Digitalisation and high-growth enterprises in Europe

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ABSTRACT

The profound implications that digital technologies have for business dynamism and the competitive environment have raised the attention of policy makers and scholars. This paper examines the link between digitalisation and firm growth, and investigates whether high-growth enterprises (HGEs) invest and adopt digital technologies differently than non-HGEs. Using the European Investment Bank Investment Survey and Generalised Least Squares as well as random-effects probit models, we find strong complementarities between different digitalisation indicators. Furthermore, firms investing in digitalisation are more likely to exhibit rapid employment, sales and labour productivity growth. Our results also highlight the heterogeneous nature of the digitalisation process and its relationship with firm performance.

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1. Introduction

The on-going digital transition has a profound impact on society and firms, receiving attention of policy makers (EIB, 2022). From an economic perspective, digitalisation has implications for business dynamism and the competitive environment (Calvino and Criscuolo, 2019). On the one hand, digitalisation diminishes barriers to entry for firms in various industries and opens up new market opportunities that can lead to the emergence of high-growth enterprises (henceforth HGEs)[1] (Benedetti-Fasil et al., 2021). Digital business models and digital activities are closely related to concepts such as high-growth start-ups, scale-ups and unicorns (Rückert et al., 2020; Testa et al., 2022; Coad et al., 2024). On the other hand, digital business models and network effects might lead to a ''winner-takes-all'' dynamic, reducing business dynamism and firm entry (Autor et al., 2020; Dhyne et al., 2020).

Earlier evidence showed that especially those firms that increased their up-take of digital technologies were already more digitalised before the crisis (EIB, 2022; Teruel et al., 2023). One driver relates to complementary investments that are necessary for a successful uptake (Corrado et al., 2017; Mohnen et al., 2018) or different types of digital technologies (Bartelsman et al., 2017; DeStefano et al., 2020). For instance, the use of robots and artificial intelligence (AI henceforth) are fostering structural reorganisations reducing uncertainty, or supporting decisions-making with high-quality information. Furthermore, multinationals can enhance their production capacity with 3D printing and AI. This paper investigates why firms implement new digital technologies (henceforth NDT), and under which conditions these investments lead to firm growth.

Björkdahl (2020) stressed the challenge for digitalised firms[2] to capture their returns on investment, mainly due to the intangible nature of digital assets and the complexity of complementary investments needed for their implementation (Cho et al., 2023). NDTs differ in terms of their capacity to transform a business model or bring about innovation. Hence, we assume that digital technologies vary in their incidence on firm growth. We distinguish between basic digital tools (which include ''software, data, IT networks and website activities'') and more advanced NDTs. NDTs are classified into two categories following Frank et al.

[1] HGEs are defined according to the OECD-Eurostat as an average annualized employment growth greater than 10% per year over the past three years and have at least 10 employees at the beginning of the growth period.

[2] The concept of digitalised firms refers to the firms that have invested in some kind of digital technologies.

(2019). First, "front-end" technologies (drones, robotics, 3-D printing, and virtual reality) have an end-application purpose in a firm's value chain. These technologies transform manufacturing activities based on smart manufacturing and change the ways workers perform their activities based on the support of smart working. Second, "base" technologies (big data analytics and AI, cloud computing and services, platform technologies, and Internet of Things (IoT henceforth)) are a base for front-end technologies. Base technologies provide connectivity and intelligence for front-end technologies.[3]

This paper analyses two distinct questions. Firstly, we assess firm-specific determinants that lead to an increase in digitalisation efforts. In this context, we explore how complementarities between investments in ''basic'' digitalisation (software and data) lead to a higher level of investments in NDTs. Secondly, we analyse whether these different NDTs lead to stronger firm growth, using multiple dimensions.

Our main database is the European Investment Bank Investment Survey (henceforth EIBIS) covering all EU-27 member states for the years 2018-2020. Our main results are the following. First, HGEs show a higher propensity to adopt front-end NDTs. We also confirm the complementarity in investments among basic digital technologies and NDTs. Turning to the growth outcomes, higher investment in basic digital technologies is positively associated with employment, sales and labour productivity growth; while the adoption of NDTs does not affect the short-term growth measures. Furthermore, HGEs expect higher growth over the coming three years due to investments in NDTs. Finally, we provide evidence on the heterogeneous relationship between NDTs on firm performance. Our results contribute to the extensive literature on digitalisation and firm growth (Gal et al., 2019; Cathles et al., 2020; Dhyne et al., 2020; Cirillo et al., 2023).

