



**The effects of digital adoption due to Covid-19  
on Northern Ireland SMEs performance:  
New empirical results**

**ERC Research Report**

**May 2021**

# The effects of digital adoption due to Covid-19 on Northern Ireland SMEs performance: New empirical results

Dr Hoang Minh Luong<sup>1</sup>, Dr Anastasia Ri<sup>2</sup> and Professor Nola Hewitt-Dundas<sup>1</sup>

<sup>1</sup> Queen's University Belfast

<sup>2</sup> Aston Business School

The Enterprise Research Centre is an independent research centre which focusses on SME growth and productivity. ERC is a partnership between Warwick Business School, Aston Business School, Queen's University School of Management, Leeds University Business School and University College Cork. The Centre is funded by the Economic and Social Research Council (ESRC); Department for Business, Energy & Industrial Strategy (BEIS); Innovate UK, the British Business Bank and the Intellectual Property Office. The support of the funders is acknowledged. The views expressed in this report are those of the authors and do not necessarily represent those of the funders.

## TABLE OF CONTENTS

<b>1. Introduction .....</b>	<b>4</b>
<b>2. Conceptual framework and research hypotheses .....</b>	<b>7</b>
<b>3. Measuring firm digitalisation: A literature review .....</b>	<b>9</b>
3.1. Measures of firm digital readiness .....	9
3.2. Measures of firm digital adoption level.....	10
<b>4. Data and measurement.....</b>	<b>12</b>
<b>5. Methodology.....</b>	<b>15</b>
<b>6. Empirical results.....</b>	<b>17</b>
<b>7. Conclusion.....</b>	<b>21</b>

## 1. Introduction

The Fourth Industrial Revolution<sup>1</sup> and new digital technologies are transforming how people live and work. Big data, artificial intelligence and cloud computing offer opportunities to improve productivity and spur growth. However, while being considered to lag behind other UK regions in digital adoption, Northern Ireland also faces the highest share of jobs threatened by digitalization (OECD, 2018a).

The Covid-19 pandemic has further increased the necessity of firm digital adoption and implementation. In the economic recovery plan published in 2020, the Economy Minister emphasised that digitalisation and access to data are key strategic issues that can help the Northern Ireland economy not only to cope with the unprecedented situation of the pandemic, but also to grasp the opportunities that the pandemic presents.<sup>2</sup>

This is also confirmed by a survey from KPMG in August 2020, which revealed that the pandemic had significantly, and in many cases permanently, changed the way Northern Ireland companies operate, with 88 per cent of CEOs stating that the pandemic had accelerated the creation of new digital business models and revenue streams.<sup>3</sup>

In this report, we focus on the digital transformation process of Northern Ireland small and medium-sized enterprises (SMEs) during the Covid-19 pandemic. Specifically, we aim to answer the following questions: (1) does the adoption and implementation of digital technology have a 'direct' effect on firm performance? (2) does the adoption and implementation of digital technology have an 'indirect' effect on performance through innovation activity in the firm? (3) what are factors that motivate firms to adopt digital technology? And (4) what constraints do small and medium sized firms (SMEs) identify as preventing their adoption of digital technology?

Utilising a new ERC Business Futures survey on 178 Northern Ireland SMEs, we report several findings:

---

<sup>1</sup> The Fourth Industrial Revolution is characterised by a fusion of technologies – such as artificial intelligence, gene editing, and advanced robotics – that is blurring the lines between the physical, digital and biological worlds. More information can be found in: [Government Policy Paper: Regulation for the fourth Industrial Revolution](#)

<sup>2</sup> [DfE: Minister outlines importance of Northern Ireland's digital sector](#)

<sup>3</sup> [KPMG: Digital Acceleration report](#)

- (1) there is a significant and positive 'direct' effect of digital adoption and implementation on NI SMEs performance as measured through turnover;
- (2) no significant 'indirect' effect of digital technology adoption on firm performance was found. Indirect effect is assessed by examining where technology has led to innovation in the firm, but this has not translated through to turnover;
- (3) Internal readiness of firms for the adoption of digital technology e.g. digital skills, digital technology strategy etc. has a positive effect on firm performance;
- (4) the main motivations for digital technology adoption in NI SMEs were the challenges from public health and social distancing regulations associated with Covid-19, the adoption of technology by competitors and firms' perceptions of how digital technology would support their business operations. In other words, digital technology adoption was driven by factors external to the firm rather than due to internal strategic planning;
- (5) the constraints to adoption of digital technology vary for small and medium-sized enterprises. While having appropriate digital skills is an important consideration for all firms, for medium-sized enterprises (50 to 250 employees) risks of cyber security and engagement of the wider workforce with digital technologies are the prevailing concerns. For small enterprises (less than 50 employees), adequate broadband infrastructure and the compatibility of new technology with existing systems are commonly identified constraints.

The results support our hypotheses that instead of the commonly observed – 'indirect' effect of firm digitalisation on its performance through firm's innovation activities (Kroll et al., 2018; Hanelt et al., 2021), Covid-19 has created an environment whereby SMEs digital transformation has had a 'direct' effect on performance. This is important, as without digital transformation, many SMEs might not be able to operate in light of social distancing and other health and safety regulations. However, we argue that the situation also creates a further opportunity for SMEs' development and growth, as having in place updated and new digital technologies might boost future SMEs innovation, and from that further improve productivity and growth. We believe that these insights are important for policy implications in the near future, where the focus should be directed to supporting SMEs' innovation as well as labour training, in order to fully appropriate the benefits of recent digital adoption and implementation.

