in Production (p.w.)					0.151***		
					[0.024]		
AI user in Administration (p.w.)						0.197***	
						[0.026]	
AI user in Marketing (p.w.)							0.233***
							[0.023]
Constant	-0.108	-0.021	-0.162***	-0.107**	-0.015	-0.172***	-0.099**
	[0.068]	[0.054]	[0.062]	[0.050]	[0.054]	[0.062]	[0.050]
Observations	1,703	1,703	1,703	1,703	1,703	1,703	1,703
R-squared	0.210	0.121	0.174	0.157	0.121	0.165	0.176

* Significant at 10% level; ** significant at 5% level; *** significant at 1% level.

Table 9: Results - AI Starters - Dummies for Categorical Variables

	AI user	AI-Prod	AI-Adm	AI-Mark
El. Commerce p.w. = 1, BtoB or BtoC	0.034	-0.014	0.013	0.045**
	[0.028]	[0.022]	[0.025]	[0.018]
El. Commerce p.w. = 2, BtoB and BtoC	-0.028	-0.040	-0.026	0.051**
	[0.037]	[0.028]	[0.033]	[0.024]
ICT Training and Recruitment p.w. = 1, Training or Recruitment	0.054*	0.009	0.039	0.008
	[0.032]	[0.024]	[0.028]	[0.021]
ICT Training and Recruitment p.w. = 2, Training and Recruitment	0.052*	0.006	0.080***	0.011
	[0.031]	[0.024]	[0.027]	[0.020]
Security Systems: Basic	-0.040***	-0.039***	-0.044***	-0.012
	[0.013]	[0.010]	[0.011]	[0.008]
Security Systems: Intermediate	0.059***	0.027*	0.033**	0.025**
	[0.018]	[0.014]	[0.016]	[0.012]
Security Systems: Advanced	0.001	-0.008	0.003	0.008
	[0.012]	[0.009]	[0.010]	[0.008]
CRM p.w. = 1, Client Info or Marketing	-0.018	-0.034	-0.027	0.007
	[0.029]	[0.022]	[0.025]	[0.019]
CRM p.w. = 2, Client Info and Marketing	0.019	-0.016	0.013	0.053***
	[0.027]	[0.021]	[0.024]	[0.018]
Web/Social Media p.w. = 1, Web Info or Social Media	0.054*	0.034	0.026	0.012
	[0.032]	[0.025]	[0.028]	[0.021]
Web/Social Media p.w. = 2, Web Info and Social Media	0.085**	0.043	0.044	0.027
	[0.037]	[0.028]	[0.033]	[0.024]
Employees = 2, from 50 to 249	0.014	0.030	-0.027	0.008
	[0.057]	[0.043]	[0.050]	[0.037]
Employees = 3, from 250 to 499	0.018	-0.021	0.001	0.041
	[0.060]	[0.046]	[0.052]	[0.039]
Employees = 4, from 500 to 999	0.073*	0.029	0.055*	0.042*
	[0.038]	[0.029]	[0.033]	[0.024]
Employees = 5, 1000 and more	0.144***	0.087***	0.107***	0.074***
	[0.040]	[0.030]	[0.035]	[0.026]
Utilities	-0.100	-0.011	0.028	-0.031
	[0.096]	[0.073]	[0.084]	[0.062]
Construction	-0.113	-0.045	-0.024	-0.019
	[0.076]	[0.058]	[0.066]	[0.049]
Trade&Transport	-0.016	-0.005	0.049	0.026
	[0.062]	[0.047]	[0.054]	[0.040]
Professional Services	0.029	0.001	0.113**	0.023
	[0.065]	[0.049]	[0.056]	[0.042]
Communication and ICT	0.110	0.002	0.154**	0.113**
	[0.076]	[0.057]	[0.066]	[0.049]
Manufacturing	0.008	0.062	0.029	-0.013
	[0.063]	[0.048]	[0.055]	[0.041]
Constant	-0.035	0.005	-0.075	-0.072
	[0.072]	[0.054]	[0.062]	[0.046]
Observations	1,294	1,294	1,294	1,294
R-squared	0.109	0.073	0.099	0.080