The paper is structured as follows. The next section reviews the main theoretical and empirical works and describes our hypotheses. Section 3 describes our data and key variables and presents descriptive statistics. Section 4 outlines the methodology, while our main estimation results are discussed in Section 5. Finally, we conclude and discuss policy implications.

[3] For example, AI affects how firms take decisions and innovate (Babina et al., 2024), platforms which connect consumers to service providers facilitate firms identify consumers' willingness to pay (Falk and Hagsten, 2015), additive technology lowers the cost of producing goods for markets with low volumes (Jiang et al., 2017).

2. Literature review

2.1. Adoption of NDTs and digital complementarities

When it comes to the adoption of NDTs, HGEs are of particular interest since they contribute disproportionally to aggregate economic outcomes (Flachenecker et al., 2020; Benedetti Fasil et al., 2021). A string of papers has investigated the digitalisation process of HGEs and related aspects. Teruel et al. (2022) highlights the complex relationship between the internationalisation process of a firm, the up-take of digital technologies and the start of a high-growth phase. Coad et al. (2022) point out that it was especially already digitalised firms that have increased their digital activities due to COVID-19. Teruel et al. (2023) provide evidence that HGEs may be more likely to expect a long-term effect of COVID-19 on the increased use of NDTs. Hence, we investigate whether HGEs are also more focused on investing into digitalisation than non-HGEs.

H1: HGEs are more likely to adopt digital technologies.

Recent evidence suggests that there is a certain persistence in the process of digitalisation between already digitalised versus non-digitalised firms, resulting in a so-called ''digital gap''. For instance, Rückert et al. (2021) and EIB (2022) show that firms that already implemented advanced digital technologies are more likely to report that they continue implementing them in the future.

This persistent gap might be explained by the increasing technological complexity which requires continuous investments. Previous studies have identified strong complementarities of digital technologies with other intangible assets such as organisational capital and management skills (Schivardi and Schmitz, 2020) or R&D (Corrado et al., 2017; Mohnen et al., 2018). Hence, firms must have complementary knowledge to implement NDTs successfully. The adoption of NDTs might be path-dependent, since those firms that have developed a significant body of knowledge will be better learners and hence will be able to generate and absorb more knowledge in the future.

This path-dependence is more intense nowadays. The current technological wave integrates NDTs improving firms' business processes and enhancing their competitiveness. However, NDTs differ in their functionalities. Frank et al. (2019) consider that, on the one hand, front-end technologies have an end-application purpose in a firm's value chain. These technologies transform manufacturing

activities based on smart manufacturing, and change the ways workers perform their activities based on the support of smart working. On the other hand, base technologies provide connectivity and intelligence for front-end technologies. In this sense, front-end technologies include technologies related to automation, while base technologies allow the data collection, its integration and analysis. Therefore, we hypothesise that previous investment in capacities regarding basic IT such as software, web and data may facilitate the adoption of NDTs, since it may generate a certain knowledge stock that facilitates the adoption of more advanced technologies.

H2: There are complementarities among different digital technologies.

2.2. Effects of digitalisation on firm growth

Research on the impact of digitalisation on sales and productivity growth generally finds a positive effect attributable to digital technologies' ability to reducing search, replication, transportation, tracking, and verification costs (Falk and Hagsten, 2015; Gal et al., 2019; Cathles et al., 2020; DeStefano et al., 2020; Cirillo et al., 2023; Oh and Kim, 2023). In other words, digitalisation fosters sales and productivity growth because it lowers search costs of customers, widens the potential for scope and quality of search, or enables easy replication of digital goods at low (or zero) marginal costs (Goldfarb and Tucker, 2019). Conversely, evidence finding negative or neutral effects emphasize the costs associated with the adoption and implementation of these technologies (Joensuu-Salo et al., 2018). Factors contributing to these costs include the complementarity with managerial and organisational practices, technological uncertainty surrounding the adoption of NDTs and market uncertainty linked to potential risks in securing the relevant returns for digitalised firms (Day and Schoemaker, 2016).