The rest of the report is structured as follows. Section 2 presents our conceptual frameworks and research hypotheses. Section 3 reviews the literature on two commonly used measures of firm digitalisation: digital readiness and adoption. Sections 4 and 5

outline the data, measurement and empirical method, while our empirical findings are presented in Section 6. Key conclusions and implications are summarized in Section 7.

## 2. Conceptual framework and research hypotheses

The effect of adopting digital technology on a firm's productivity and growth is often seen as depending on the internal capabilities within the firm to harness the potential of the technology in new and improved production processes or services. Indeed, several studies have confirmed that it is *through* enhanced innovation, either product or process innovation, that we can find a significant effect of firm digitalisation on performance (Kroll et al., 2018; Hanelt et al., 2021).

However, the Covid-19 pandemic created an unanticipated and challenging environment where many firms had to adopt new digital technologies, in order to continue operating their businesses when faced with social distancing and other related public health and safety regulations. Because of that, there is the potential to identify a direct relationship between firm digitalisation and its performance, instead of the commonly observed moderated relationship between digitalisation to innovation and in turn, to changes in firm performance.

Therefore, our first two hypotheses are:

**Hypothesis 1:** Digitalisation has a significant and positive 'direct' effect on firm performance.

**Hypothesis 2:** Innovation occurring as a result of adoption of digital technology has no effect on firm performance.

Furthermore, drawing on a Technology-Organisation-Environment (TOE) framework, we also study the effects of external and internal "readiness" factors on the breadth of firm digital adoption. The TOE framework is a theoretical foundation suitable for understanding the contextual factors that influence a firm's processes and outcomes of new decision-making (Tsou and Hsu, 2015). It is also widely used in studies on firm digitalisation (Kauffman et al.; 2016; Alsheibani et al.; 2018). The framework separates the "readiness" measure into two categories: internal readiness reflects factors inside the firm, such as the level of technology infrastructure, human resources and skills, whereas external readiness contains information from outside the firm, including the suitability of existing technologies in the market, or the customers' expectation and requirements. Due to the need for digital transformation required in order to respond to the pandemic, we expect the external environment to have a stronger effect on SME adoption of new technologies.

Therefore, our third and fourth hypotheses are:

**Hypothesis 3:** External readiness has a positive and significant effect on Northern Ireland SMEs' breadth of digital adoption.

**Hypothesis 4:** Internal readiness has no significant effect on Northern Ireland SMEs' breadth of digital adoption'



### **3. Measuring firm digitalisation: A literature review**

Digital technologies have changed the way in which firms do business and interact with their customers and suppliers. According to a recent OECD report, frontier firms in digitalisation see higher productivity and revenue compared to their less digitally inclined peers in the long run (OECD, 2018b).

However, even though there has been a growth of studies on firm digitalisation, there is very little consensus about its measurement. In other words, measures of the adoption, diffusion and implementation of digital technologies across populations of firms are inconclusive and often provide only a partial view of the process of pre-adoption, adoption and implementation.

Below, we summarise the literature around two commonly used measures of firm digitalisation: digital readiness and digital adoption.

#### **3.1. Measures of firm digital readiness**

One of the key measures that has been developed is 'digital readiness' or 'technological readiness'. The original idea can be traced back to Parasuraman (2000) and Parasuraman and Colby (2001), where the authors define technology readiness as "people's propensity to embrace and to use new technologies for accomplishing goals in home life and in the workplace". They construct their technology readiness index (TRI) based on 4 dimensions: optimism, innovativeness, discomfort, and insecurity.

Recently, the concept of readiness has been extended to the industrial organisation (IO) literature. As implementing digital technologies has become one of the major strategic decisions, there is a need for organisations to assess their "readiness" level (Sony and Naik, 2019; Schumacher et al., 2016). Weiner (2009) suggests that organisational readiness for change can be considered as a state of being both psychologically and behaviourally prepared to take action (i.e. willing and able). In line with this general "readiness" definition, the firm technological readiness (TR) implies a specific type of capability to embrace and implement new technological assets (Richey et al., 2007).

Several measures of technology readiness have been proposed. For instance, Razavi et al. (2011) and Porter and Schwab (2008) develop their TR measure from a number of sub-indexes: Availability of latest technologies; Firm-level technology absorption; Foreign Direct Investment (FDI) and technology transfer; Internet users; Broadband Internet Subscriptions; and Internet bandwidth. Alternatively, Lokuge et al. (2019) base

their readiness measure on seven subconstructs: resource readiness, IT readiness, cognitive readiness, partnership readiness, innovation valance, cultural readiness, and strategic readiness. Similarly, Schumacher et al. (2016) propose a “readiness” measure based on 9 different dimensions (Strategy, Leadership, Products, Customers, Operations, Culture, People, Governance, and Technology), while a 6 dimensions’ readiness measure can be found in Sony and Naik (2019).

A more comprehensive approach can be found in Alsheibani et al. (2018), where the authors consider TR as a combination of both internal readiness (i.e. technology infrastructure, human resources and skills) and external readiness (existing suitable technologies in the market). This Technological, Organisational and Environmental (TOE) framework approach is also applied by Kauffman et al. (2016), in which they construct a measure for the readiness to adopt cloud computing based on a composite measure of criteria from 4 categories: (i) technology and performance; (ii) organisation and strategy; (iii) economics and valuation; and (iv) regulation and external environment.

### 3.2. Measures of firm digital adoption level

Even though we are in the midst of the transition towards a digital economy and society, the level of digital adoption varies widely across firms. For instance, an OECD report in 2017 confirmed that the adoption of cloud computing is more than twice as common in large firms than in small firms. Similarly, another more recent OECD report has stated that: “Many SMEs are lagging behind in the digital transition. Most of them ignore the potential benefits in productivity and competitiveness deriving from the adoption of digital technologies, cannot clearly identify their needs, or do not have enough capabilities or financial resources to access and effectively use digital instruments” (OECD, 2019).