* Significant at 10% level; ** significant at 5% level; *** significant at 1% level.

technologies only in 2020 and compared them with those that never adopted such technologies (neither in 2018 nor in 2020). The first column of Table 7 reports the results for the probability of AI adoption in general, i.e. not distinguished by business function. This probability is higher for the largest firms, especially those with more than 999 employees. The antecedent use of web and social media to collect information on actual and/or potential customers has positive impact and the same occurs for the propensity to implement, in 2018, IT security system with an intermediate level of complexity. Instead, a higher score for the implementation of basic security systems reduce the probability of AI adoption.

Column 2 of Table 7 shows that, apart from the largest size of firms and the score of basic security systems, no other explanatory variables significantly affect the probability of using AI for production. The likelihood of adopting AI for administration, instead, is also positively affected by the previous implementation of ICT training for employees coupled with the recruitment of ICT specialists, and also by belonging to the industries of Professional services and Communication & ICT. Finally, the probability to start adopting AI for marketing in 2020 is higher for the firms that (along with being the biggest ones, belonging to Communication & ICT, and achieving higher scores for security systems of intermediate complexity) used e-commerce and CRM applications in 2018.

Tables 8 and 9 illustrate the regression results when instead of using categorical independent variables ranging from 0 to 2 (e.g. 0 for firms not using web nor social media, 1 for those using web or social media, and 2 for those using both) a dummy variable for each category is included. The only variables that are not dichotomous refer to the scores achieved for IT security systems of different complexity. The findings reported in both tables are consistent with those already commented. So, the usefulness of such tables rests on the possibility of interpreting the estimated parameters of most explanatory variables in terms of probability increase. For instance, looking at the first column of Table 8, the antecedent usage of web or social media raises the probability of AI adoption in 2020 by 6.1% while when both of them were previously used the same probability increases by 11.2%.

5 Concluding remarks

The discussion surrounding the opportunities and risks associated with the current and potential applications of AI primarily focuses on the behavior and performance of the few large players (aka tech-giants) dominating the provision and exploitation of AI technologies. A minor role in this debate is played by their diffusion in the rest of the business sector. As we have documented in this paper, despite their potential to generate new business opportunities, the adoption of AI technologies by firms remains low, even in the most advanced economies (see Section 2).

Several factors contribute to this trend, such as shortages of ICT skills, uncertainties stemming from the rapid evolution of AI technologies, lack of customized solutions, insecure data protection. To address these and other challenges firms must anticipate and accompany the AI adoption with investments in other digital technologies, IT security systems, and digital skills. In their absence or inadequacy, both low adoption rates and adoption failures are likely.

Our findings show that the French firms that invested in these directions in 2018 had a higher probability to start adopting AI technologies in 2020. This support the hypothesis of a hierarchical trajectory of adoption from less to more complex and demanding technologies in terms of complementary investments. Furthermore, we find that the firms that already used AI technologies and invested in complementary technologies and skills in 2018 had a higher probability of continuing their usage two years later.

Based on these results, we contend that for analysing the adoption of complex technologies short-term analyses, based on single year observations, are not appropriate. Indeed, the usage of AI applications in a given period does not guarantee that they will be used in the future.

Concerning the specific factors that enhance the overall probability of starting and keeping the AI adoption, our results show that a significant role is played the antecedent investment in ICT skills (both in terms of training and recruitment), the use of websites and social media for gathering information on customers, and the implementation of adequate IT security systems. The need of the latter type of investment has not been sufficiently emphasised in the literature. Its importance stems for the fact that firms should protect their data not only for defensive purposes but also to comply with laws and regulations protecting privacy.

Interesting differences emerge when the AI usage is distinguished by business function. To start and keep adopting AI technologies in production (including lo-

gistics) is only affected by the firm size and the belonging to manufacturing industries. Instead, the adoption in the administration (or internal) functions is facilitated by the investment in ICT skills and cybersecurity and the use of website and social media. Moreover, the likelihood of AI adoption for administrative purposes is higher for firms belonging to communication & ICT and professional services. The findings regarding the adoption of AI technologies in the marketing function are those that provide greater support to the hypothesis of a hierarchical or sequential adoption of digital technologies. In fact, the probability of starting to adopt AI in marketing is positively affected by the antecedent use of e-commerce and CRM applications.