Based on these considerations, digitalisation may have a different impact according to different measures of firm performance. Focusing on the employment effects of digitalisation, recent empirical studies (Balsmeier and Woerter, 2019; Reljic et al., 2021) have confirmed that the relationship between digitalisation and employment is complex and depends on the skills of workers and the nature of their tasks. For instance, Balsmeier and Woerter (2019) find a small but positive net effect on employment. However, their results show heterogeneity according to the type of digital technologies. While machine-based digital technologies such as 3-D printing or IoT increase employment, there are no significant effects when considering non-machine-based digital technologies such as enterprise resource planning (ERP) systems, e-commerce or cooperation

support systems. For HGEs, Teruel et al. (2022) show that digitalisation does not affect the probability of being an HGE, potentially explained by skill-biased technological change (Goos et al., 2009; Michaels et al., 2014; Balsmeier and Woerter, 2019). While the adoption of some NDTs requires hiring new specialized workers, some others can also cause the displacement of workers which are substituted by these new technologies. Hence, here we will focus on the different effects of these NDTs.

In terms of the impact of digitalisation on sales and productivity, Björkdahl (2020) emphasizes that digitalisation can potentially enhance efficiency or stimulate sales growth, particularly when complementing existing products with additional services. In this regard, Dhyne et al. (2020) show that ICT investments boost value added, especially for larger firms, but the impact varies across sectors. However, the relationship between NDTs and firm growth is not straightforward. Authors Teece (2018) and Björkdahl and Holmén (2019) have pointed out the difficulties that firms have to capitalise on the value generated by digitalisation. The main reason is that some of these NDTs function as intermediate inputs in the value chain rather than outputs so managers have the challenge of identifying ways of capitalising their investments.

H3: Digitalised firms grow faster in terms of employment, sales, labour productivity and wages.

3. Data and descriptive statistics

3.1. Data sources and key variables

Our database is the EIB Investment Survey (EIBIS). EIBIS is an EU-wide survey that compiles information annually since 2016 on investment activities by non-financial corporates, their financing requirements and the barriers they face. Using a stratified sampling methodology, EIBIS is representative across all 27 EU Member States, the UK and the US, within countries, four firm size classes (micro, small, medium and large) and four sectors (manufacturing, services, construction and infrastructure).[4] Our sample belongs to waves 2019-2021 (financial years 2018-2020) because the question on the use of NDTs was introduced in the 2019 wave. We include firms belonging to the 27 EU countries.

[4] More information on EIBIS is available at https://www.eib.org/en/publications-research/economics/surveys-data/eibis/about/index.htm

Additionally, we use the Structural Business Statistics from Eurostat that provide data on sales and employees between years 2017 and 2019 at sector and country levels. This allows us to estimate the sectoral average productivity (sales per employee) at country level.

Our main variable is *HGE*, which is a dummy variable identifying firms with an average annualized employment growth greater than 10% per year over the past three years and at least 10 employees at the beginning of the growth period, following the OECD-Eurostat definition (Petersen and Ahmad, 2007).

We use three different measures related to a firm's digitalisation. First, ''basic'' digitalisation is defined as investment in ''software, data, IT networks and website activities''. We construct two variables: a dummy if the firm invested in this digital activity and, if so, to which degree. Second, a dummy identifies firms that invested in NDTs. Third, NDTs are classified in "front-end" technologies (drones, robotics, 3-D printing, augmented or virtual reality) and "base" technologies (big data, AI, cloud computing and services, platform technologies and IoT).

Finally, our growth measures identify firms that have grown 10% or more in terms of sales, employment, labour productivity and wages. Second, we use a measure for growth expectations since the EIBIS in 2020 introduced a question whether companies that introduced NDTs expected positive employment growth in the following three year. The first group of variables will capture the short-term growth, while the second one will identify expected growth in the medium-term.

3.2. Descriptive statistics

This subsection provides a short overview of some key descriptive statistics. Table 1 shows some preliminary differences in digitalisation between HGEs and non-HGEs.

Table 1. Firms (%) according to their investment in digital technologies. Financial year 2020. Weighted by added value.

	Non-HGE	HGE
Firms investing in software and data	70.4	77.8
Investment in software and data over sales (%)	4.8	6.2
Firms digitalising during COVID-19	52.1	57.9
Firms adopting NDTs	62.0	63.6
Firms adopting front-end NDTs	28.3	24.9

Firms adopting base NDTs	51.1	49.2
Number of firms	4,447	464

Note (1): a firm may simultaneously be investing in front-end and base NDTs.
Note (2): The classification of HGEs is based on the financial year 2019. Firms where HGE status is not available are excluded.

First, a larger share of HGEs invests in software and data in comparison with non-HGEs. Concerning the investment intensity, it is relatively low but the values remain higher for HGEs**.** Conversely, a significantly larger share of HGEs have digitalised as a response to COVID-19 in comparison with non-HGEs. Interestingly, we observe that the share of firms investing in NDTs is slightly larger for HGEs than for non-HGEs. Conversely, when we distinguish by typologies of NDTs, HGEs present a lower share of NDTs.