To reflect this different level of firm digital adoption, several measures have been proposed. The most common measure is a set of binary variables that reflect whether a firm has adopted any specific kind of digital technology. For example, two other OECD studies – Gal et al. (2019) and Mosiashvili and Pareliussen (2020) have documented a significant effect of firm digital adoption on productivity, in which separate measures of digital adoption for different types of technology are used, such as high-speed broadband internet or cloud computing services. Similarly, Cusolito et al. (2020) confirm the significant effects of digital technology adoption on total factor productivity and factor demand, using measures of firm digital adoption reflecting whether email or website adoption is confirmed. In addition, there is a rich strand of literature on firm digital

adoption of the specific e-business technology (Chatzoglou and Chatzoudes, 2015; Febrianti et al., 2020).

Besides, Haller and Siedschlag (2011) use both binary measures (e.g. whether a firm adopts a website or online transaction) and continuous measures (the shares of employees using a computer and the share of sales associated with digital activities) to reflect firm digital adoption level.

A more general measure of digital adoption can be found in Hollenstein (2004), where the author constructs four categorical measures of digital adoption based on the time period of adoption to a specific technology; the intensity of digital adoption (the number of ICT elements adopted); and the percentage of employees using each technology. Nine specific elements, including email, internet, intranet, extranet, etc. are included in this study. With the similar consideration of different digital technologies, the “Going Digital: The challenges facing European SMEs” report from British Business Bank in 2019 introduces a new definition of a digitalised SME as firm engaged in at least three digital activities among their listed 8 categories.

Overall, even though there are still some variations, the literature has shown some considerable improvements in measuring digital readiness and adoption. First, for firm’s digital readiness, the TOE framework provides a comprehensive and systematic view on several factors that reflect the level of firm readiness in adopting digital technologies. However, in reality, these factors might not be as independent as stated in the theory. Therefore, in this report, we apply the TOE framework while taking into consideration also the information from our data. More details on how to construct our two measures of internal and external readiness statistically, are presented in Section 4 below. Second, with regards to digital adoption, the improvement can be seen from the change in focusing on each specific type of technology to a more general approach in which all available existing types of technologies are accounted for in assessing the level of firm digital adoption. Here, similar to the British Business Bank’s report in 2019, we consider a digitalised SME as one who has reported the adoption of at least 5 digital technologies.

#### 4. Data and measurement

Our data is from Enterprise Research Centre (ERC)'s new major survey of UK SMEs - the Business Futures Survey. This survey, carried out during Autumn 2020, set out to understand the experiences of SMEs over the previous 12 months, as well as the impact of the COVID-19 pandemic. The Northern Ireland sample consists of 178 SMEs.

Our measures of SME digital "readiness" are constructed based on the TOE framework approach from Asheibani et al. (2018) and others. We apply exploratory factor analysis (EFA), a statistical technique that examines the underlying constructs and identifies the smallest number of hypothetical factors that can parsimoniously explain the covariation observed among a set of observed variables (Watkins, 2018). From our survey data, EFA results confirm that two measures of internal and external digital readiness can be derived.<sup>4</sup>

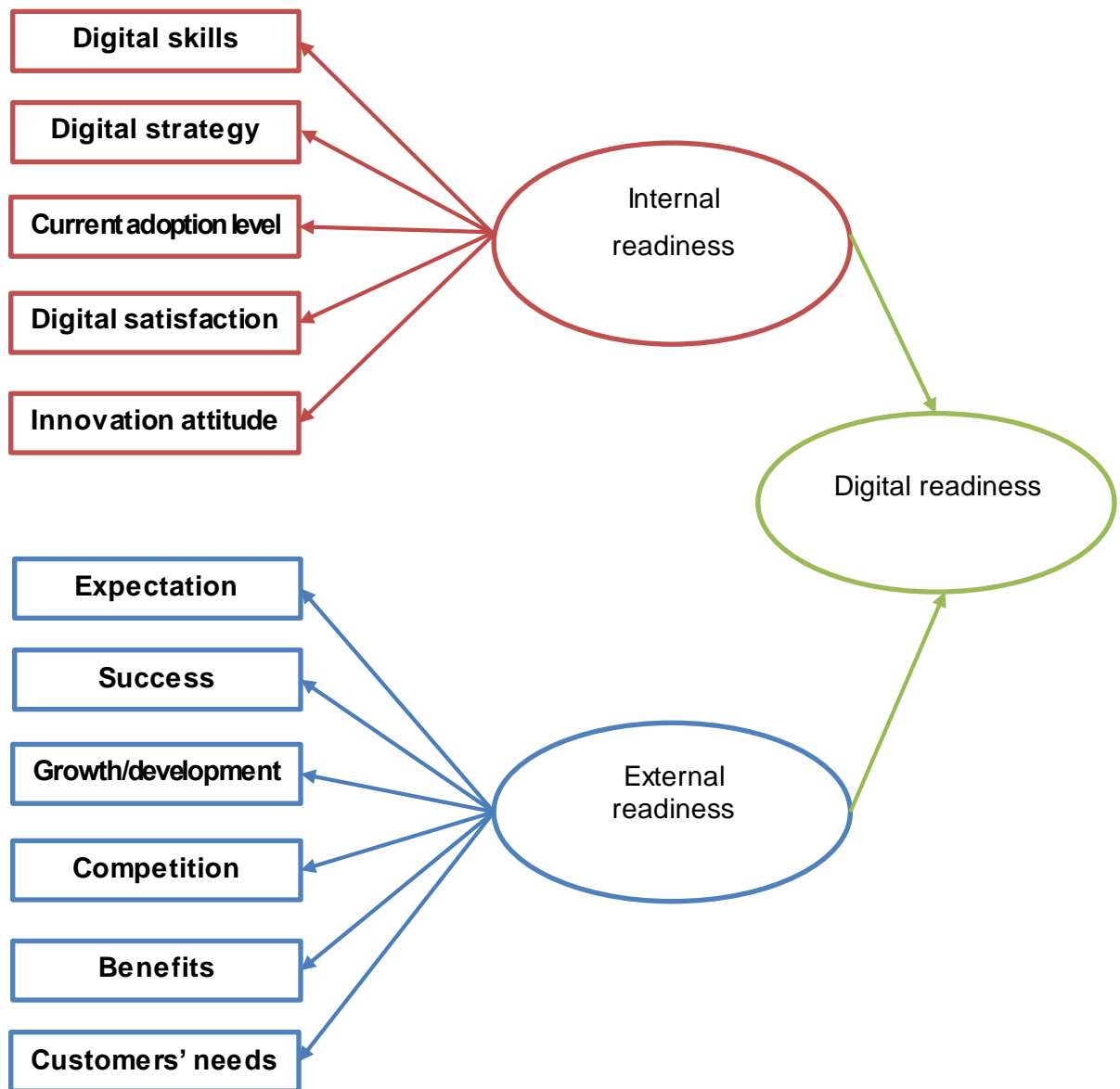
Figure 1 shows that the internal readiness measure is constructed based on information from 5 criteria, while the external readiness measure is based on 6 criteria.<sup>5</sup>