To support the transition of the whole business sector to the so-called Fourth Industrial Revolution the main policy suggestion arising from our findings is the following: rather than solely relying on incentives for acquiring hardware equipment and software applications, policymakers should prioritize investments in digital skills and IT security systems. This is especially important for small and medium-sized firms, as they have a lower propensity to adopt advanced digital technologies and a higher probability of adoption failures.

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A1 Variable definitions

- DEPENDENT VARIABLES
- AI user: dummy variable equal to 1 if the firm adopts AI in any of the production, administration or marketing functions or in all of the three activities, and equal to 0 otherwise;
- AI user in Production: dummy variable equal to 1 if the firm uses AI in production and/or logistics, and taking value 0 otherwise;
- AI user in Marketing: dummy variable equal to 1 if the firm uses AI in marketing, and taking value 0 otherwise;
- AI user in Administration: dummy variable equal to 1 if the firm uses AI for administration and/or business management, IT security, human resource management and recruitment, and taking value 0 otherwise.

- INDEPENDENT VARIABLES
- AI user (p.w.): dummy variable equal to 1 if the firm was already an AI user in the 2019 wave, and taking value 0 otherwise;
- AI user in Production (p.w.): dummy variable equal to 1 if the firm was already an AI user in production in the 2019 wave, and taking value 0 otherwise;
- AI user in Marketing (p.w.): dummy variable equal to 1 if the firm was already an AI user in marketing in the 2019 wave, and taking value 0 otherwise;
- AI user in Administration (p.w.): dummy variable equal to 1 if the firm was already an AI user in administration in the 2019 wave, and taking value 0 otherwise;
- El. Commerce (p.w.): categorical variable equal to 0 if in the 2019 wave the firm had no active channel both for business-to-business (BTB) and business-to-consumer (BTC) electronic commerce, equal to 1 if only one of the two channels was active, equal to 2 if both channels were active;

Table A.1: Factor analysis

Number of obs = 9,110				
Method: principal-component factors Retained factors = 3				
Rotation: (unrotated) Number of params = 42				
Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor1	5.16698	3.85666	0.3445	0.3445
Factor2	1.31032	0.30466	0.0874	0.4318
Factor3	1.00566	0.07520	0.0670	0.4989

Source: TIC 2019 and 2021, INSEE. Own calculations.

- ICT Training and Recruitment (p.w.): categorical variable equal to 0 if in the 2019 wave the firm had not recruited ICT specialised personnel and had not provided ICT training to workers, equal to 1 if only one of the two activities were performed, equal to 2 if both activities were in place;

- Security Systems (Basic, Intermediate, Advanced): factors extracted from the principal component factor analysis (see Tables A.1 and A.2) on the basis of the following variables: $secu\_mdp$, strong password authentication; $secu\_maj$, regular software updates; $secu\_sauv\_ext$, external data setup; $secu\_acces$, computer network access control; $secu\_presta$ carrying out activities related to IS security by external service providers; $secu\_pol\_dp$, policy of access correction and erasure of personal data; $secu_vpn$, Virtual Private Network (VPN); $secu\_conserv\_log$, retention of logs for the analysis of security incidents; $secu\_doc$, documentation of IS security measures, practices and procedures; $secu\_form\_vol$, staff information through voluntary training; $secu\_form\_oblig$, staff information through mandatory training; $secu\_bio$, authentication and identification by bio metric methods; $secu\_chiffrement$, data encryption techniques; $secu\_eval$, information system risk assessment; $secu\_tests$, information system security testing;

- CRM (p.w.): categorical variable equal to 0 if in the 2019 wave the firm did not use a CRM application i) to collect, store and make available to different department customers' information and ii) to analyse customers'information for marketing purposes, equal to 1 if CRM was used only for one of the two activities, equal to 2 if CRM was used for both activities;