Finally, Table 2 analyses the expected impact of NDTs on employment among firms that adopted NDTs. First, HGEs are less prone to expect an employment change due to their investment in NDTs. On the one hand, 78.2% of HGEs do not expect any change, while for non-HGEs the share is equal to 70.3%. On the other hand, they have a lower share of firms expecting a decrease in their workforce in comparison with non-HGEs.

Note that most firms consider that NDTs will not have an impact on the number of employees in the coming three years. However, there is a small difference when classifying firms between those ones that implement base technologies and front-end technologies. 16% of firms that apply front-end technologies expect to decrease the number of employees, while 11% of firms using base technologies expect to decrease the number of employees.

Table 2. Firms (%) according to their expected impact of NDTs in terms of employment in three years. Financial year 2020. Weighted by value added. Respondents belong to those only investing in NDTs.

	HGEs classification		**NDT classification**	
Type of impact	**Non-HGE**	**HGE**	**Base techs**	**Front-end techs**
No impact	70.3	78.2	71.2	68.8
Decrease	13.5	4	11.1	16.4
Increase	15.4	15.8	16.6	14.7
Number of firms	2,257	272	2,080	1,062

Note: The classification of HGEs is based on the financial year 2019.

4. Econometric methodology

To analyse if HGEs are more likely to invest in digitalisation (H1), we use two different models to capture the intensive (equation 1) and extensive (equation 2) margins of digitalisation:

$$BasicDTint_{it} = \alpha_{1i} + \beta_{11} HGE_{it-} + X_{it-1}\beta_{12} + \delta_{1it} + h_{1ic} + \varepsilon_{1it} \quad (1)$$

$$Prob(DT_{it}) = \alpha_{2i} + \beta_{21} HGE_{it-1} + X_{it-1}\beta_{22} + \beta_{23} BasicDTint_{it-1} + \delta_{2it} + h_{2ic} + \varepsilon_{2it} \quad (2)$$

where the dependent variables are *BasicDTint* (the intensity of investment in software and data, in logarithms)[5] and *DT* is a vector of dummies indicating that the firm *i* in year *t* invested or adopted digital technologies (*BasicDT*, *NDT*, *NDTfront* and *NDTbase*). *HGE* is an indicator variable identifying high-growth enterprises. We must take into account that we only know if a firm adopted or not a NDT, but we do not know the amount of investment. The introduction of *BasicDTint* in Equation (2) allows us to investigate H2.

Secondly, we focus on the relationship of these digitalisation efforts with firm growth (H3):

$$Prob(y_{it}) = \alpha_{3i} + DT_{it-1} + X_{it-1}\beta_{32} + \delta_{3it} + h_{3ic} + \varepsilon_{3it} \quad (3)$$

where *y* identifies if a firm *i* has grown in terms of employees, sales, labour productivity or wages larger than 10% between periods *t-1* and *t* (*gr_employ*, *gr_sales*, *gr_labprod* and *gr_wage*). As stated previously, *DT* is a vector of variables indicating investment in different forms of digitalisation activities.[6]

Finally, all equations include X_{it}, a set of explanatory variables such as firm age *(young)* and the level of innovation *(inno_firm, innov_country, inno_world)*. Young firms potentially use newer assets, which could be more compatible with newer technologies (Ma et al., 2022; Cho et al., 2023). Additionally, innovation outcomes are linked with technological diffusion (Aaldering and Song, 2021; Blichfeldt and Faullant, 2021). We also include firm size and an indicator variable whether a firm is a subsidiary, as firms belonging to a business group or firms that have larger size are more likely to have more knowledge-based capital (Dhyne et al., 2020; Cho et al., 2023). Additionally, the sectoral labour productivity (and its squared term) and sectoral dummies control for the variation among sectors in

[5] We transform log(x+1) to account for firms with 0 investments. We estimated Tables 3-6 without this transformation and the results are qualitatively similar. The results are available upon request to the authors.

[6] The dummy HGE is excluded as explanatory variable in equation (3) to avoid endogeneity.

terms of returns of ICT (Dyne et al., 2020). Finally, a is a constant, β are the coefficients to be estimated, δ and η are controls for year and country, and ε is the error term.