---

<sup>4</sup> The reliability of these two "readiness" measures is confirmed by two criteria: (i) both have an eigenvalue greater than 1, and (ii) their Cronbach's alpha take the values of 0.78 and 0.73, much higher than the threshold of 0.5 for any accepting factor (Acock, 2013).

<sup>5</sup> More information about these criteria can be found in Table A1 in the Appendix.

Figure 1: Measures of digital “readiness” – constructed by EFA method



With regards to firm digital adoption, a binary variable is used to reflect whether a firm has adopted at least 5 of the 10 digital technologies presented in the questionnaire.<sup>6</sup> These types of technologies range from Internet of things and cloud computing solutions to some of the most recent and advanced technologies such as augmented and virtual

---

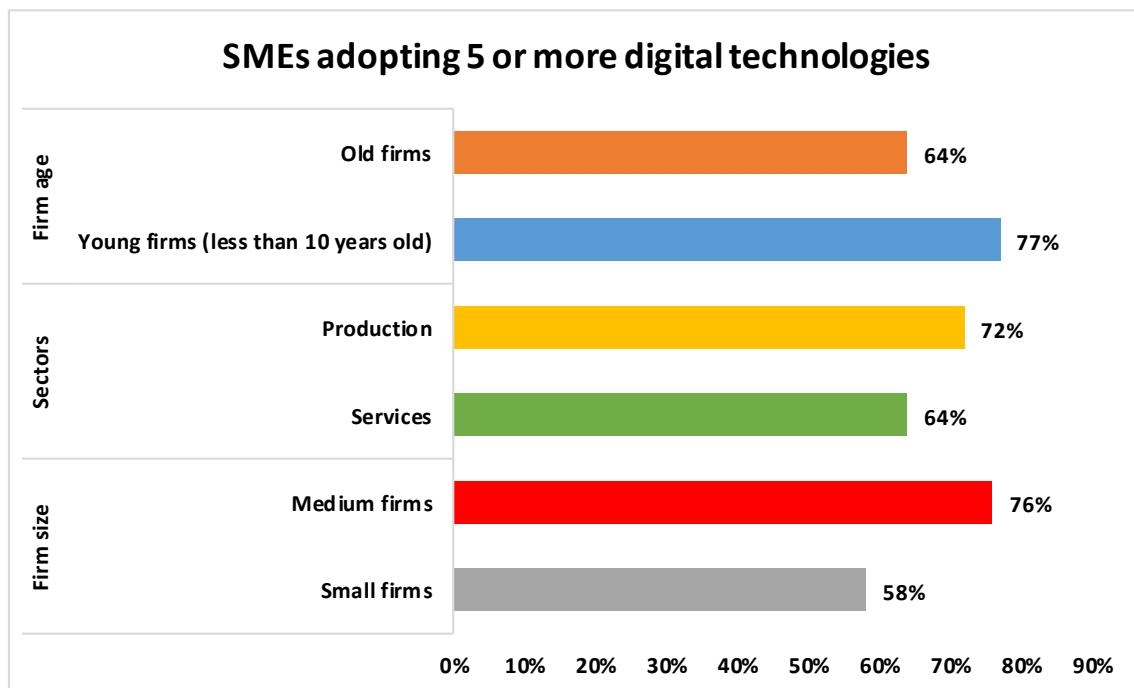
<sup>6</sup> We choose number 5 (over 10 digital technologies) due to the fact that 5 is both the mean and the median of the number of digital technologies used by NI SMEs in our sample.

reality or artificial intelligence and machine learning.<sup>7</sup> Figure 2 highlights the breadth of digital adoption for Northern Ireland SMEs across firm characteristics.

While a larger proportion of young firms (less than 10 years old) tend to have wider breadth of digital adoption (adopting at least 5 different types of digital technologies) than older firms (more than 10 years old), it is perhaps less intuitive that a higher proportion of SMEs in production sectors reported a wider breadth of digital adoption than SMEs in service sectors. Yet, as might be expected, the proportion of medium sized firms (50-250 employees) reporting a wide breadth of digital adoption is higher than that for small firms (less than 50 employees).