- Web/Social Media (p.w.): categorical variable equal to 0 if in the 2019 wave the firm was not using the company's website to analyse the behaviour of visitors and was not making use of social media, equal to 1 if only one of the

Table A.2: Factor loadings (pattern matrix) and unique variances

Variable	Factor1	Factor2	Factor3	Uniqueness
		Security Systems:		
	Intermediate	Basic	Advanced	
$secu\_mdp$	0.5168	0.1331	0.3043	0.6225
$secu\_maj$	0.4584	0.4713	0.2548	0.5028
$secu\_sauv\_ext$	0.3672	0.3425	0.3052	0.6547
$secu\_acces$	0.6242	0.3873	-0.0991	0.4506
$secu\_presta$	0.1007	0.5007	0.2546	0.6744
$secu\_pol\_dp$	0.5910	-0.0127	-0.1688	0.6221
$secu\_vpn$	0.6939	0.1431	-0.2858	0.4164
$secu\_conserv\_log$	0.7408	0.1506	-0.2587	0.3616
$secu\_doc$	0.6846	-0.3041	-0.0687	0.4340
$secu\_form\_vol$	0.6526	-0.2917	0.0009	0.4890
$secu\_form\_oblig$	0.4897	-0.4596	0.2542	0.4844
$secu\_bio$	0.2948	-0.2517	0.5892	0.5026
$secu\_chiffrement$	0.6088	-0.2295	0.2004	0.5365
$secu\_eval$	0.7868	-0.0602	-0.1690	0.3488
$secu\_tests$	0.7515	-0.0282	-0.1344	0.4163

Source: TIC 2019 and 2021, ENSEE. Own calculations.

two activities were in place, equal to 2 if both activities were in place.

- AI Technology-related variables used for the descriptive analysis:
  - Image: dummy variable equal to 1 if the firm uses AI for image recognition, and taking value 0 otherwise;
  - Language: dummy variable equal to 1 if the firm uses AI for language analysis and recognition, and taking value 0 otherwise;
  - Machine Learning: dummy variable equal to 1 if the firm uses AI for machine learning, and taking value 0 otherwise;
  - Task automation: dummy variable equal to 1 if the firm uses AI for automation of tasks, and taking value 0 otherwise;
  - Machinery automation: dummy variable equal to 1 if the firm uses AI for automation of machinery, and taking value 0 otherwise.

A2 Additional Tables

Table A.3: AI use in Production by Wave

Production		2019 wave		
		yes	no	Total
2021 wave	yes	71	163	234
	% row	*30.34*	*69.66*	*100*
	% column	*29.96*	*10.75*	*13.35*
	no	166	1353	1519
	% row	*10.93*	*89.07*	*100*
	% column	*70.04*	*89.25*	*86.65*
	Total	237	1516	1753
	% row	*13.52*	*86.48*	*100*
	% column	*100*	*100*	*100*

Source: TIC 2021 Wave, INSEE. Own calculations.

Table A.4: AI use in Administration by Wave

Administration		2019 wave		
		yes	no	Total
2021 wave	yes	121	228	349
	% row	*34.67*	*65.33*	*100*
	% column	*44.32*	*15.41*	*19.91*
	no	152	1252	1404
	% row	*10.83*	*89.17*	*100*
	% column	*55.68*	*84.59*	*80.01*
	Total	273	1480	1753
	% row	*15.57*	*84.43*	*100*
	% column	*100*	*100*	*100*

Source: TIC 2021 Wave, INSEE. Own calculations.

Table A.5: AI use in Marketing by Wave

Marketing		2019 wave		
		yes	no	Total
2021 wave	yes	84	119	203
	% row	*41.38*	*58.62*	*100*
	% column	*39.81*	*7.72*	*11.58*
	no	127	1423	1550
	% row	*8.19*	*91.81*	*100*
	% column	*60.19*	*92.28*	*88.42*
	Total	211	1542	1753
	% row	*12.04*	*87.96*	*100*
	% column	*100*	*100*	*100*

Source: TIC 2021 Wave, INSEE. Own calculations.