Equation (1) is estimated using Generalised Least Squares (GLS) and Equations (2) and (3) are estimated using a random-effects (RE) probit model.[7] The RE model allows us to control for time-constant unobserved heterogeneity that is not correlated with the explanatory variables. Both models are more efficient in comparison with cross-sectional models. Finally, the panel nature of the database allows us to include the explanatory variables in lags to partly mitigate the potential endogeneity between dependent and explanatory variables. However, including a lag also reduces our sample size by one wave. Our results should always be interpreted as conditional correlations rather than causal effects. All equations are estimated with robust standard errors.

5. Results

5.1. Determinants of digitalisation investments

Our first empirical analysis focuses on the determinants of the digitalisation process. Specifically, we ask whether HGEs are more likely to invest in digital technologies (H1) and whether complementarities exist among different types of digital investments (H2). Table 3 displays the results of the probability of investing in software and data, its intensity, and in NDTs. For the latter, we distinguish between base and front-end NDTs.

Concerning H1, a high-growth spurt in the previous period is positively associated with the probability of investing in software and data (column (1)) and the adoption of front-end NDTs (column (3)). The variable is not statistically significant for the intensity of investment in software and data. As such, our results indicate that a previous growth period is related to the extensive margin of software investment, but not necessarily the intensive margin.

Regarding H2, we find that adopting NDTs is correlated with higher investments into software and data (columns (4)-(6)). This result suggests complementarity

[7] Our analysis relies on waves 2019-2021 since questions related to the adoption of NDTs are only available for this period. Due to the short temporal dimension of the panel, the introduction of firm fixed effects could lead to convergence issues.

between the adoption of basic and advanced digital technologies. Our results show that NDTs such as IoT, virtual reality, and 3-D printing need a certain degree of complementary investments in relevant software and data to fully unlock their potential.

Finally, our results also indicate a positive association between digitalisation and firm-level innovation, in line with Aaldering and Song (2021) and Blichfeldt and Faullant (2021) who find that the adoption of DT may be related to firm innovation.

Table 3. Determinants of investing in digital technologies. Financial years 2018-2020.

	(1)	(2)	(3)	(4)	(5)	(6)
	BasicDT	**BasicDTint**	**NDT**	**NDT**	**NDTbase**	**NDTfront**
$BasicDTint_{i,t-1}$				0.179***	0.190***	0.124***
				[0.018]	[0.017]	[0.026]
$HGE_{i,t-1}$	0.120***	0.028	0.087	0.083	0.033	0.159*
	[0.046]	[0.031]	[0.059]	[0.058]	[0.056]	[0.082]
$innov\_firm_{i,t-1}$	0.222***	0.224***	0.262***	0.191***	0.144***	0.185***
	[0.034]	[0.023]	[0.042]	[0.042]	[0.040]	[0.060]
$innov\_country_{i,t-1}$	0.184***	0.389***	0.671***	0.579***	0.397***	0.709***
	[0.062]	[0.047]	[0.081]	[0.081]	[0.075]	[0.106]
$innov\_world_{i,t-1}$	0.286***	0.433***	0.690***	0.583***	0.437***	0.628***
	[0.060]	[0.045]	[0.078]	[0.077]	[0.071]	[0.096]
Obs.	13,268	12,104	11,981	11,981	11,981	11,981
Id.	11,882	8,169	8,124	8,124	8,124	8,124
Wald χ^2	508.1***	796***	794***	868***	1000***	640.3***

Control variables included. Robust standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1.
Note: Column (1) includes all firms. Columns (2), (4), (5) and (6) include firms that have invested in software and data since the amount of investment over total sales is expressed in logs.

5.2. Relationship of digitalisation on firm growth

This subsection focuses on how different NDTs are associated with firm growth (H3). Table 4 reports the results of the probability of growing versus remaining stable in terms of employees and sales.[8]

Table 4. Probability of growing rapidly versus remaining stable in terms of employees and sales. Financial years 2018-2020.

	(1)	(2)	(3)	(4)	(5)	(6)
	gr_employ			*gr_sales*		
$BasicDTint_{i,t-1}$	0.034**			0.067***		
	[0.016]			[0.015]		

[8] Employment growth corresponds to firms that grew the number of employees by more than 10%. The group of firms that are classified as stable are firms that have changed between -10% and 10%.