Figure 2: Northern Ireland SMEs' breadth of digital adoption by firms characteristics

Source: *ERC Business Futures Survey 2020*




---

<sup>7</sup> The list of all 10 digital technologies included in our questionnaire is reported in Table A2 in the Appendix.

## 5. Methodology

To test for the effect of firm's adoption of digital technologies on business performance (both directly and indirectly through innovation activities) we apply an innovation production function.

Our measure of firm performance (*turnover*) is a binary variable that reflects whether an enterprise has reported at least the same or increased turnover in the last 12 months. We believe this measure is more appropriate for such a challenging and uncertain situation under the Covid-19 pandemic, in which maintaining the same turnover with the previous period can be seen as a positive signal of firm performance.

In equation (1), our main explanatory variable is a binary variable that reflects whether a firm has increased its innovation activities due to its digital adoption and implementation in the previous 12 months. This measure reflects the effect of firm digital transformation on innovation and in turn, the effect of this innovation on performance.

In equation (2), we test the direct effects of firm digital readiness and the breadth of digital adoption on firm performance. Two measures of digital readiness - external readiness (*ER*) and internal readiness (*IR*) - are applied, while the breadth of digital adoption is a binary variable that reflects whether a firm has applied at least 5 different digital technologies in our survey (more details of the variables can be found in the Appendix).

$$turnover_i = \beta_{11} innov_i + \gamma_{1,n} X_i + u_{1i} \quad (1)$$

$$turnover_i = \beta_{21} Dig\_adopt_i + \beta_{22} ER_i + \beta_{23} IR_i + \gamma_{2,n} X_i + u_{2i} \quad (2)$$

Then, we explore further the effect of firm digital readiness, measured by two variables - external and internal readiness - on the breadth of firm digital adoption. Here we are seeking to better understand the drivers of digital adoption among NI SMEs and the role of factors internal and external to the firm in this.

$$Dig\_adopt_i = \beta_{31} ER_i + \beta_{32} IR_i + \gamma_{3,n} X_i + u_{3i} \quad (3)$$

We follow previous studies to control for several firm characteristics as follow:

- Firm size – a binary variable that reflects whether a firm is small (less than 50 employees) or medium-sized (50 to 250 employees).

- Firm age is another factor that might influence SMEs' innovation and performance (Classen et al. 2014). Therefore, we use another binary variable that reflects whether a firm is less or more than 10 years old.
- Exporting and innovative activity have been linked through both competition and learning effects (Hervas-Oliver et al., 2014; Love and Roper, 2015). Hence, a binary variable is also included indicating whether a firm has sold products/services outside the UK.
- Competition is another factor that might strongly influence firm innovation and performance. Here, we rely on the survey and add another binary variable that reflects whether a firm agreed that competition is one of the major obstacles to their success.
- Finally, we also control for whether a firm has a business plan.

As our dependent variables (*turnover* in equations 1 and 2, and *Dig\_adopt* in equation 3) take a binary form, we apply the probit regression with robust standard errors.



## 6. Empirical results

Results of equations (1) and (2) are presented in Table 1. It can be seen from column (A) of Table 1 that there is no significant effect of the increasing innovation activities due to digital transformation on firm performance and growth. This is in line with our expectation that where digital adoption has led to innovation, the benefits of this have not yet materialized for the firm in terms of turnover. There is therefore a lack of support for an indirect relationship between adoption of digital technology and firm performance (through innovation).

Turning to assessment of a direct effect between digital technology adoption and performance, results from column (B) of Table 1 show clearly the direct and positive effect of digital transformation on firm performance and growth. Indeed, both the breadth of firm digital adoption and the internal readiness measure report positive and significant effects on firm performance (turnover).

With regards to our control variables, both column (A) and (B) of Table 1 indicate that there is not much difference between small and medium firms, or young (less than 10 years old) and older firms, as the uncertain and challenging environment appears to have affected all Northern Ireland SMEs similarly. In addition, no significant difference is found between those SMEs with a business plan, or engaged in exporting activity, and their performance over the previous 12 months. However, where firms experience high levels of competition this had a negative impact on their turnover performance, with this being statistically significant in column (B) of Table 1.

Table 1: (A) Indirect effect of digital adoption through innovation on business turnover and (B) Direct effect of digital adoption on business turnover (marginal effects reported)

	(A) Turnover	(B) Turnover
Innovation	-0.088 (0.80)	
Breadth of digital adoption		0.207* (0.111)
External readiness		-0.051 (0.040)
Internal readiness		0.096** (0.044)
Firm size (= 1 if small firm)	-0.051 (0.083)	-0.094 (0.090)
Firm age (= 1 if less than 10 years old)	-0.062 (0.120)	-0.153 (0.128)
Business plan	-0.001 (0.091)	-0.163 (0.102)
Competition	-0.102 (0.081)	-0.176* (0.096)
Export	0.141 (0.086)	0.126 (0.099)
Industry effects	Yes	Yes
Number of observations	153	123

Note: The dependent variable – *turnover* - takes the value 1 if a firm's turnover remained static or grew over the previous 12 month period and the value 0 if it declined. Standard errors are in parentheses. \*\*\*, \*\*, and \* indicate the level of significance at 1%, 5%, and 10% respectively.

We also explore the effect of digital readiness measures on the breadth of SMEs digital adoption. Results of equation (3) are presented in Table 2.