$NDT_{i\ t-1}$		0.062			0.063	
		[0.041]			[0.038]	
$NDTbase_{i,t-1}$			0.053			0.03
			[0.042]			[0.040]
$NDTfront_{i,t-1}$			0.04			-0.011
			[0.054]			[0.050]
$innov\_firm_{i,t-1}$	0.055	-0.022	-0.022	0.007	-0.04	-0.035
	[0.038]	[0.047]	[0.047]	[0.036]	[0.044]	[0.044]
$innov\_country_{i,t-1}$	0.117*	0.07	0.069	-0.049	-0.015	-0.008
	[0.070]	[0.084]	[0.084]	[0.067]	[0.081]	[0.081]
$innov\_world_{i,t-1}$	0.258***	0.247***	0.243***	0.079	-0.014	-0.006
	[0.065]	[0.081]	[0.081]	[0.061]	[0.077]	[0.077]
Obs.	10,066	7,421	7,421	9,229	6,524	6,524
Id	7,152	5,799	5,799	6,693	5,265	5,265
Wald χ^2	458.2***	297.9***	297.7***	540***	312.5***	310.9***

Control variables included. Robust standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1

Our results show, on the one hand, investment in software and data and NDTs shows a positive relationship (column (1)) with the probability of growing rapidly in terms of employees. On the other hand, NDTs do not have a statistically significant coefficient. However, firms that develop innovations new to the world are more likely to grow in terms of employees. Furthermore, investment in software and data (column (4)) shows a positive association with the probability of increasing rapidly sales.

Table 5 investigates the relationship between digitalisation and the growth of labour productivity and wage. We find that the intensity of investment in software and data (column (1)) is positively associated with labour productivity growth. This is in line with our results with sales growth as the dependent variable, which is the main productivity component. In other words, investment in basic digitalisation still has an important role to increase sales and labour productivity.

Digitalisation is not significantly related to an increase in wages, at least not in the short term. The only exception is in column (6), where those firms that invest in base NDTs are less likely to increase their average wages. However, changes in the skill (and wage) distribution may occur before investment in digitalisation.

Table 5. Probability of growing rapidly versus remaining stable in terms of labour productivity and wages. Financial years 2018-2020.

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
	gr_labprod			*gr_wage*		
$BasicDTint_{i,t-1}$	0.061***			0.021		
	[0.014]			[0.015]		
$NDT_{i\ t-1}$		0.018			-0.014	
		[0.035]			[0.036]	

$NDTbase_{i,t-1}$			-0.017			-0.066*
			[0.037]			[0.037]
$NDTfront_{i,t-1}$			0.007			0.043
			[0.046]			[0.046]
$innov\_firm_{i,t-1}$	-0.023	-0.079*	-0.076*	0.008	-0.02	-0.017
	[0.035]	[0.041]	[0.041]	[0.035]	[0.040]	[0.040]
$innov\_country_{i,t-1}$	-0.077	-0.066	-0.061	0.07	0.029	0.032
	[0.065]	[0.076]	[0.076]	[0.065]	[0.075]	[0.075]
$innov\_world_{i,t-1}$	0.02	0.009	0.014	-0.007	-0.056	-0.055
	[0.060]	[0.072]	[0.072]	[0.062]	[0.072]	[0.073]
Obs.	8,795	6,286	6,286	8,599	6,321	6,321
Id	6,544	5,181	5,181	6,345	5,168	5,168
Wald χ^2	583.8***	368.4***	368.9***	437.4***	326.2***	328.2***
Control variables included. Robust standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1						

5.3. Extension. Expectations of employment growth among digitalised firms

This subsection explores the factors associated with the expected employment change due to digitalisation during COVID-19 (Table 6) and relates to H3. Our equation is the following:

$$Prob(exp\_empl_{it}) = \alpha_{4i} + \beta_{41} HGE_{it-1} + X_{it-1}\beta_{42} + DT_{it-1}\beta_{43} + \delta_{4it} + h_{4ic} + \varepsilon_{4it} \qquad (4)$$

where *exp_empl* corresponds to a positive expected impact in terms of employment in the next three years due to the adoption of NDTs during COVID-19. This variable is only available in EIBIS wave 2021 and for firms which have previously adopted NDTs belonging. We also include an indicator variable identifying HGEs. Additionally, we include our set of proxies of digitalisation (*DT*) which have been previously presented in section 4.

Table 6. Probability of expecting an increase of employees over the following three years due to digitalisation (only firms that invested in NDTs). Financial year 2020.