It can be seen clearly from Table 2 that only the external readiness measure has a positive and significant effect on the breadth of firm's digital adoption, while the effect of firm internal readiness is small and statistically insignificant. This, again, suggests that the digital transformation of Northern Ireland SMEs in the previous 12 months has been driven by a firm's perceptions of its importance as enabling them to navigate Covid-19 and to respond to customers relative to competitors. Internal factors such as the digital skill levels of employees, having a digital strategy and seeking to implement an incremental technology adoption strategy or indeed seeing technology as a driver of innovation had an insignificant effect on technology adoption over the previous 12 months. This presents a challenge in ensuring that the external conditions that motivated

digital adoption in the previous 12 months are supported with the internal capabilities to implement these technologies and appropriate the benefit of them through turnover growth.

Table 2: The effect of digital readiness on the breadth of digital adoption (marginal effects reported)

	Digital Adoption Estimate
External readiness	0.083*** (0.027)
Internal readiness	0.022 (0.032)
Firm size (= 1 if small firm)	0.107 (0.070)
Firm age (= 1 if less than 10 years old)	0.177 (0.111)
Business plan	0.026 (0.081)
Competition	0.305*** (0.066)
Export	0.018 (0.079)
Industry effects	Yes
Number of observations	132

Note: The dependent variable – *Dig\_adopt* - takes the value of 1 if a firm has adopted at least 5 digital technologies and 0 if fewer than 5 technologies adopted. Standard errors are in parentheses. \*\*\*, \*\*, and \* indicate the level of significance at 1%, 5%, and 10% respectively.

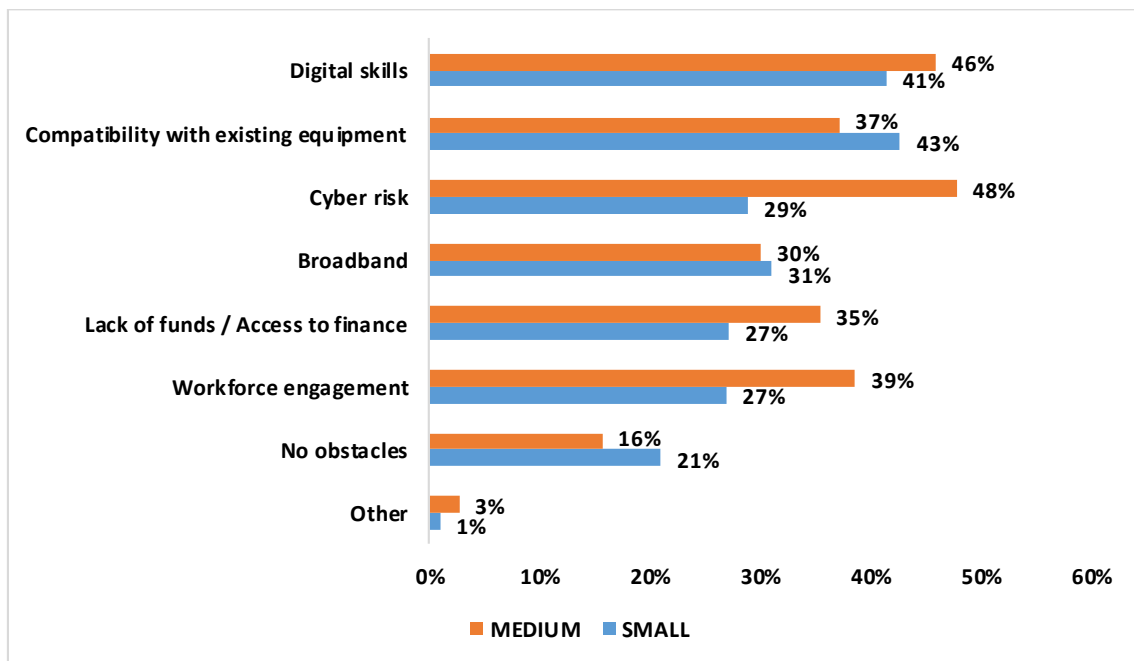
Relating to that, Figure 3 below shows some of the major obstacles for small and medium-sized firms that might be worth considering. It can be seen from Figure 3 that a high proportion of both small and medium firms in Northern Ireland state that lack of digital skills is one of the main obstacles to digital technology adoption. This is in line with OECD (2020) research, in which one of the main conclusions is that skills should be at the core of the policy response to the pandemic.

However, apart from the well-known lack of skills, our data also indicates that cyber risk is a dominant concern for almost half of medium sized firms (48 per cent) along with concerns about the engagement of employees with new technology (39 per cent). For small firms beyond having the necessary digital skills, there is also widespread concern about the compatibility of new digital technologies with their existing equipment (43 per cent) and adequate broadband infrastructure to support digital technologies (31 per

cent). Policies supporting SMEs in addressing these issues might be impactful, in order to fully appreciate the benefits of the digital transformation during the Covid -19 pandemic period.

Figure 3: Obstacles to adoption of digital technology as cited by small and medium sized firms

Source: ERC Business Futures Survey 2020



## 7. Conclusion

As indicated in our previous report for DfE and Invest NI<sup>8</sup>, 2020 saw significant progress in the adoption and implementation of digital technologies among Northern Ireland SMEs, largely attributable to the Covid-19 pandemic. Public health and associated social distancing and other health and safety regulations created a requirement for firms to adopt and use more digital technology of different types, as traditional face-to-face business operations were curtailed.

In this report, we provide some early results on how that digital transformation process has affected SMEs' performance. Utilising the new ERC Business Futures survey, our findings confirm that the 'direct' effect of digital transformation on SMEs' performance is positive and statistically significant. However, we document no 'indirect' effect from the common 'innovation' channel, in which the new digital adoption and implementation helps increasing SMEs' innovation activities and through that, further affects their performance and future growth. It is important to remember that these findings relate to a very specific period when firms were dealing with the Covid-19 pandemic. It is possible that over a longer time period, a part of this effect through innovation channel might become evident, but without further support from the government to induce SMEs' innovation activities, the benefits of this might not be fully and totally appropriated.

Where firms have internal digital skills and a technology adoption strategy, this internal readiness has a positive effect on performance. However, here we find a disconnect between capability to adopt digital technology and the drivers of adoption in the pandemic period. Digital technology adoption has been motivated more by external factors including the challenges from public health and social distancing regulations associated with Covid-19, the adoption of technology by competitors and firms' perceptions of how digital technology would support their business operations. It is likely that the pandemic has accelerated the pace of digital technology adoption and while this could be advantageous for firms, what is crucial in the near future, we believe, is to strengthen SMEs' internal capabilities, in order to ensure that the maximum benefit of these technologies can be appropriated in terms of business performance.

---

<sup>8</sup> [DfE - The impact of Covid-19 on Northern Ireland SMEs: Evidence and comparison with the rest of the UK](#)

Finally, even within the confines of this study, undertaken in a very specific period of the Covid-19 pandemic, the performance benefits of digital technology adoption are clear. Further efforts to support SMEs' digital adoption and implementation need to account for different size of enterprises and the constraints that they face. While having appropriate digital skills is an important consideration for all firms, for medium-sized firms risks of cyber security and engagement of the wider workforce with digital technologies is a prevailing concern. For small firms, adequate broadband infrastructure and compatibility of new technology with existing systems are commonly identified constraints.

## References

- Acock, A.C. (2013). *Discovering structural equation modeling using Stata*. Stata Press Books.
- Alsheibani, S., Cheung, Y., and Messom, C. (2018). Artificial intelligence adoption: AI-readiness at firm-Level. *PACIS*, 6, 26-32.
- British Business Bank (2019). *Going Digital: The challenges facing European SMEs*. Retrieved from: [https://www.british-business-bank.co.uk/wp-content/uploads/2019/11/going-digital-the-challenges-facing-european-smes-european-sme-survey-2019\\_2.pdf](https://www.british-business-bank.co.uk/wp-content/uploads/2019/11/going-digital-the-challenges-facing-european-smes-european-sme-survey-2019_2.pdf)
- Chatzoglou, P. and Chatzoudes, D. (2016). Factors affecting e-business adoption in SMEs: an empirical research. *Journal of Enterprise Information Management*, 29(3), 327-358.
- Classen, N., Carree, M., Van Gils, A., & Peters, B. (2014). Innovation in family and non-family SMEs: An exploratory analysis. *Small Business Economics*, 42, 595-609.
- Cusolito, A.P., Lederman, D., and Pena, J. (2020). The Effects of Digital-Technology Adoption on Productivity and Factor Demand: Firm-level Evidence from Developing Countries. *The World Bank Policy Research Working Paper*, No. 9333.
- European Commission (2019). The Digital Economy and Society Index (DESI), European Commission. Retrieved from: <https://ec.europa.eu/digital-single-market/en/desi>
- Febrianti, M.A., Yudhistira, G.A., and Kusriani, E. (2020). *Adoption of e-Business: A systematic literature review*. In: 2020 International Conference on Decision Aid Sciences and Application (DASA). IEEE.
- Frank, A.G., Dalenogare, L.S., and Ayala, N.F. (2019). Industry 4.0 technologies: Implementation patterns in manufacturing companies. *International Journal of Production Economics*, 210, 15-26.
- Gal, P., Nicoletti, G., Renault, T., Sorbe, S., and Timiliotis, C. (2019). Digitalisation and productivity: In search of the holy grail – Firm-level empirical evidence from EU countries. *OECD Economics Department Working Papers*, No. 1533.
- Haller, S.A. and Siedschlag, I. (2011). Determinants of ICT adoption: Evidence from firm-level data. *Applied Economics*, 43(26), 3775-3788.

- Hanelt, A., Firk, S., Hildebrandt, B., and Kolbe, L.M. (2021). Digital M&A, digital innovation, and firm performance: an empirical investigation. *European Journal of Information Systems*, 30(1), 3-26.
- Hervas-Oliver, J.L., Sempere-Ripoll, F., and Boronat-Moll, C. (2014). Process innovation strategy in SMEs, organizational innovation and performance: A misleading debate? *Small business economics*, 43(4), 873-886.
- Hollenstein, H. (2004). Determinants of the adoption of Information and Communication Technologies (ICT): An empirical analysis based on firm-level data for the Swiss business sector. *Structural change and economic dynamics*, 15(3), 315-342.
- Kauffman, R.J., Ma, D., and Yu, M. (2016). A metrics suite of cloud computing adoption readiness. *Electronic Markets*, 28, 1–27.
- Kroll, H., Horvat, D., and Jäger, A. (2018). Effects of 24igitalization and 24igitalization on manufacturing companies' production efficiency and innovation performance. *Fraunhofer ISI Discussion Papers*, No. 58.
- Lokuge, S., Sedera, D., Grover, V., and Dongming, X. (2019). Organizational readiness for digital innovation: Development and empirical calibration of a construct. *Information & management*, 56(3), 445-461.
- Luong, H.M, Hopley, L., and Hewitt-Dundas, N. (2021). The impact of Covid-19 on Northern Ireland SMEs: Evidence and comparison with the rest of the UK, Department for Economy. <https://www.economy-ni.gov.uk/publications/impact-covid-19-northern-ireland-smes-evidence-and-comparison-rest-uk>
- Love, J.H., & Roper, S. (2015). SME innovation, exporting and growth: A review of existing evidence. *International Small Business Journal*, 33(1), 28-48.
- Mosiashvili, N. and Pareliussen, J. (2020). Digital technology adoption, productivity gains in adopting firms and sectoral spill-overs – Firm-level evidence from Estonia. *OECD Economics Department Working Papers*, No. 1638.
- OECD (2020). *OECD skills strategy Northern Ireland (United Kingdom): Assessment and recommendations*. Retrieved from: [https://www.oecd.org/skills/centre-for-skills/OECD\\_Skills\\_Strategy\\_Northern\\_Ireland\\_Report\\_Summary.pdf](https://www.oecd.org/skills/centre-for-skills/OECD_Skills_Strategy_Northern_Ireland_Report_Summary.pdf)
- OECD (2019). *The OECD digital for SMEs global initiative: Harnessing the digital revolution for SMEs and entrepreneurs*. Retrieved from: <https://www.oecd.org/cfe/smes/digital-smes.htm>