	(1)	**(2)**	**(3)**
		exp_empl	
$BasicDTint_{i,t-1}$	0.074**		
	[0.032]		
NDT_{it-1}		0.191**	
		[0.077]	
$NDTbase_{i,t-1}$			0.247***
			[0.071]
$NDTfront_{i,t-1}$			-0.086
			[0.083]
$HGE_{i,t-1}$	0.267**	0.334***	0.331***
	[0.105]	[0.101]	[0.100]
$innov\_firm_{i,t-1}$	0.148*	0.157**	0.155**
	[0.080]	[0.077]	[0.076]
$innov\_country_{i,t-1}$	0.392***	0.396***	0.402***
	[0.128]	[0.123]	[0.122]

$innov\_world_{i,t-1}$	0.525***	0.528***	0.530***
	[0.121]	[0.116]	[0.115]
Obs.	3717	4112	4112
Id	3103	3393	3393
Wald χ^2	161.1***	174.3***	179.9***

Control variables included. Robust standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1

First, HGEs have higher positive expectations regarding the employment effects of digital technologies than non-HGEs. Note that most of firms expect their digitalisation investments to have no impact on future employment growth (Table 2). Hence, our estimations indicate that HGEs are more likely to expect to have a positive outcome.

Moreover, firms that invested more intensively in software and data tend to expect higher employment growth in the next three years. Firms that were already investing in advanced digital technologies in the previous year are more likely to expect positive employment growth.

Additionally, when we distinguish according to the nature of NDT, there is a positive coefficient of the base NDTs on the expected probability of increasing employees. This underlines the transformative capacity of base NDTs in the short-term. Finally, firms innovating at country- and world-level show a positive association with the expected probability of growing in terms of employment.

6. Discussion

The emergence of NDTs has led to a growing expectation that digitalisation will transform industries (EIB, 2022) and foster the emergence of disruptive HGEs (Testa et al., 2022). However, previous evidence shows that the digitalisation gap between digital and non-digital firms is widening (Rückert et al., 2021; Teruel et al., 2022). In particular, superstar firms have shaken up markets by adopting new digital technologies. As a result, they have displaced traditional business models. In order to understand the potential impact of NDTs, we analyse the European Investment Bank Investment Survey (EIBIS) to observe the relationship between high-growth enterprises and their digitalisation.

Our results shed light on several stylised facts. First, one of the most important contributions of our study is uncovering a complementarity between less and more advanced technologies. This finding is consistent with previous literature

pointing out a technological path-dependency and more importantly in "winner-takes-all" dynamic (Autor et al., 2020).

Second, as a contribution to the extensive literature on digital technologies and firm growth (Gal et al., 2019; Cathles et al., 2020; Dhyne et al., 2020; Cirillo et al., 2023), our results suggest that the categories of base and front-end digital technologies seem to be associated differently with firm growth. Although we must be cautious regarding ascribing causal interpretations, base technologies such as IoT or Big Data are positively linked with employment growth.

Furthermore, new technological bursts generate uncertain growth expectations. The non-significant coefficients of NDTs on our short-term growth measures highlight these uncertain returns. Similarly, Cirillo et al. (2023) find that only a minority of firms is able to increase their sales and productivity due to their digitalisation activity. In line with Björkdahl (2020), our results stress the challenge for digitalised firms to capture their returns on investment, mainly due to the intangible nature of digital assets and the complexity of complementary investments needed for their implementation.

Finally, our results show that HGEs and innovative firms that invested in NDTs during COVID-19 are more likely to anticipate employment growth in the next three years. This result underlines the potential of digitalisation to scale innovative businesses.

Our research has important managerial implications by providing managers with information to select optimal strategies for the implementation of NDTs. The emergence of HGEs in a highly competitive environment requires the most suitable strategies. In this sense, our results show that the adoption of new digital technologies needs the deployment of complementary innovations in order to foster growth particularly in the medium term. This insight might lead to more effective managerial decision-making driving growth and competitiveness of the organisation.

Our analysis is not without caveats. First, our results should not be interpreted as causal relationships, but only as (conditional) correlations due to endogeneity issues. Second, the temporal window is short and we are not able to capture medium-term effects. Investments in NDTs may manifest their results in the medium and long term. Third, it cannot be ignored the use of NDTs reported

through surveys may be subject to subjective answers. Finally, our measures of firm growth could be enlarged to other measures which are outside the scope of this study (profitability, funding access, etc.).

Future research could take various paths. First, there is a need to assess the relevance of financial constraints on the adoption of NDTs and their potential detrimental impact in the emergence of firms with high scaling capacity. Second, future studies could focus on identifying the causal effect of implementing digital technologies. The access to a longer time dimension would facilitate the identification of the change in the relationships between the digitalisation process and firm performance.