- OECD (2018a). *Job creation and local economic development 2018: Preparing for the future of work*. Retrieved from: [https://www.oecd-ilibrary.org/employment/job-creation-and-local-economic-development-2018\\_9789264305342-en](https://www.oecd-ilibrary.org/employment/job-creation-and-local-economic-development-2018_9789264305342-en)
- OECD (2018b). *Towards the implementation of the G20 roadmap for 25igitalization: Skills, business dynamics and competition*. Retrieved from: [http://www.oecd.org/g20/OECDreport\\_Implementation\\_G20\\_Roadmap.pdf](http://www.oecd.org/g20/OECDreport_Implementation_G20_Roadmap.pdf)
- OECD (2017). *Enhancing the Contributions of SMEs in a Global and Digitalised Economy*.
- Parasuraman, A. (2000). Technology Readiness Index (TRI): A Multiple-Item Scale to Measure Readiness to embrace New Technologies. *Journal of Service Research*, 2(4): 307-320.
- Parasuraman, A. and Colby, C.L. (2001). *Techno-Ready Marketing: How and Why Your Customers Adopt Technology*. 2001: The Free Press.
- Porter, M. E. and Schwab, K. (2008). *The Global Competitiveness Report 2008-2009*. Geneva: World Economic Forum.
- Razavi, S., Mostafa, G., Rohollah, A.B., and Kashani, M. (2011). Relationship between technological readiness and innovation: A secondary analysis of countries global competitiveness. *European Journal of Scientific Research*, 59(3), 318-328.
- Richey, R.G., Daugherty, P.J., and Roath, A.S. (2007). Firm technological readiness and complementarity: capabilities impacting logistics service competency and performance. *Journal of Business Logistics*, 28(1), 195-228.
- Rubino, M., Vitolla, F., Raimo, N., and Garcia-Sanchez, I.M. (2020). Cross-country differences in European firms' 25 igitalization: the role of national culture. *Management Decision*, 58(8), 1563-1583.
- Schumacher, A., Erol, S., and Sihh, W. (2016). A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises. *Procedia Cirp*, 52, 161-166.
- Sony, M. and Naik, S. (2019). Key ingredients for evaluating Industry 4.0 readiness for organizations: a literature review. Benchmarking: *An International Journal*, 27(7), 2213-2232.
- Tsou, H.T. and Hsu, S.H.Y. (2015). Performance effects of technology–organization–environment openness, service co-production, and digital-resource readiness: The

case of the IT industry. *International Journal of Information Management*, 35(1), 1-14.

Watkins, M.W. (2018). Exploratory factor analysis: A guide to best practice. *Journal of Black Psychology*, 44(3), 219-246.

Weiner, B.J. (2009). A theory of organizational readiness for change. *Implementation science*, 4(1), 1-9.

## Appendix

**Table A1: Constructed digital “readiness” measures: External readiness and internal readiness**

Measures	Components	Survey question
External readiness (ER)	Growth/development	Do you expect your business will use more digital technologies in future?
	Success	Do you think that businesses who use digital technologies are more successful?
	Expectation	Do you think that more and more businesses are using new technologies?
	Competition	Do you think that investing in digital solutions will keep your business ahead of competitors?
	Benefits	Do you agree that introducing new technologies takes time but the benefits are worth it?
	Customers’ needs	Do you think that customers expect your business to use the latest digital technologies?
Internal readiness (IR)	Digital skills	Do you think that your employees have the skills to introduce any new technologies?
	Digital strategy	Do you have a digital strategy?
	Current adoption level	Is your company keeping up with the latest technologies?
	Digital satisfaction	Do you think that digital technology your business has adopted met your expectations?
	Innovation attitude	Do you think that your business’s innovation relies on having the latest digital technologies

**Table A2: 10 digital technologies included in our questionnaire**

	Type of digital technology
1	Website to sell goods or services
2	Online marketing and social media
3	Accounting or HR software
4	Customer Relationship Management system
5	Video conferencing such as teams or zoom
6	Cloud computing solutions
7	Computer Aided Design Software (CAD)
8	Internet of things (connected devices)
9	Augmented and Virtual reality
10	Artificial intelligence and machine learning

**Table A3: Summary statistics**

Variables	Observations	Mean
Turnover (= 1 if a firm's turnover has at least the same as last year)	166	0.617
Innovation (=1 if a firm reported increasing innovation due to digital adoption)	178	0.391
Breadth of digital adoption (Dig5)	178	0.450
External readiness (ER)	143	0.999
Internal readiness (IR)	143	-0.102
Business plan	165	0.700
Competition	178	0.384
Exporter	177	0.443