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Appendix

Table A-1 Description of variables

Name	Description
gr_employ *gr_sales* *gr_labprod* *gr_wage*	Dummy identifying if the firm increased (reference = remain equal) employees, sales, labour productivity and wage in more than 10% between "t" and "t-1" (reference = remain equal).
exp_empl	Dummy identifying if the firm expect in the next three years to increase (reference = remain equal) the employees due to investment in NDTs.
FIRM CHARACTERISTICS	
HGE	Dummy identifying if the firm is a HGE.
young	Dummy identifying if the firm operates 10 or less years in the market (reference = more than 10 years)
employees	Employees (in logs)
subsidiary	Dummy identifying if the firm is a subsidiary of another firm
Services, Construction, Infrastructure	Dummy equal to 1 if the firm belongs to services, construction or infrastructure (reference = manufactures)
labprod *labprod2*	Turnover per employee in average (logs) at sector (2 digit NACE code) and country and its quadratic value.
INNOVATION & DIGITALISATION	
innov_firm *innov_country* *innov_world*	Dummy identifying if the firm developed an innovation new to the firm, market or world (reference = non-innovator)
BasicDT	Dummy identifying if the firm has invested in software and data.
BasicDTint	Share of investment in software and data over total sales
NDT	Dummy identifying if the firm has a NDT.
NDTfront *NDTbase*	Dummy identifying if the firm has adopted front-end (3-D printing, robotics, augmented and virtual reality, and drones) or base (IoT, big data and analytics, and platform technologies) NDTs.
COUNTRY DUMMIES	
Dummies identifying the country (reference = Sweden)	

Table A-2. Descriptive statistics. Mean, standard deviation and correlation matrix

	Mean	Std. Deviation	Correlation matrix (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
gr_employ	0.0403	0.1969	1.0																
gr_sales	0.3817	0.4858	0.34	1.00															
gr_labprod	0.4634	0.4987	0.07	0.73	1.00														
gr_wage	0.5233	0.4995	0.05	0.17	0.21	1.00													
exp_empl	0.2203	0.4145	0.07	0.06	0.02	0.06	1.00												
$\ln(\text{BasicDTint})_{t-1}$	0.9095	1.0665	0.04	0.06	0.06	0.02	0.10	1.00											
HGE_{t-1}	0.1025	0.3033	0.13	0.15	0.09	0.11	0.09	-0.00	1.00										
NDT_{t-1}	0.5229	0.4995	-0.02	-0.03	-0.02	-0.04	0.06	0.09	0.02	1.00									
$NDTbase_{t-1}$	0.4315	0.4953	-0.00	-0.04	-0.04	-0.07	0.09	0.13	-0.02	0.72	1.00								
$NDTfront_{t-1}$	0.2062	0.4046	-0.03	-0.03	-0.01	-0.01	-0.04	0.00	0.04	0.42	-0.03	1.00							
$innov\_firm_{t-1}$	0.0572	0.2323	-0.00	-0.02	-0.06	0.01	0.01	0.12	0.01	0.04	0.05	0.04	1.00						
$innov\_country_{t-1}$	0.0139	0.1172	-0.03	-0.00	0.01	0.01	0.05	0.10	-0.01	0.07	0.07	0.01	-0.17	1.00					
$innov\_world_{t-1}$	0.0155	0.1236	-0.01	0.00	0.02	-0.03	0.06	0.15	0.01	0.10	0.08	0.15	-0.20	-0.08	1.00				
$young_{t-1}$	0.8580	0.3490	-0.10	-0.16	-0.15	-0.09	-0.06	-0.03	-0.09	0.01	-0.00	0.06	0.05	0.02	0.00	1.00			
$\ln(\text{employees})_{t-1}$	3.6694	1.5737	-0.08	-0.15	-0.13	-0.12	-0.05	-0.05	0.10	0.11	0.07	0.20	0.05	-0.02	0.06	0.18	1.00		
$subsidiary_{t-1}$	0.0696	0.25457	-0.02	-0.08	-0.07	-0.05	-0.06	-0.04	0.00	0.08	0.05	0.08	0.01	-0.02	0.02	0.02	0.20	1.00	
$\ln(\text{labprod})_{t-1}$	0.1328	1.3564	-0.08	-0.10	-0.09	-0.06	-0.06	0.04	-0.01	0.08	0.03	0.15	-0.01	-0.03	0.12	0.10	0.23	0.22	1.00
$\ln(\text{labprod2})_{t-1}$	1.8575	3.1144	-0.05	-0.06	-0.05	0.00	-0.06	0.04	-0.01	0.04	0.02	0.11	-0.01	-0.04	0.07	0.05	0.13	0.12	0.63